SPACE TECHNOLOGY AND SECURITY: THE INDIAN PERSPECTIVE

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CERTIFICATE

Certified that the thesis entitle "Space Technology and Security: The Indian Perspective" submitted by Sri. Sambaturi Vijayasekhara Reddy, on fulfillment of the requirement for the Award of the Doctor of Philosophy of this university, is his original work. This thesis has not been submitted for any other degree to this or any other University.

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SPACE TECHNOLOGY AND SECURITY: THE INDIAN PERSPECTIVE

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Abbreviations

ABM	antiballistic missile.
ACDA	Arms Control and Disarmament Agency.
ASAT	antisatellite.
ATACAMS	Army Tactical Missile System, United States.
BARC	Bhabha Atomic Research Center.
BMD	Ballistic Missile Defence System
C^3I	Communications, command, control, and intelligence.
CEP	Circular Error Probability.
CNES	Centre National d'Etudess Spatiales (National Centre of Space Studies, France.
COPUOS	Committee on the Peaceful Uses of Outer Space.
COSPAR	Committee on Space Research.
CSIR	Council for Industrial and Scientific Research.
DFVLR	Deutsche Forschungs and Versuchsanstalt fur Luft and Raumfaht (German Aerospace Research Establishment).
ELV	Expendable Launch Vehicle.
ESCES	Experimental Satellite Communication Earth Station.
DAE	Department of Atomic Energy, India.
DoD	Department of Defence, United States.
DOS	Department of Space, India.
ELDO	European Launch Development Organisation.
ELV	Expendable Launch Vehicle.
ESA	European Space Agency.
ESRO	European Space Research Organisation.
FROG	Free Rocket Over Ground
ICBM	Intercontinental Ballistic Missile.
ICSU	International Council for Scientific Unions.
IGMDP	Integrate Guided Missile Development Programme.
IGY	International Geophysical Year.
IMD	Indian Meteorological Department.
INCOSPAR	Indian National Commission for Space Research
INIOE	International Indian Ocean Expedition.
INSAT	Indian National Satellite System.
INTELSAT	International Telecommunications Satellite Organisation/Consortium.
IQSY	International Year of the Quite Sun.
IRBM	intermediate-range ballistic missile.

ISAC	ISRO Satellite Center.
ITU	International Telecommunications Union.
LANDSAT	NASA's Land Survey remote sensing satellite.
LOX	Liquid Oxygen.
MAD	mutual assured destruction.
MIRV	multiple independently targeted reentry vehicle.
MRBM	medium-range ballistic missile.
NASA	National Aeronautics and Space Administration.
NATO	North Atlantic Treaty Organisation.
NPL	National Physical Laboratory.
PGMs	precision guided munitions.
PRL	Physical Research Laboratory, Ahmedabad.
RAND	Research and Development Corporation, United States.
SAC	Space Application Center, Ahmadabad.
SALT	Strategic Arms Limitation Talks (or Treaty).
SAM	surface-to-air missile.
SLBM	submarine launched ballistic missile.
SSM	surface-to-surface missile.
TERLS	Tumba Equatorial Rocket Launching Station.
TIFR	Tata Institute for Fundamental Research, Bombay.
UN	United Nations.
VSSC	Vikram Sarabhai Space Center.
WTO	Warsaw Treaty Organisation.

CHAPTER ONE

INTRODUCTION

Space as a new area of state action was formally inaugurated with the launching of scientific satellites, first by the Soviet Union and later by the United States as part of their contributions to the international science programme, the International Geophysical Year of 1957. However, early space explorations had strong military overtones. Not only were the basic technologies of space exploration derived from military missiles, but military objectives remained at the forefront. Early space explorations were also strongly motivated by political considerations. In an atmosphere of open struggle for global influence, both the United States and the Soviet Union held their achievements in spaceflight as an evidence of national power, efficacy of national governmental systems and scientific prowess. To a lesser extent, this was also the context in which Europe, Canada and China initiated their space explorations. However, due to the growing importance of civilian space applications, especially satellite based communications systems, as well as due to the emergence of a rough strategic parity between the two Super Powers in the mid-1960s, the military monopoly over space was broken and the political dimension of space became less significant. Commercial and industrial interests came to the fore. These considerations injected a pragmatic element in the funding and utilisation of space among nations interested in outer space activities. As space technologies matured and as space applications became widespread, there emerged an intensified commercial competition between and within the space faring nations. In the early 1980s, Europe acquired access to the geo-stationary orbit with their Ariane rockets and ended the U.S. monopoly over commercial space products and services. In the mid-1980s, the Soviet Union and China made a bid to enter the lucrative and growing market for space products and services. Japan, India and Brazil also emerged on the horizon, acquiring the capabilities to launch satellites.

In a short span of four decades, space activities have multiplied and spread, offering a variety of services, stimulating entirely new industries, creating numerous operational capabilities, and spawning new national, regional and global organisations. Today, in addition to the Soviet Union/Russia and the United States, a few more countries have acquired the capabilities of independent access and use of outer space. And space applications have spread even wider. Some 140 nations are utilising the services provided by a variety of satellites in some form or the other. However, the United States and the Soviet Union/Russia remain leading space powers in terms of investments and activities. They alone are capable of conducting manned space operations and they launch numerous satellites for a wide variety of applications. In 1988, they spent around $ 35 billions each on space programmes, which amounted to 87 per cent of world-wide space investment. The remaining 13 per cent, roughly $ 10 billion, was spent by the rest of the world, with Europe spending 40 per cent of this amount, China around 30 per cent, Japan around 15 per cent and all other nations together spending about 15 per cent[1].

Space technology and outer space activities are characterised by unique features. In the first instance, they are inherently global in character. Rockets and the satellites transcend national and regional borders. While rockets can travel across the globe, satellites placed in the geo-stationary orbit cover one-third of the globe. It is for this reason that research, development and applications of space technologies have always involved a significant amount of international co-operation. Second, space technologies are derived from a range of multi-disciplinary and multi-industrial sources. A synthesis and integration of many disciplines ranging from astronomy, aerodynamics, mechanics, electronics, chemistry and physics and material sciences to fabrication technologies and management are involved in the design and development of spacecraft and space launchers. Given the complexity and magnitude of the effort involved, space activities and achievements of a nation are indicative of that nation's economic, technological and organisational capabilities. Closely related to this aspect of space technologies is the fact that they are at or near the cutting edge of technological development. Due to the particularly strong emphasis on research and development, the experimental character of many of these products, and the highly qualified personnel employed to build and orbit satellites, space industry is widely seen as the spearhead of technological developments. Finally, space technologies are

[1] Lopez V and D Vadas, *The US Aerospace Industry: A Global Perspective for the 1990s* (Washington D.C., 1991), p. 15.

predominantly dual-use in character, i.e. they can be employed for both civilian and military purposes. About two-thirds of relevant, basic space technologies have dual-use. This fact is made clear by consideration of Table 1 on page 4. It is for these reasons that space is an area of strategic activity and space technology can make significant contributions not only to national and international security but also towards scientific knowledge, large scale public services, international competitiveness and international co-operation.

The strategic character of outer space activities, be it for civilian or military purposes, has numerous implications for international security. The crowding of the geo-stationary orbit, the problem of space debris, the use of nuclear power sources, the use and transfer of remotely sensed data are some of the aspects having such implications. In addition, pressures on international security are generated by the use of outer space technologies for military purposes. The use of outer space and space technologies for military purposes has taken two directions. One is the 'non-weapon' or 'non-aggressive' use of space for supporting military activities on ground to enhance the performance of terrestrial forces. The other is the use of space for destroying space-based and ground-based assets of an adversary. Under the former come the various kinds of dedicated and non-dedicated satellites that are launched for enhancing the performance of the terrestrial forces, whether nuclear or conventional. In the latter category fall the space weapons, anti-satellite (ASAT) and ballistic missile defence (BMD) systems. The use of satellites for military support functions and the development of space weapons began almost immediately after 1958. Although both the Super Powers already possess some ASAT capabilities, neither of them have deployed such a system. BMD systems, on the other hand, are at various stages of development and no space-based weapon system has yet been deployed. This categorisation of military uses of space is made for the sake of analytical convenience and it should be noted that there are technologies which readily fall into both 'weapon' and 'non-weapon' categories. For instance, ballistic missiles have so far been deployed as terrestrial surface-to-surface systems and are therefore not categorised as space weapons. However, they fly a large part of their trajectory through space and have potential anti-satellite applications, making them space weapons.

Table 1: Select Space Technologies: Current Civil and Military Uses

Generic Technology Applications	Civil Uses	Military Uses
1) Satellite Communication systems	Fixed satellite service	Fixed satellite service
	Broadcasting satellite service	Broadcasting satellite service
	Mobile satellite service: *land *air *maritime mobile	Mobile satellite service: *land *air *maritime mobile
	Inter-satellite service	Inter-satellite service
2) Satellite Remote sensing/Imaging	Earth resources observation	Reconnaissance systems
	Environmental monitor	Environmental monitor
	Meteorological service	Meteorological service
	Atmospheric Research	
	Geophysics/Geodesy	Precision targeting
	Oceanographic	Oceanographic
	Cartography	Cartography
		Nuclear Test Detection
		Early Warning systems
	Treaty Compliance Verification	Treaty Compliance Verification
3) Satellite Navigation System	Navigation services	Navigation services
4) Rocket Propulsion	Space launch services	Space launch services
	Space propulsion systems	Space propulsion systems
	Sounding rockets	Sounding rockets
		Orbital reaction control systems
		Ballistic missiles: ground sea and air
		Anti-ballistic missiles
		Anti-satellite systems
		Interceptor propulsion
		Escape/Evasion systems
5) Satellite Search and rescue systems	Search and rescue services	Search and rescue services
6) Space Sciences and Exploration systems	Space research	
	Astrophysics	
	Cometology	
	Space science/ microgravity research	
	Exploration	Exploration
	Planetology	
	Solar Physics	
	Environmental definition	
7) Technology Demos	Technology Demons	Technology Demos
8) Tracking, Telemetry and Control systems	TT & C	TT & C
	Monitoring & data collection	Monitoring & data collection
9) Permanent Manned Orbiting Stations	Observation, Labs, Mission staging	Observation, Labs, Mission staging

Source: Stephen E. Doyle, *Civilian Space Systems: Implications for International Security* (UK, 1994), p. 5.

With both the Super Powers seeking to preserve their option to deploy weapons as well as carry out support military functions in space, it has not been possible to establish an outer space regime clearly defining 'space', 'peaceful uses of space' and 'space weapons' and prescribing norms on what can or cannot be done in space. The principal legal instrument for regulating the use of outer space is the Outer Space Treaty of 1967. It declares outer space 'the province of all mankind' the exploration of which 'shall be carried out for the benefit and in the interests of all countries...'. It guarantees all states freedom of exploration and scientific research. At the same time, the Treaty prohibits 'the establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies'. No 'objects carrying nuclear weapons or any type of weapons of mass destruction' are to be placed in orbit around the earth, but the use of military personnel for scientific research or other peaceful purposes is explicitly permitted.

The Outer Space Treaty fails to define outer space and contains no specific reference to its economic development potential. The Treaty has led to the establishment of two legal regimes: one for the moon and other celestial bodies, which are to be used *exclusively* for peaceful purposes; and the other for outer space, the Treaty nowhere saying that this is to be used *exclusively* for peaceful purposes. This inconsistency has given rise to different interpretations of the Treaty and a fierce debate between the Super Powers on what exactly constitutes the military uses of outer space. The different interpretations and the failure to arrive at an agreement has permitted the continuous militarisation of outer space.

Unhindered by any legal restrictions, ballistic missiles, which fly through space and military satellites, which are stationed in different orbits of outer space have multiplied. With more countries gaining access to outer space, ballistic missiles and military satellites have also spread horizontally. In fact, over a period of time, they have acquired some legitimacy. Missiles that are capable of penetrating hostile enemy defences became the indispensable instruments for maintaining a nuclear deterrent posture. Similarly, various kinds of military satellites (especially, reconnaissance, navigation and communication satellites), by supplying the cold war adversaries with accurate information on the military activities of each other as well as providing timely warning of an attack and reliable conduits for crisis management, are seen as having supported deterrence, arms control verification and strategic stability in general.[2]

As space technologies advanced and became reliable, the reliance of the military on space kept on increasing. Military satellites became an important war-fighting aid for terrestrial armed forces. Virtually every type of military operation, from small conventional conflicts to strategic nuclear war, came to involve the use of satellites in some significant way. Reconnaissance satellites are being used more and more to detect, track and target military forces such as naval ships; communication satellites are increasing combat effectiveness by the rapid and reliable distribution of military information; and navigation satellites are guiding munitions to their targets with near perfect precision. The number of countries using satellites for military purposes is also growing. In addition to the nuclear weapon states (the Super Powers, Britain, France and China), Israel launched a reconnaissance satellite in the late 1980s. India has capabilities in this area, although it has not yet launched a satellite for these purposes.

The increasing reliance of the armed forces on space systems has increased the incentives to deny their benefits to other nations and their armed forces. As a result, an important transformation in the use of outer space for military purposes is taking place in the form of development of dedicated weapons systems. In the 1980s, both the Super Powers renewed their efforts for developing anti-satellite (ASAT) weapon systems. A variety of ASAT systems, ground-to-space and space-to-space weapons were under development. Another weapon system that regained prominence in the 1980s was the ballistic missile defence (BMD) system. Like the ASAT system, BMD systems came under consideration in the late 1950s itself. However, it was held in check by a bilateral treaty, the Anti-Ballistic Missile (ABM) Treaty, agreed up by the United States and the Soviet Union in 1972. By this treaty, they agreed "not to develop, test, or deploy ABM systems or components which are sea-based, air-based, space-based, or land-based". By prohibiting defences against strategic weapons, this treaty ensured that the MAD (mutually assured destruction) capability on either side remained credible. In spite of the ABM Treaty, the development of BMD systems re-emerged as an official objective of the

[2] Paul B. Stares, 'Space Technology-Security Related Developments' *Disarmament* (New York), vol. XIII (1), 1990., pp. 101-118.

United States in 1983, when President Reagan launched the Strategic Defence Initiative (SDI). The work on space-based and ground-based defence systems against ballistic missiles under the SDI and the Soviet announcement in 1986 that it too is engaged in research on BMD system increased the prospects for the deployment of weapons in space.

It is important to recognise that although space weapons are categorised according to their missions- offensive ASATs and the defensive BMDs, there is a strong relationship between ASAT and BMD technologies. The basic principles of operation of these weapons are very similar, although their characteristics may differ considerably, depending on their applications. Since satellites are soft targets, the energy required to destroy them is much less than that needed to destroy a hard target, such as a missile or a nuclear warhead. BMD sensors and weapons that have ASAT applications include both space-based systems (to detect, track and intercept missiles in the early phases of their flight) and ground-based systems (to track and intercept missiles during the terminal phase). The close relationship between ASAT and BMD technologies became very much evident in September 1986, when the United States conducted a complex SDI-related test in the guise of ASAT tests. In that test, the U.S. used a satellite instead of nuclear warhead for interception thus carrying out a BMD test without violating the ABM Treaty. In a similar way, the ASAT technologies that are under consideration have potential BMD applications. Given this, 'the technical, political and diplomatic actions taken in one sphere will almost certainly affect the other'[3].

Apart from the complexity of the technologies involved in ASAT and BMD systems, strong international opinion against the weaponisation of space has kept in check the deployment of these weapon systems. The end of the cold war and the disintegration of the Soviet Union has weakened the support for these weapons programme in the United States. Besides, the resource base of Russia (the erstwhile Soviet Union) has also weakened. However, the ASAT and BMD programmes have gained a technological momentum of their own and research and development on various components of these weapons are taking place in several countries which happen to be formal or informal allies of the United States.

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[3] B. Jasani, 'Emerging Technologies', *Disarmament*, vol. X (2) Summer, 1987, pp. 21-37.

Efforts to establish a regime for the peaceful uses of outer space have continually floundered because for political and military reasons, both the United States and the Soviet Union were unwilling to accept controls on space technologies. With economic and commercial interests in space technologies and applications coming to the fore in the 1970s, these efforts became further complicated. In a real sense, the international treaties which have been negotiated are little more than the product of mutual agreements between the two leading space powers, the United States and the Soviet Union. The rest of the world has been asked or is required to either adhere to or adopt them. When other nations have argued that new arrangements are both necessary and desirable, they have met with opposition from the Super Powers. The proposal to create an International Satellite Monitoring Agency (ISMA), first made by the French government in 1978, is a case in point. In the latter half of the 1980s, the Soviet Union came round to supporting the ISMA proposal and in addition proposed the setting up of a World Space Organisation (WSO) to co-operatively manage all global space activities. As with the Soviet support for ISMA, the United States has dismissed the WSO concept, preferrring the co-ordination of national efforts rather than centralised international management organisations[4].

It is in the context of growing reliance of nations on space technologies for civilian and military purposes that the United States began to express concern over the spread of space launcher capabilities in the Third World and its military implications. Space launchers can be employed to develop ballistic missiles, strategic launcher systems for nuclear weapons and satellites for guidance and targeting of those weapons. Citing nuclear proliferation concerns and adverse impact of ballistic missiles on regional stability, especially in the Middle East and South Asia, the United States and other members of the G-7 (the UK, Canada, France, West Germany, Italy and Japan) announced a set of 'Guidelines for Sensitive Missile Relevant Transfers'. These guidelines which are widely referred to as the Missile Technology Control Regime (MTCR) are intended to restrict the international transfer of space technologies necessary for the production of nuclear capable

[4] The U.S. support for international management organsiations has favoured those in which private components lead or at least are represented, such as the INMARSAT (International Maritime Satellite Organisation) and the INTELSAT (International Telecommunication Satellite Organisation). Thomas E. Cremins, ' Security in the Space Age', *Space Policy*, February, 1990., pp. 33-43.

missiles i.e. missiles which could be used as nuclear weapons delivery systems. India's SLV-3, which successfully orbited a satellite into near earth orbit in 1980, was an important factor in raising Western concerns over the emerging missile problem in the Third World.[5]. In 1989, when India successfully test fired the Agni, an intermediate-range ballistic missiles, it became the prime target of the MTCR.

In the above context, we have attempted a study of the evolution and progress of the Indian space programme to see how a programme that was intended to achieve long-term security (given that development itself is an element of security) got associated with security in the immediate and narrow sense of military production programmes.

The Indian Space Programme

Among the Third World countries, India has an extensive and the most advanced space programme. Its space programme can be traced to the setting up of the Indian National Commission for Space Research (INCOSPAR) in 1961. Beginning in 1963, India started launching sounding rockets from the Thumba Equatorial Rocket Launching Station (TERLS), an international sounding rocket facility that had been established with assistance from the United States, the Soviet Union and France. In 1969, the Indian Space Research Organisation (ISRO), the brain and backbone of the Indian space programme, was set up. Space activity was transformed into an institutionalised programme with an assigned budget, specified goals and projects in space application when, in 1972, a separate Space Commission and a Department of Space were created along the lines of the Atomic Energy Commission and the Department of Atomic Energy. In other words, the space programme graduated from a small scientific activity into a co-ordinated programme with politically determined objectives that had to be justified in the Parliament.

India's foray into space was essentially a part of its development strategy that laid emphasis on industrialisation on a large scale. In sharp contrast to the space programmes existing elsewhere in the world that had military or grandiose purposes at the forefront, the Indian programme assigned priority to social and economic objectives. For a

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[5] Aaron Karp, 'Ballistic Missile Proliferation in the Third World', *SIPRI Yearbook 1989: World Armaments and Disarmament* (London, 1990), p. 297.

developing country with the size and diversity of India, space technology was seen as an economically cost-effective solution to many of its economic and social problems. The programme and policy was deliberately linked to the productive system. The specific social and economic objectives of the space programme relate to the use of satellites for communications, both in respect of telecommunications, and television, remote sensing of natural and renewable earth resources and meteorological observation and forecasting.

As in other national endeavours, self-reliance was the main thrust of the strategy employed in the accomplishment of India's space policy objectives. India sought to achieve self-reliance in the entire gamut of space technologies- satellites and the vehicles to orbit them and ground support equipment to utilise satellite services. However, in the short run, it was willing and eager to borrow technology from diverse sources to build its own capabilities. The leading space powers, the United States, the Soviet Union and France played an important role in building India's capabilities in the utilisation of space technology. In the early 1960s, the United States trained Indian engineers in rocket launching and range operations. In the 1970s, it assisted India in conducting a massive experiment in satellite-based communications and built the first generation satellites of the Indian National Satellite System according to Indian requirements. The Soviet Union, apart from launching different categories of satellites, helped India in establishing a firm base in satellite technology. France strengthened the sounding rocket programme at TERLS in the 1960s and helped to establish India's capabilities in liquid propulsion technology.

By judiciously mixing international assistance and domestic effort, India acquired a fair level of indigenous capability to build its own satellites and launch vehicles by the end of the 1970s. In 1980, by launching a 35 kilogram scientific payload into orbit with the indigenously built SLV-3, India became the seventh country (after the United States, the Soviet Union, Britain, Japan, France and China) capable of independently fabricating rockets that could inject satellites into the orbit.

Although SLV-3 was a civilian venture, it raised a host of domestic and international issues regarding the ultimate objective and technological capabilities of India in the advanced and sophisticated areas of nuclear and space technology. These issues no doubt emanate from the dual-use character of space technologies. With India having already exploded a nuclear device in 1974 and its refusal to sign the Non-Proliferation Treaty, security concerns over the Indian space programme became explicit in the early 1980s. The 1983 decision of the Government of India to establish design and production capabilities in a range of guided missiles within the country, appeared to confirm the Western fears over the proliferation of ballistic missiles. In 1989, India became a country of proliferation concern for the regime, when India went ahead with the testing of an intermediate-range ballistic missile in the face of opposition from the MTCR member countries. Since then the regime has placed restrictions on technology transfers to India's missile and space projects. In the years after the 1991 Gulf war, when there was a broadening of the scope of the regime, the regime began to target India's short-range missiles as well. Since then India has come under intense bilateral and multilateral pressures from the technologically advanced countries to cap and roll back its missile programme.

The United States, the leader of the MTCR, stated that the regime was not intended to discourage international co-operation in the peaceful uses of outer space. However, both because of the large number of dual-use technologies controlled by the regime as well as because of the selective implementation strategy adopted by the MTCR, the regime came to adversely affect international co-operation in the peaceful uses of outer space and civilian space programmes in the Third World. The ISRO-Glavkosmos contract of 1991, providing for the delivery of two cryogenic rocket boosters along with the know-how for their manufacture in India, had to be modified under pressure from the MTCR. The United States even imposed sanctions on the two contracting space agencies for allegedly violating the regime guidelines. The impact of technology controls will be wide. This is because modern industrial economies are highly dependent on precision machining, high-strength and high-temperature alloys, sophisticated avionics and other technologies which together constitute " missile technologies". In this context, it would be useful to critically examine the MTCR and its impact on India's security and development.

The primary objective of this study is to examine how the Indian space programme that was intended to contribute to 'development' which itself can be an element of security in the broader sense of the term, is being associated with security in the immediate and narrow sense of the term. Second, the study examines the impact of

MTCR on India's security as well as development. In examining these objectives, the study will focus on: (a) the Indian space policy, the evolution and development of the space programme; (b) the nature of dual use technologies, the linkages that exist between India's space and missile programmes; and (c) the technology transfer polices and mechanisms adopted by the advanced countries of the North and their impact on India's industrial and technological development in general and its space programme in particular.

The study has the following hypotheses:

India's forays into space technology were basically intended to tap this advanced technology for peaceful economic developmental purposes.

Opportunities created by the growing indigenous capabilities in space technology were seized by India to develop missiles to meet its security requirement

Discriminatory technology control regimes will affect India's security as well as economic development.

The methodology followed in this study is both historical and analytical. The study gives a brief historical account of the evolution of the Indian space and missile programmes. It traces the history of the shifts that have occurred in the technology transfer policies of the advanced countries of the North. In this connection, it critically analyses the Missile Technology Control Regime. In addition, India's space and missile programmes are critically analysed in terms of changes in the political and strategic environment of the country.

Given the paucity of literature on the Indian space programme the study depends heavily on primary sources. The primary sources of the study include not only the various official reports and documents of the Indian Space Research Organisation and the DRDO but also the text of the MTCR guidelines and Technical Annex, national legislation of the MTCR members, technology policy statements of the Government of India, the Annual Reports of Department of Space, Department of Atomic Energy, Ministry of Defence and Ministry of External Affairs, reports of the United Nations and its agencies on science and technology, outer space activities and disarmament, Surveys of Stockholm International Peace Research Institute, annual reports of the Arms Control and Disarmament Agency of the U.S. et cetera. The secondary sources include books and articles written by political analysts, defence experts, scientists and science reporters as well as those of retired officials of the Ministry of Defence, Department of Space and Ministry of External Affairs. It also includes seminar papers (wherever available) newspaper reports and articles.

The study is divided into seven chapters, including this introduction. The second and third chapters trace the evolution of the Indian space programme from its inception up to 1987. The focus of these chapters is on the accumulation of technological capabilities by the civilian space programme. Chapter two deals with the evolution, features and progress of the space programme up to 1972, the year in which it emerged as an institutionalised programme. Chapter three examines developments in the civilian space sector since its emergence as a full-fledged programme in 1972 till 1987, the year in which the Missile Technology Control Regime was formally unveiled. The fourth chapter examines the missile development efforts in the defence sector and how the civilian space programme came to be progressively associated with missile development efforts in the 1980s. The fifth chapter examines the rising concerns of the industrialised nations of the North with the proliferation of ballistic missiles and traces the evolution of the multilateral export control mechanism i.e., the Missile Technology Control Regime. Chapter six comes back to examine the progress made by the Indian space programme since 1987 and in this process evaluates the impact of the MTCR on India's high-technology space programmes. The seventh is the concluding chapter.

CHAPTER TWO

INDIA'S ENTRY INTO SPACE TECHNOLOGY: SPACE PROGRAMME UPTO 1972

After the Soviet Union and the United States heralded the dawn of space age in 1957, almost all other countries took it for granted at the outset that major space programs were beyond their financial scope. Even the industrialised nations of Europe, with the possible exception of France, shared this outlook. The Indian prime minister, Jawaharlal Nehru, stated in early 1960 that although India was 'high up in the list of advanced countries' in the field of atomic energy, it cannot go far in space exploration because of its want of resources.[1]

Yet the appeal of space remained strong. In Europe, that appeal was strong in the official and industrial quarters. Outer space activity was widely believed to be an important element in the technological base for economic and military security. The European nations therefore proceeded to pool their resources and establish a central facility for theoretical and experimental activity as well as establish a common launching capability. These efforts led to the setting up of the European Launch Development Organisation (ELDO) and the European Space Research Organisation (ESRO) under the leadership of Britain and France. In India, the appeal of space was largely confined to the scientific community engaged in the various branches of upper atmospheric/geophysical sciences. It soon got translated into a national space programme when it became clear that the subject of outer space is likely to be of increasing importance in the near future and that international co-operation on an extensive scale could be brought about in this field.[2]

1. INTERNATIONAL CO-OPERATION IN OUTER SPACE ACTIVITIES

International science programmes sponsored by non-governmental organisations played an important role in the evolution of the world outer space regime. In fact, the early satellites which heralded the dawn of the space age were launched as a part of one such programme—the International Geophysical Year 1957-58 (IGY). It was in 1954, when the

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[1] *New York Times*, 6 January 1960.

[2] Government of India (hereafter, India), Department of Atomic Energy, *Annual Report, 1960-61*, p. 20.

state of rocket technology provided sufficient hope for satellite ventures, that the International Council for Scientific Unions (ICSU) included space sciences as one of the objectives of the IGY. The scientists participating in the IGY General Assembly at Rome in October 1954 recommended that "thought be given to the launching of small satellite vehicles".[3] At the time of the IGY, non-orbiting sounding rockets were available to a few nations; United Kingdom, which collaborated with Australia, France, which did not undertake an IGY rocket programme; Japan and the Soviet Union; and the United States which worked closely with Canada. But only two nations had satellite launch capability. In October 1957, the Soviet Union demonstrated that capability by launching the first man-made satellite, Sputnik, as a part of its contribution to the IGY.

COSPAR

The IGY was a collection of national programmes independently working towards purely scientific objectives, co-ordinated by a non-governmental mechanism. In the IGY's one and half years, some 60,000 scientists and technicians from some 66 countries participated in a centrally planned, co-ordinated study of the earth and its cosmic environs.[4] The value of co-operation established by the success of the IGY led to the setting up of a successor enterprise in the non-governmental realm—Committee on Space Research (COSPAR). Established as a special committee of the ICSU in September 1957, COSPAR's first meeting took place in London in November 1958, where a charter was

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[3] The World Committee for the International Geophysical Year (CSAGI) met in Rome in 1954, establishing a Rocket Group for the first time. Among its recommendations were the following:
(2a) It is urged that as many countries as possible undertake programs of small rocket soundings and, in addition, that currently planned small rocket programs be expanded, but with no dimunution of effort in the large rocket programs......
(2c) CSAGI recommends that the geographic coverage of the large rocket sounding programmes, now planned by the United States and France, be extended at least during the IGY by the participation of other nations...
(2g) In view of the great importance of observations, during extended periods of time, of extra-terrestrial radiations and geophysical phenomena in the upper atmosphere, and in view of the advanced state of present rocket techniques, CSAGI recommends that thought be given to the launching of small satellite vehicles, to their scientific instrumentation, and to the new problems associated with satellite experiments, such as power supply, telemetering, and orientation of the vehicle.

[4] This programme involved the planning and execution of investigations directed at the physics of the upper atmosphere (solar activity, aurora and airglow, cosmic rays, geomagnetism, ionospheric physics), the earth and heat regimen (meteorology, oceanography, glaciology) and the earth's structure and shape (seismology, gravity, latitude and longitude determinations).

adopted despite some political problems. The membership of the COSPAR was established as consisting of 'national' members representing academies of sciences and of 'union' members representing the scientific union of the Council. The national members were the countries (Australia, Canada, France, Japan, the Soviet Union, the United Kingdom and the United States) active in rocket and satellite work and in tracking or other aspects of space research.

COSPAR was successful in continuing and even extending the IGY pattern of co-operation in space. Annual programmes were gathered and distributed, with their content approved. Annual general assemblies and a space bulletin were initiated to serve as authoritative timely medium of international communications. An annual series of Rocket Weeks was established and special topics were studied including space needs for radio frequency allocations, the properties of the upper atmosphere, etc. The COSPAR also took a leading role in international programmes of the Geophysical Committee of the ICSU—World Magnetic Survey and the International Year of the Quite Sun (IQSY) which were set to take place when the solar activity was at its lowest in 1964-65.

The role of COSPAR in international co-operative programmes got stabilised by the fact that the U.S. offered and promoted its space collaborative programmes through this forum and other non-governmental forums such as the International Astronautical Federation, and through informal contacts with scientists.

United Nations

If COSPAR promoted international co-operation in space research at the non-governmental level, the United Nations (and its agencies) served the same purpose as an inter-governmental or political forum. In 1958, the Thirteenth General Assembly considered various threats to national security and opportunities associated with space exploration and appointed an Ad Hoc Committee of 18 nations to review existing UN activities and resources relating to peaceful uses of outer space, to explore areas of appropriate and possible international co-operation, to consider organisational arrangements for facilitating such activities within the framework of the UN and to identify legal problems which might arise from activities associated with the exploration of outer space.[5] The Ad hoc Committee recommended that no new specialised agency or other autonomous intergovernmental organisation be established and that the General Assembly establish its own committee to consider means for facilitating co-operation and for studying and resolving legal problems in the field of outer space. In December 1959, the General Assembly adopted a 12-nation resolution (Resolution 1472 XIV) on international co-operation in peaceful uses of outer space which provided for the creation of a 24-member Committee on the Peaceful Uses of Outer Space (COPOUS). Among other things, COPUOS was "to study practical and feasible means for giving effect to programmes in peaceful uses of outer space which could appropriately be undertaken under UN auspices". This resolution specified three areas of activity which could be undertaken: (a)"continuation on a permanent basis of the outer space research carried on within the framework of the IGY, (b) mutual exchange and dissemination of information on outer space research and (c) encouragement of national research programmes for the study of outer space and the rendering of all possible assistance towards their realisation".[6]

After the political difficulties between the East and the West in connection with the establishment of the COPUOS were ironed out, in December 1961, the General Assembly unanimously adopted Resolution 1721 XVI which reiterated that the UN should provide a focal point for international co-operation in the peaceful exploration and uses of outer space. Among other things, this resolution asked the Committee, in co-operation with the Secretary-General, and making full use of the functions and resources of the Secretariat: (a) to maintain close contact with organisations concerned with outer space matters; (b) to provide for the exchange of such information on outer space activities as Governments might supply on a voluntary basis; and (c) to assist in the study of measures to promote international co-operation in outer space activities.[7] These terms of reference have since provided the general guidance for the activities of the Committee in promoting international co-operation in the peaceful uses of outer space.

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[5] General Assembly Resolution 1348 XII 13 December 1958.

[6] *United Nations Yearbook 1959* (New York, 1960), pp. 24-29.

[7] *United Nations Yearbook 1961* (New York, 1962), pp. 32-35.

U.S.A.: Co-operation in Space Research

The United States took the lead in opening up its space programme for international co-operation in the peaceful uses of outer space. In 1958 the National Aeronautic and Space Administration (NASA) was established with the express design to bring world leadership in space technology and exploration to the United States. At the same time, the National Aeronautic and Space Act which established NASA asked it to establish co-operative ties with other countries interested in outer space. The duality of competition (for pre-eminence) and collaboration (with other countries) was a conscious and deliberate policy pursued for the security of the former and promise and hope of the latter.[8] While leadership was necessary in view of the political-military importance of outer space, international co-operation held the hope that man's first steps into outer space taken openly and in concert would check the extension of conflict into new areas by reducing differences between the two Super Powers. At another level, international co-operation was equally important for operating a programme that was inherently 'global' in character and for tapping the resources of other countries. Last but not the least, in the context of the open struggle between the Super Powers for global influence, international co-operative programmes served propaganda purposes.

At the second meeting of the COSPAR in March 1959, the U.S. made the first concrete proposal for international co-operation in space research. At that meeting, the U.S. National Academy of Sciences offered, on behalf of NASA, to place in orbit individual experiments or complete satellite payloads, of mutual interest, prepared by scientist of other nations. This offer was essentially directed at the European allies who had the required scientific and technical competence necessary for co-operation.[9] After the third COSPAR meeting in Nice, in February 1960, U.S. co-operative programmes broadened beyond the European field and expanded in scope. Over the next couple of years, NASA encouraged and assisted (1) joint sounding rocket programmes utilising small non-orbiting rockets to carry out a variety of experiments in upper atmosphere, (2)

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[8] Walter A MacDoughall, *...the Heavens and the Earth: A Political History of the Space Age*, (New York: Basic Books, 1985). See also Arnold W. Frutkin, *International Cooperation in Space* (Delhi: Sterling Publishers, 1966).

[9] MacDoughall, ibid. p.207.

overseas ground support activities in connection with orbiting experiments in satellite communications, meteorology, ionospheric studies and other fields, (3) joint operation of satellite tracking and data acquisition facilities, and (4) research and training arrangements to assist personnel of co-operating countries to gain technical competence necessary for co-operation.[10]

The scope of co-operative programmes was, however, limited for reasons of national security. It was largely confined to space sciences and did not extend to the versatile tools of space exploration, particularly, rocket technology. Co-operation in space activities was limited in another sense. The U.S. insisted that co-operation should not take the form of aid or support but involve substantive co-operation in the areas of mutual interest. Each nation was asked decide for itself whether it wished to spend money and material on some aspect of space technology. If it did so, the U.S. invited mutually beneficial proposals. There was no courting of such proposals just for the sake of 'co-operation'. The U.S. avoided raising the hopes of Third World countries, which clearly had no role to play in space science and technology. The requirement that each co-operative project be of valid scientific content and reflect mutual interest meant that 'each co-operative project became a constructive element of the space programme of the NASA, approved by appropriate programme officials and justifying the expenditure of funds for the U.S. portion of the joint undertaking'.[11]

The U.S. offer of co-operative space programme stimulated the scientific and industrial communities in Western Europe. An internal competition for control of space planning and operations emerged within the European nations that evinced interest in space research. Engineer-based groups contended the matter with science-based groups and military with civilian and industrial. NASA, therefore, established criteria for the recognition of foreign agencies with which to deal in co-operative space projects. Given its own civilian stamp and its keenness to ensure substantive co-operation (funds and facilities), which it reckoned would be ensured by a government agency, NASA asked the interested countries to designate a central, civilian, and government sponsored, if not

[10] Frutkin, n. 8, p. 41.

[11] ibid., p.33.

governmental authority to deal with NASA.

It is in the context of the subject of international co-operation in peaceful uses of outer space gaining prominence and the United States making concrete proposal for co-operation that Indian scientists and policy makers evinced interest undertaking space research on an organised basis. By then, India had a solid base in upper atmospheric studies that was built over several decades of research in geophysics, solar physics and earth sun relationship.

2. INDIAN SCIENCE IN THE PRE SPUTNIK ERA

Modern science had its origin in colonial India beginning with the survey work in geography and botany that was carried out by Jesuit missionaries and amateur researchers in the 18th century. It became a institutionalised activity, for all practical purposes, with the establishment of the Asiatic Society of Bengal by William Jones in 1784. Under amateur scientists, drawn from colonial administrative services, the focus of science was on survey in the fields of geology, botany and zoology. To support this work, a host of field organisations and institutions were established under the Asiatic Society. Studies in astronomy and geophysical sciences, including meteorology, also emerged in this early phase of modern science in colonial India.

Astronomical studies based of modern techniques began in the late 18th century, when the colonial administration set up the Madras Observatory for promoting the knowledge of astrology, geography and navigation in India. Over a period of time, this Observatory made significant contributions to the preparation of a star catalogue, and discovery of asteroids and variable stars. In 1900, a Solar Physics Observatory was set up at Kodaikanal under the Indian Meteorological Department. Its pioneering work was concerned with the sun spectra, hydrogen content of solar prominence, spectrum of night sky, variation in the area of hydrogen absorption and the meteorological and seismological studies as well.[12] In the area of geophysical studies, Colonial India participated in the global study of the earth's magnetism in the 1830s. A few years later, a magnetic observatory was established in Colaba/Alibagh which gradually developed into one of the

[12] Indian National Science Academy, *Science in India: 50 years of the Academy* (New Delhi, 1985), p. 48.

primary observatories of the world.

Meteorological studies also began in India in the mid 19th century and gathered momentum with the establishment of the Indian Meteorological Department (IMD) in 1875. With a network of over 125 observatories, the IMD undertook studies in seismology, solar physics and geomagnetism. In 1914, it introduced weather forecasting system utilising the upper air data.

The latter half of the 19th century witnessed the professionalisation as well as Indianisation of science. The period 1850-1950 saw the gradual emergence of Indian scientists, technologists, and technicians, either formally trained by Europeans or informally schooled by works of Europeans. By the beginning of the 20th century, Indians had acquired the requisite expertise in several branches of modern science, including atmospheric and geophysical sciences. Even though state support for science was negligible, major scientific centers in India were in the forefront of scientific developments during this period. Whether the Indian scientists were victims of neo-colonialism, investigating problems that were delineated by European scientists, or there was already an internationalisation of science that was at work, is debatable, European ideas had a catalytic effect on Indian science and technology. A number of Indian scientists working in the country (J.C. Bose, J.N. Bose, C.V. Raman and M.N. Saha) and abroad (Homi J. Bhabha and Subramanyam Chandrasekhar) made notable contributions to modern science. With scientific research emerging as an integral part of independent India's plans for economic development and as a major objective of state policy, these studies received an added impetus.[13] Let us briefly sketch the developments in the fields intimately tied to the space science and technology.

Since the discovery of cosmic rays by Hess, an Austrian physicist, in 1912, cosmic ray studies had attracted the attention of scientists whose basic callings were as diverse as astrophysics, geophysics, plasma physics and radio chemistry. The new and exciting discoveries made in this field in Europe and the U.S.A engaged active interests in the major scientific centers of India. In the 1930s, M N Saha made an ambitious plea of

[13] ibid., p.83.

photographing of the sun by sending instruments to a height of 50 km.[14] About the same time, Homi J. Bhabha and Heitler developed the theory of cascade showers, for the understanding of electron-proton showers in cosmic rays and won instant international acclaim. By the mid-1940s, the Palit Laboratory in the Calcutta University, the Bose Institute in Calcutta, the Indian Institute of Science in Bangalore and the Presidency College in Calcutta were operating the most sophisticated instruments of that period, the counter controlled cloud chambers for studying the properties of cosmic ray particles. Towards the end of the decade, with the establishment of the Tata Institute for Fundamental Research (TIFR) and the appointment of Bhabha as its first director, the cosmic ray study team shifted along with Bhabha from Indian Institute of Science, Bangalore to TIFR, Bombay. In the 1950s, cosmic ray research was expanded with teams of young generation scientists and the cosmic ray research at TIFR proliferated in many areas of frontline research. By the end of the decade, a start was made in space platform-based studies utilising large plastic balloons developed by the TIFR.[15]

The pursuit of cosmic ray research had become attractive to the Indian scientists for several reasons. As a field which has throughout been in the forefront of scientific developments, as a field intimately related to so many important branches of research which utilise some of the most advanced instrumentation and employ the newest theoretical concepts and more important, as a field relatively inexpensive to work in, cosmic ray research was perceived to be ideally suitable for the scientists of a developing country aspiring to play an important role in international science and technology.[16]

In a similar manner, ionospheric studies took firm root in India within a few years after the discovery of the ionosphere in 1925 by Appleton and Barnett and by Briet and Tuve. Under the leadership of S.K. Mitra, Calcutta University emerged as a leading center

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[14] D.S. Kothari and A.S. Nagarajan, "Exploration Prospects", *Seminar*, November, 1960., p.12.

[15] The TIFR under the Department of Atomic Energy (DAE) had emerged as the most important center for cosmic ray and elementary particle physics in the 1950s. Bhabha justified the DAE's decision to concentrate its research on comic rays thus "New information has been received from this work in India about the behavior of elementary particles energies which lie far beyond the scope of even the largest accelerator." On this point there has been some difference of opinion among Indian scientists. MN Shah a critique of the work of DAE, held a contrary view .See *Jr. of Geological, and Metallurgical Society of India*, vol. xxv 1957.

[16] M.G.K. Menon, 'Some Aspects of Cosmic Ray Research', *Journal of Scientific and Industrial Research*, vol. 24, March 1965.

of studies in aeronomy in the early 1930s. Prof. Mitra's famous book "Upper Atmosphere" published by the Asiatic Society in 1947, made an important contribution to the growth of upper atmospheric and ionospheric studies not only in India but also elsewhere.[17] In 1942, the growth of ionospheric studies received an impetus with the setting up of the Radio Research Committee of the Council for Scientific and Industrial Research (CSIR). A number of stations of All India Radio (AIR) began hourly observation of ionospheric parameters. The Colaba/Alibagh and the Kodaikanal Observatories were by then already engaged in round the clock recordings of the ground level variations of the geomagnetic field. In the 1950s, there was a spurt in the upper atmospheric studies at various centers such as the Physical Research Laboratory (PRL), Andhra University, the National Physical Laboratory (NPL), New Delhi and the All India Radio. Most of these places adopted the advanced techniques for the study purposes. In addition to traditional experiments, the technique of cosmic noise measurement, pioneered by A.P. Mitra was extensively used in the country.[18] Indian scientists adopted space techniques in right earnest for aeronomic studies with the dawn of the space era.

The first step in this direction was the establishment of a precision optical tracking system at the Nainital Observatory in 1958. During the IGY, the Nainital Observatory was equipped with a Baker Nunn tracking camera and other associated instruments loaned by the Smithsonian Astrophysical Observatory, U.S.A.. This tracking station is one of the 12 such stations scattered throughout the world for the measurement of satellite position and time coordinates. This observatory also participated in a U.S. Naval Observation programme involving the photographing of the Moon.[19] Another space technique adopted was the use of satellite orbital data for upper air studies at the NPL. By examining the drag experienced by the satellites due to atmospheric and solar radiation pressures it is

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[17] Prof. Mitra and his colleagues developed the neutral atmosphere model which formed the basis for predictions of the lifetime and orbital decelerations of satellites when Sputnik I was launched in 1957, V.V. Agashe, J.H. Sastri and R Sridhar, 'Structure Energetics and Dynamics of the Low-Altitude Upper Atmosphere' in K.R. Verma, ed., *Advances in Space Research in India: A Three Decade Profile* (New Delhi, 1994)., p.99.

[18] This was in fact the only method available in the pre-satellite era for deriving the top side ionization distribution .The cosmic radio noise technique and its upgraded version, the 'riometer' developed at the NPL proved to be a valuable tool for monitoring the ionoshperic effects of atmospheric nuclear explosions conducted by the Super Powers during 1961--62. ibid. p. 96.

[19] N.V. Sagar, "Harvesting Data From Space", *Span*, August, 1962.

possible to estimate some of the upper atmospheric parameters, like particle density, temperature etc. Such attempts were made by a research group at the NPL. It analysed data of about 46 satellites starting from Sputnik-I to Aerial, the British satellite launched in 1964, covering different epochs of solar activity and wide range of perigee heights. Starting in 1962, the NPL research group also attempted to measure total electron content in atmosphere by receiving radio beacon transmissions form COSMOS-V satellite. Later, in 1965, the PRL, Defence Electronics Research Laboratory and Astrophysical Observatory at Kodaikanal began receiving the beacons.[20]

This brief sketch of the development of upper atmospheric sciences in India clearly brings out that Indian scientists kept pace with scientific developments in the West, designed and adopted advanced techniques to study the scientific phenomena encountered in outer space and made some notable contributions to the field. We also observed that Indian scientists and technicians took an active role in the IGY's space research programme and thereafter carried out ground-based and space platform-based studies relating to outer space phenomena. Yet it was only in 1961 that the modern era of space research may be said to have made a formal beginning. For in that year, recognising the growing importance of the peaceful uses of outer space and the opening up of opportunities for international co-operation in this field, India took the first step in undertaking space research on an organised basis by setting up the Indian National Committee for Space Research (INCOSPAR). Before we proceed to examine the evolution of the Indian space programme and policy it will be useful to examine the science and technology policy and practice of independent India which provides the broader context in which the Indian space programme evolved. This will provide a clue to the nature of the Indian space programme.

Science and Technology in India

At the time of India's independence, the science scene was of a widespread though diffused scientific activity. Even so, the contours of the future developments in the form of national laboratories of the CSIR, the Department of Atomic Energy (DAE), of

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[20] These stations covered very important regions like the equatorial electrojet region and the equatorial anomaly regions. See S. R. Khastgir, *A Decade of Science in India* (Indian Science Congress Association, 1973).

institutes of technology were already emerging. The task of the Indian government and more particularly of its first Prime Minister, Jawaharlal Nehru, was to strengthen, co-ordinate and direct these developments to subserve the goals of socio-economic development.

The key elements of independent India's development strategy, planning, industrialisation and scientific research, had their roots in the anti-colonial national movement. In the 1920s and 1930s, a vigorous pressure group had emerged in favour of heavy industrialisation based on scientific research as a reaction to the British policy of emphasising agriculture over industry and to the anti-industrialism of Gandhi. This group gained wider acceptance when Jawaharlal Nehru became the chairman of the National Planning Committee in 1938. It was largely because of Nehru's prominent role in the national movement, his intimate association with the scientific community and the support that he lent to science and science based technology that science became one of the priorities of the Indian National Congress in the 1940s[21]and thereafter.

Nehru's views and ideas about the role of science and science based technology in India's development are important because of the central place which he came to occupy in the first decade and half of independence. These have been well documented and therefore a detailed analysis is not being offered here. Sufficient here to say that under the influence of the Soviet success in planned economic development, Nehru was convinced that the "future belongs to science and to those who make friends with science".[22] He regarded science as an important factor of change in social attitudes, values, and outlook through the widespread dissemination and inculcation of what he called the 'scientific temper'. He was, however, mainly concerned with the application of scientific knowledge through technology as a critical means of achieving rapid material

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[21] The Congress Party Election Manifesto of December 1945, prepared for anticipated elections to the interim government at the Center, declared that "Science, in its instrumental fields of activity, has played an ever increasing part in influencing and moulding human life and will do so in even greater measure in the future. Industrial, agricultural and cultural advance, as well as national defence, depend upon it. Scientific research is therefore a basic and essential activity of the state and should be organised and encouraged on the widest scale" See 'Congress Manifesto, 11 December 1945', Appendix I in P Sitaramayya, *History of the Indian National Congress*, vol. II (Delhi, 1969)., p. iv.

[22] Baldev Singh, ed., *Jawaharlal Nehru on Science and Society: A Collection of his Writings and Speeches* (New Delhi, 1988)

progress in a poor society and as a source of national power for a newly independent country. He expressed his abiding faith in the instrumental value of science thus: "It is science alone that could solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people"[23]. Of considerable significance is the fact that Nehru rejected the Gandhian concept of Ramarajya as the ultimate aim of Indian nationalism. In 1945, he wrote to Gandhi that in order to protect India from foreign aggression and to achieve economic independence India had to be made 'a technologically advanced country'. Heavy engineering and machine making industry, scientific research institutions and electric power were the three fundamental requirements of India's independence.[24]

After attaining independence, scientific research was integrated with development planning and promotion of science and technology became an important objective of state policy. The first Five Year Plan, which was basically a preparatory one for planning in India, emphasised the role of science thus: "In the planned economy of a country, science must necessarily play a specially important role. Improvements in techniques evolved as a result of scientific research bring about great increases in production in the different sectors of the economy. A balanced programme of research covering every sector of the economy is, therefore, essential for the development of a country".[25] During the Second Five-Year Plan period, Nehru drafted and placed before the Indian parliament, the Science Policy Resolution in 1958. This resolution broadly spelt out the twin objectives underlying the development of Indian capacity in science and technology. The first was to meet the challenge of the rising expectations of the Indian people in their most basic material and social needs such as food, housing, health, education and employment. The other was to remove, or at least reduce, the dependent industrial and technological relationships with the advanced countries in the North and thus assert greater economic and political autonomy in the international system. As Nehru said earlier at the Indian Science

[23] Quoted in *Science in India*, n. 12, p 83.
[24] Cited in Ward Morehouse and Brijen Gupta, 'India: Success and Failure' in Aaron Segal, ed., *Learning By Doing: Science and Technology in the Developing World* (Boulder, 1984), p.192.
[25] Cited in *Science in India...*, n. 12, p.84.

Congress in Jan 1958, the state should encourage science "not only because it is the right thing to do but even from the narrow opportunistic point of view that it is becoming important to do so. If you do not, you get left behind, you get weak".[26] These basic objectives underlying the promotion of science have continued to inform the Indian policy process in the years after Nehru.

Whether Nehru and his scientific aides were aware of the complexities of the process of linking scientific research through technology to the productive sectors of the society, is not clear, and forms the subject of some recent studies on the role of science and technology in India[27]. The evidence we have suggests that he assumed cultivation of India's scientific capabilities as a sufficient public policy goal in and of itself. It was assumed that once these capabilities were sufficiently strong, the critical linking process through science based technology would occur on a broad scale. For instance, the Science Policy Resolution laid down broad guidelines for the government 'to foster, promote, and sustain by all appropriate means, the cultivation of science, and scientific research in all its aspects—pure, applied and education', but did not elaborate and/or establish clear linkages between science and technology and science and industry.

3. BEGINNING OF THE SPACE PROGRAMME

By the beginning of the 1960s, the Indian scientific community, which was engaged in understanding the scientific phenomena in outer space, had developed a positive interest in the subject of space research and its peaceful applications. Satellites technology and rockets provided new opportunities for carrying on and strengthening geophysical and aeronomic research. Moreover, satellites-weather and communications-appeared to hold great promise in the immediate future with significant implications for agriculture, education, industry and other areas of economic endeavour.[28] But was space research worth the cost and effort? D.S. Kothari, the then scientific advisor to the Ministry of

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[26] Nehru's address to the Indian Science Congress at Madras in January 1958, *Proceedings of the Indian Science Congress*, Part I (Madras, 1958), p.37.

[27] For instance, Ward Morehouse and Brijen Gupta, n. 24, Shiv Vishwanathan, *Organising for Science* (Delhi, 1985), Radhika Ramasubban and Bhanwar Singh, 'The Orientation of the Public Sciences in a Post-Colonial Society: The Experience of India' in Stuart Blume and others, eds., *The Social Direction of the Public Sciences: Sociology of the Sciences Yearbook, XI* (Dordrecht, 1987).

[28] Satish Dhawan, 'Manned Flight', *Seminar*, November, 1960., p.18.

Defence and an influential personality in the science policy process, felt that it is too early to give a definite answer. Nevertheless, he argued that space research "may not be such a costly luxury as imagined...When more reliable forecasting becomes possible, the satellite may very well pay for itself in saved crops and human lives alone...and communication satellites hold great promise".[29]

An important factor that finally persuaded the Indian government to formally launch a national space programme was the opening up of opportunities for international co-operation in space research. With the subject of international co-operation emerging on the agenda of governmental and non-governmental international organisations and with the United States making concrete proposals for co-operative projects in space research in 1959 and 1960, the cost of space research appeared no longer prohibitive. It is in this context that the TIFR, an autonomous laboratory under the Department of Atomic Energy (DAE), that had emerged as the most important center in India for cosmic ray and elementary particle physics, evinced interest in initiating space research in India. Already engaged in space platform based studies utilising plastic balloons developed at the institute, the TIFR saw satellites and rockets providing new opportunities for carrying out upper atmospheric research.[30]

Entrusted with the subject of space research and its peaceful applications in 1961, the DAE began to develop the Physical Research Laboratory (PRL), Ahmadabad, into a major center for space research. The PRL, which was established jointly by the Ahmadabad Education Society and the Kharmaskestra Education Foundation in 1948 had been working in the area of cosmic rays, atmospheric and theoretical physics. In 1961, the DAE decided to finance the entire research work at the PRL[31] which was now expanded

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[29] Kothari and Nagarajan, n. 19, p. 12.

[30] The cosmic ray research committee of the DAE had been organising annual cosmic ray symposia since 1955. The DAE had established a high altitude cosmic ray lab in Gulmarg-Aparwat area of Kashmir and as a contribution to the IGY had conducted balloon flights to study scientific phenomena encountered at 20-30 kilometers height. In the immediate years preceding the constitution of the INCOSPAR, the TIFR participated in an international collaboration organised by University of Chicago to study ultra high energy nuclear interaction, took part in an experiment of Gamma Ray spectrum at balloon altitude, and carried out large plastic balloon studies jointly with the U.S. in March/April 1961. India, Department of Atomic Energy (DAE), *Annual Report 1961-62*. These international scientific programmes were essentially a by product of the IGY research programme and in some cases represented a continuation of some elements of that programme.

[31] India, DAE, *Annual Report, 1962-63*, p. 19.

to include electronics, space physics, solar and cosmic radio astronomy, aeronomy, high atmospheric and radio physics. That year, the PRL was equipped with a mobile telemetry station with directional antenna and radio receiver for upper atmospheric research.[32] In early 1962, when the Indian National Committee for Space Research (INCOSPAR) was set up, the head of the PRL, Dr Vikram A Sarabhai was made its chairman. With this, the PRL became de facto the main center of activities in space sciences in India

Establishment of the INCOSPAR

Early in 1962, the DAE constituted the Indian National Committee for Space Research (INCOSPAR) with the following terms of reference:

advise the Government on promotion of research in and exploration of space and its utilisation for peaceful purposes;

promote international co-operation in space research and exploration and in the peaceful uses of space and participation in the UN Committee on the Peaceful Uses of Outer Space and other international organs with similar objectives;

laise with the COSPAR of International Council of Scientific Unions (ICSU) and other national and international organs interested in the research in and the peaceful uses of space and generally to contribute and support national and international activities likely to contribute to the development of the peaceful uses of space.[33]

The first space research project identified by the INCOSPAR related to the use of sounding rockets for studying the region of the atmosphere 40 to 200 kilometers space. In terms of science and scientific techniques, this represented an extension of the space platform based studies utilising plastic balloons. Sounding rockets, which carry instruments to the earth's atmosphere in a vertical trajectory provide access to this region of the atmosphere which is beyond the reach of balloons and satellites.[34] More important, sounding rocket research programme was relatively inexpensive and involved

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[32] The equipment was supplied by NASA as a part of the DAE-NASA collaborative programme in upper atmosphere. It was used to receive signals from certain scientific satellites used for research in ionospheric propagation. The station, which was entirely manned by Indian personnel, provided the Indian crew with valuable training in the procedure of operating a telemetry station. See Sagar, n. 19.

[33] India, DAE, *Annual Report, 1961-62,* p. 17.

[34] They permit measurements along their flight path, sometimes telemetering this information to the earth, sometimes permitting optical or sound measurements, sometimes returning a package to the earth for recovery and examination.

simple techniques when compared to space boosters. It was thus an excellent point of departure for a developing country wishing to enter into space studies.

The region between 40 and 200 kilometers of the atmosphere is of great significance for understanding some of the processes by which weather is affected. Its importance also was in the fact that the ionosphere, which makes long-range wireless communication possible through reflection of short radio waves, is located in this region. Moreover, upper atmospheric phenomena over India was characterised by some special features. In the 1940s, scientific phenomena peculiar to the equatorial anomaly regions and equatorial electrojet regions were first identified. Since then, these regions have continued to engage the attention of a large number of researchers. Both these regions are located within the country, a unique feature emanating from the country's geographical location and its continental size.

In early 1962, the INCOSPAR began talks with NASA to evolve a space research programme using sounding rockets. During these talks, the U.S. suggested that the proposed rocket range be offered for use internationally and that UN sponsorship be sought. Thereafter, the U.S. introduced into the Technical Subcommittee of the COPUOS a resolution for UN sponsorship of sounding rocket ranges in scientifically critical locations. The resolution received unanimous support in the Subcommittee, its parent body, and ultimately in the General Assembly. Even the COSPAR drew attention to the major gaps in world coverage of sounding rocket launch sites and urged that a site be established on the magnetic equator as soon as possible, as a first step in creating and using international sounding rocket facilities under UN sponsorship. In September 1962, Indian delegation at the COPUOS offered to be the host state for the facility on the terms proposed by the committee.

The technical appeal for such a proposal lay in the fact that India was uniquely situated close to the geomagnetic equator which is of special interest for scientific investigations in the fields of meteorology, agronomy and certain aspects of astronomy (due to low background radiation).[35] The geomagnetic equator passes mostly through oceanic regions and the land areas in this belt are rather inaccessible for the most part.

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[35] V. Sudhakar, *Sounding Rockets of ISRO* (Bangalore, December, 1976), p. 1.

Very few countries advanced in science and technology are located on these latitudes. Secondly, the idea of an international facility close to the geomagnetic equator assumed importance and a compelling urgency in view of the International Indian Ocean Expedition (INIOE) and the International Year of the Quite Sun (IQSY), the two programmes of the ICSU involving an extensive synoptic sounding rocket programme in meteorology, aeronomy, ionosphere, solar activity and the earth's magnetic field. To this one may add the political appeal of establishing an international facility in a developing country of non-aligned status which not only served a propaganda purpose but also provide an opportunity for the scientists and engineers of the contending Super Powers to work together.

The U.S. suggestion for setting up an international facility in India struck a right cord in the Indian scientific and official circles for two reasons. For one thing, the appeal of an international facility was strong in the Indian scientific community for it provided them with an opportunity to establish close contacts with scientists, engineers and technologists from nations that are technically far more developed. At another level, the proposal was in tune with India's internationalism. Indian diplomacy had placed a high premium on East West co-operation as an essential condition for peace and development. The establishment of a international facility in a non-aligned country appeared to provided a opportunity for the Super Powers, which were also the leading space powers, to work towards an outer space regime based on co-operation rather than conflict. Giving expression to this belief, the Indian representative at the COPUOS meeting in February 1963 said "co-operation in outer space may reduce international tensions and create understanding and mutual confidence leading to co-operation in other matters on this planet of ours".[36]

When the subcommittee of the COPUOS that met in May 1962 called for the creation and operation of an international facility, India offered to be a host state for the facility on the terms proposed by the committee. The COPUOS in its report to the General Assembly in December 1962 suggested fourteen principles for the creation and operation of international sounding rocket launch facilities. By these principles, each sounding

[36] UN Record, A/AC.105/PV.13.

rocket launching facility was to be the responsibility of the country (the host state) within whose territory it was located.[37]

Establishment of the Thumba Station

Having offered to be a host state for the rocket facility, the main task of the INCOSPAR was to establish a launching station in time for participation in the international scientific programmes particularly, the IQSY and the INIOE. Thumba, a fishing village near Trivendrum was identified as a rocket launching station for carrying out equatorial studies[38]. Training of the staff and minimum equipment for the Thumba Equatorial Rocket Launching Station (TERLS) was provided by the NASA through an agreement concluded between DAE and NASA in October 1962. The agreement provided for joint scientific experiments to explore the upper atmospheric winds and equatorial electrojet from a site established on the geomagnetic equator. The DAE was to provide four sodium vapour release payloads, appropriate photographic equipment, supporting meteorological data, telemetry and data analysis, launching site and supporting facilities and personnel for launching operations. NASA was to provide four Nike Cajun and nine Nike Apache vehicles, suitable launching device on loan basis, training for Indian personnel responsible for conducting the launching operations, ground tracking and telemetry equipment and ground instrumentation on loan basis.[39]

With a small group of scientists and engineers trained in launch operations at NASA, the TERLS became operational in November 1963, when a American sounding rocket, Nike Apache, was launched with a sodium vapour payload supplied by France. France

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[37] A launching site would be recognised as an international facility of the COPUOS if it conformed to the principles established. The sounding rocket launching facilities would only be used for peaceful scientific experiments. The basic principles suggested by the Committee provided for the following: The host state would be responsible for making working agreements with the user nations for providing, through voluntary agreements, funds or equipment or both, for reporting periodically to the Committee on the operations and use of these sounding rocket launching facilities; and for the management and operation of the range. Data on the experiments, schedules and firings for launchings at these facilities would be reported by the host and user states both to the Committee and the COSPAR. See, *United Nations Yearbook 1962* (New York, 1963), p. 51.

[38] Initially, two sites were identified, Thumba, a fishing village and another one near Quilon. The former was finally chosen for its thin levels of population density and low fishing activity. See Vikram A. Sarabhai, 'India enters Space Age', *Indian and Foreign Review*, February, 1964.

[39] *Foreign Affairs Record*, April, 1963., p. 47-8

later equipped the range with a launcher, a radar and high-speed camera for photographing of rockets. The U.S.S.R. also strengthened the range with a MI-4 helicopter for range surveillance and payload recovery duties and equipment for payload testing.[40] India was thus suitably equipped to take an active part in the international scientific programmes, the IQSY and the IIOE.[41]

In early 1964, responding to the INCOSPAR's invitation, a UN team visited the TERLS to consider whether it confirmed to the principles laid down by the UN. Composed of scientists from Argentina, Brazil, Japan, Sweden, U.S.A. and the U.S.S.R., the UN team was unanimous in recommending UN sponsorship. The Thumba station became the first international sounding rocket launching facility to be sponsored by the UN when the Scientific Subcommittee formally accorded sponsorship in May 1965. It became freely available to all members states of the UN wishing to enter the field of space research, especially those which were unable to support such a programme except through international co-operative effort.

Meteorology and Communications

In addition to basic research programmes, space research extended into two major applied branches—meteorology and communications. In 1964, the DAE extended the MOU with NASA to develop a meteorological sounding rocket system through a co-operative programme which will contribute to the INIOE.[42] While the U.S. provided meteorological sounding rockets and radar equipment and general technical advice, India took responsibility for all aspects of operating the TERLS and agreed to plan and co-ordinate its meteorological sounding rocket launches with other participating countries through the International Meteorological Center of the INIOE. Beginning with the three meteorological rocket sounding in July 1964, a series of experiments using Judi-Dart rockets were conducted from the TERLS. Some of these were conducted as a part of the IQSY and the INIOE which involved synoptic launchings of sounding rockets in different

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40 'International Facility for Space Research', *Journal of Scientific and Industrial Research*, February 1968.

41 In fact, the second launch from the Thumba range on 8 January 1964, was part of the IQSY study. It carried scientific payloads designed specially for these experiments.

42 The INIOE was expected to provide information on the dynamics of circulation between 100000 and 200000 feet for use in the study of meteorology and planetary atmosphere. *Nuclear India*, vol. 2.(10) March 1964.

parts of the world to obtain simultaneous measurements of winds and turbulence in the ionosphere. Britain and the Soviet Union also launched their meteorological sounding rockets from the TERLS as a part of these international projects. The Soviet Union soon became a major partner in meteorological studies at the TERLS. In collaboration with the Soviet State Committee for Hydro-Meteorological and Natural Resources Control, weekly M-100 rocket flights were carried out from the TERLS beginning in December 1970. As a result, the Indian meteorological studies carried out from the TERLS contributed much upper atmospheric data for eastern hemisphere weather analysis.[43]

The year 1964 also saw India making a foray in the area of satellite communications. Recognising the need for setting up a research and training center to enable developing countries gain competence in satellite communication technology, the Governing Council of the UN Special Fund decided to set up and fund an satellite communication earth station in India. The Experimental Satellite Communication Earth Station (ESCES) which was set up in Ahmadabad began to provide research and training facilities in satellite communication technology since 1967, when it became operational.

In 1964, India also became the founder member of the INTELSAT (International Telecommunication Satellite Organisation), a global consortium established to provide on a commercial basis, the space segment required for international public telecommunication services of high quality and reliability on a non-discriminatory basis to all areas of the world[44]. That year, the DAE also extended the bilateral co-operative agreement with NASA to include experimental tests in satellite communications.

In the mid-1960s, the idea of utilising television media as a means for supporting development programmes gained prominence in the Indian planning circles. In 1966, the Chand Committee Report made a forceful recommendation for setting up a television system in India. In this context, the Indian space scientists at the DAE conceptualised satellite television as a powerful tool for meeting the educational and informational needs

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[43] *Space: Research Technology Applications* (hereafter *Space*), vol. 7 (5), September-October 1980.

[44] With a modest contribution of one million dollars, India's shareholding amounted to just 1/2 per cent (whereas the U.S. had 60 per cent shares). Although only those with a shareholding of 1 1/2 % were given automatic permanent representation in the Management Board, India in view of its geographical position, its status as the most populous country, of growth potential in traffic and political and other factors, staked a claim for voice in the management. *Radio Times of India* (New Delhi), March 1965

of the rural population. They took an active role in the Delhi Instructional Television that took shape as a pilot project catering to different audience groups for instruction and education—citizen civic education, Delhi School Project and the Krishi Dharshan. The last named programme was a collaborative venture of the DAE, the Indian Agricultural Research Institute and the Delhi Administration. Beginning in 1966-67, the DAE initiated several technical and economic studies to determine the system configuration, cost and significance of a synchronous satellite to provide a powerful national system for mass communication using television. These studies analysed the following technical options to design the most suitable satellite system in the Indian context: (1) Conventional rebroadcast stations with territorial microwave interconnections, (2) Direct broadcast from a synchronous satellite (3) Conventional rebroadcast stations with satellite interconnections, and (4) a hybrid system involving direct broadcast to some areas and five rebroadcast stations for the densely populated regions. All these studies concluded that the fourth option was the most cost effective system for providing television to all the half million villages in India.[45]

In the meantime, the idea of satellite based television for development was reinforced by the UNESCO study group on satellite instructional television in 1966-67. It identified India as particularly appropriate for an early implementation of a domestic satellite broadcast system. A UNESCO study team which visited India that year, recommended the India take up a pilot project to study the functioning of direct broadcasting system in India. The following year, the Indian government set up a National Satellite Communication (NASCOM) Study Group. It was these studies and deliberations that paved the way for the Government's acceptance, in 1969, of the DAE proposal for conducting the Satellite Instructional Television Experiment (SITE) utilising NASA's ATS-6 satellite.[46]

4 GROWING IMPORTANCE OF SPACE TECHNOLOGY

It was clear at the outset that space research cannot progress without the simultaneous development of space technology. Without their own research tools—sounding rockets and

[45] Ashok Raj and C Vishnu Mohan, 'INSAT: Evolution and Prospects', *Economic and Political Weekly (EPW)*, 14 August 1982.
[46] Department of Space, *INSAT-I* (Bangalore: ISRO, 1982).

appropriately designed scientific payloads, Indian researchers would be deprived of conducting their own individual experiments. Under the existing arrangements, they could carry out only those experiments in which there was a matching interest of the co-operating country. Moreover, promotion of pure science alone was not the factor in the policy circles. As we saw, Indian science policy makers were equally interested in practical application of space technology, for weather analysis and forecasting and communications. They were further convinced of the strategic importance of space activities. The chairman of the SACC and the head of the DAE, Homi J. Bhabha underscored this at a seminar organised by the INCOSPAR in December 1963. He said that another and perhaps the most important "reason for India going into space research was that there are many areas in which it is likely to yield results of great practical interest and importance in the near future, and we would once again be falling behind the advanced countries in practical technology if we were not to look ahead and prepare to take advantage of these new developments also...If we do not do so now, we will have to depend later on buying know-how from other countries at much greater costs".[47] It is for these reasons that the INCOSPAR began to focus attention on the construction of scientific payloads and sounding rockets and in the applied branches of space research.[48]

In early 1964, a beginning was made in the indigenous development of scientific payloads for rocket experiments. At the PRL, basic electronic digital and analogue circuits were developed from available Indian components. As a result, an integrated payload was successfully developed within a year. The indigenously designed and constructed magnetometer and the Languor payloads were meant to study electric field structure in the electrojet regions.[49] In the following years, several scientific payloads were developed at the PRL, National Physical Lab, (D region experiment payload), and Space Science and Technology Center (Dart payload). By the end of the decade, Indian scientists and engineers had acquired skills in designing and fabricating scientific payloads which

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[47] Bhabha's address at the first seminar on space technology at Thumba in December 1963. Cited in G Venkatraman, *Bhabha and his Magnificent Obsession* (New Delhi, 1994),. p. 170.

[48] India, DAE, *Annual Report 1963-64,* p.35.

[49] Magnetometers are used to study electrojet currents, their heights of occurrence and the extent in altitude. The Langmuir payload developed by the PRL had special features and was useful in measuring the basic plasma parameters of the electrojet such as the electron.

were sufficient enough for NASA to approach India for building a cosmic ray measurement instrument for one of its Apollo missions to the Moon.[50]

After the Tumba station was operationalised, the DAE approached France in early 1964 to strengthen the TERLS with additional equipment and continue rocket experiments for the remaining part of the year. The MOU signed between the DAE and the CNES in May 1964 provided for four Centaure rockets with sodium payloads and some equipment for the Thumba range.[51] The most significant feature of the Indo-French co-operation in space was the French offer to transfer Beliar and Centaure sounding rocket technology. An agreement was also signed with Sud Aviation for the licensed manufacture of Centaure rockets. The manufacture of this was entrusted to a unit of the Bhabha Atomic Research Center (BARC), the Central Workshop which was set up to design and fabricate components for scientific payloads. But space technology acquired through license from abroad was intended to be only a means to buy time. For there were simultaneous efforts to strengthen the technology base for the indigenous development and production of space technology—satellite payloads and rockets. A major research and development establishment to advance space technology was planned and eventually created in 1965.

The INCOSPAR also sought to acquire technology for a launch vehicle capable of orbiting small scientific payloads. In late 1964, it evinced interest in acquiring NASA's Scout rocket technology. The U.S. which had by then, extended its international programmes to include the transfer of rocket technology, however declined.[52] Another disappointment that INCOSPAR encountered in 1965 was with respect to the UN sponsorship for a centre for research and training in sounding rocket experiments. In mid-1964, the INCOSPAR sought UN assistance "to undertake measures to increase the utility of the Thumba station as a place of international collaboration in space experiments and to provide programmes and facilities for training scientists and technicians in certain spheres to the extent that such training may be effectively utilised at the TERLS or

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[50] Prime Minister Mrs. Indira Gandhi in the Lok Sabha, 1970. *Times of India* (New Delhi), 26 February 1970.

[51] *Nuclear India*, vol. 2(11) 1964.

[52] Brahma Chellaney, *Nuclear Proliferation: The U.S.-Indian Conflict* (Delhi, 1993).

elsewhere".[53] The proposal received a positive response from the Technical Subcommittee, but UN sponsorship was not forthcoming. The Geneva meeting of the committee in May 1965 accorded UN sponsorship only to the TERLS.

The U.S. refusal to transfer Scout rocket technology as well as the failure to get the UN sponsorship for a research and training center in sounding rocket experiments must be seen in the context of Western concerns over the proliferation of nuclear weapons and their delivery systems. Following the explosion of a nuclear device by China in October 1964, there was an heightened concern over the proliferation of nuclear weapons. A matching nuclear response by India, it was felt would make it impossible to limit the general spread of nuclear weapons. It is in this context that the military potential of the nascent Indian space programme began to attract attention,[54] resulting in technology controls and denials.

The heightened concerns over strategic issues and technology denials that were characteristic of the mid-1960s reinforced the Indian commitment to self-reliance in space technology. For a country which had been seeking to maximise its independence in the international system, the denial of rocket technology raised concerns over the dependence of a national space programme on launch services provided by advanced space powers. As Sarabhai said "the political implications of a national system dependent on foreign agencies for launching a satellite are complex. They are not negative in the present day world only in the context of the coming together of the national interest of the launcher and the user nations. As long as there is no effective mutuality or interdependence between the two, many nations left with the ground segment would probably feel the need for some measure of redundant capability under complete national jurisdiction".[55] It was because of these concerns that the development of indigenous capabilities in the entire spectrum of space technology, launch vehicles, satellites and supporting technology for ground operations became a fundamental feature of the Indian space effort. India's civilian

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[53] Chakravarthy at COPUOS, 8th December 8,1964., A/AC,105/PV.30.

[54] Alistair Buchan, 'The Dilemma of Indian Security', *Survival*, vol. 2 (5), August 1965. p.204-7.

[55] Address to the United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, August 1968. The text is reprinted in Kamla Chowdhry, ed., *Vikram Sarabhai: Science Policy and National Development* (Delhi, 1974), p. 36.

space programme came to resemble in many ways its atomic energy programme where the acquisition of complete national control over the entire fuel cycle was a strong impulse.

However, external factors, particularly considerations of national power, alone were not responsible for the growing emphasis on space technology. There were equally compelling internal or domestic factors which contributed to this thrust on science and technology in general and space technology in particular. One is the shift of emphasis in economic planning from industry to agriculture and the other is the growing problem of the unemployed science graduates and the brain drain.

In the 1960s, there was a change in the orientation of development planning. The armed conflict with China in 1962 and with Pakistan in 1965 and the two consecutive droughts led to large imports of food grains and a serious foreign exchange crisis. In the mid-term appraisal of the Third Five Year Plan, the National Development Council, drew attention to the crisis in the agriculture sector and recommended that the "highest priority be given to agriculture".[56] The realisation of the central importance of agriculture meant that even for the growth of industries, it was essential that the national economy remained progressive and stable. In January 1965, the Durgapur AICC's 'Resolution on Economic and Social Policy' re-emphasised the importance of agriculture and demanded that the "requirements of agriculture by way of materials, skills and finance must at all times be the first charge of available resources".[57]

This shift in emphasis did not mean a fundamental reform or reverting to the practices and principles of Gandhian village economy, but a greater commitment to the mechanisation of agriculture. The mid-term appraisal of the Third Five Year Plan stressed the urgent need for improved farm implements and machinery and recommended that "increasing use be made of institutions engaged in agriculture research, education and

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[56] India, Planning Commission, *Mid-term Appraisal of the Third Five Year Plan* (New Delhi, November, 1963), p. 177.

[57] All India Congress Committee (AICC), 69th Session, *Durgapur, Resolutions*, January, 1965, pp. 8-11. This resolution stressed that agriculture development cannot take place in isolation. It calls for a revolution in the rural economy, for which an all round and comprehensive development of the rural sector is absolutely essential.

training of progressive farmers in developing extension facilities".[58] In this context, space research and its applications-communication, meteorological and remote sensing services- which held great promise for the vast rural economy, became an area of added emphasis. For the country's development planners, the attraction of space technologies was enhanced by the fact that these 'did not discriminate against people living far from urban centers'.[59]

Already in the mid-1950s, the idea of communication for development was firmly established among Indian and international development planners and the government of India launched the Rural Radio Forums (RRF) in 1956 to disseminate developmental information to the rural population. Subsequent plans also had given high priority to broadcasting in the form of community listening. Although the RRFs did not expand on the scale envisaged in the five year plans, largely because of the mixed feedback on the effectiveness of radio, television caught the imagination of the Indian development planners. A DAE-NASA study in 1967 on satellite based television system, concluded that this was the most cost effective system for providing television to all the half million villages in India. Other applications of space technology- weather forecasting and remote sensing of natural resources-also held a promise for the rural economy. Thus, a national space programme with accent on application of space technology for development, fitted well with the rural orientation that the development plans came to assume in the 1960s.

Another factor that contributed towards a national commitment to space technology and applications was the emergence of the phenomenon of the unemployed science graduates and the related problem of 'brain drain'. As early as 1958, the year in which the Indian parliament adopted the Science Policy Resolution, Nehru acknowledged the problem of underutilisation of scientific and engineering personnel. He believed that with "proper organisation and planning" this could be overcome in time[60]. However, the

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[58] *Mid-Term Appraisal* ..., n. 56.

[59] Space scientists stress that space technology makes no discrimination between urban and rural areas. See, for instance, Prof. Yash Pal in *Space*, vol. 1(4). November, 1974.

[60] 'We suffer today, on the one hand from a lack of trained personnel-engineers and the like, scientists and the like, and yet they are hardly used enough , we have plenty of unemployment in our country. That shows a lack of proper organisation and planning. Obviously that cannot be done quickly. It takes time'. *Proceeding of the 45th Indian Science Congress*, n. 26, p.39.

problem became worse in the 1960s and emerged on the agenda of the major political parties in the country.[61] The scientific community within the country expressed concern over the problem of the migration of fellow scientist and called for building effective scientific teams and expansion of facilities for research in universities and labs.[62] It is in this context that gained wider support.

It was for these reasons that in the mid-1960s, there emerged a firm national commitment for an extensive and self-reliant space programme. The latter half of the decade witnessed the establishment of the basic infrastructure necessary for designing and building sophisticated hardware involved in space technology; rockets, satellites and ground equipment for space applications. The basic strategy for the development of space technology in the country was laid down at this time. It was a strategy of step-by-step approach to the attainment of self-reliance in developing complex systems such as satellites and launch vehicles-by taking up a number of small individual projects, each by itself modest in character, but progressively involving increasing complexity and sophistication. The Space Science and Technology Center (SSTC) that was set up in 1966-67 to strengthen the sounding rocket programme was also entrusted with the task of developing expertise in aerospace engineering, sounding rockets of superior performance and a modest satellite launcher.

With the space effort gathering momentum in the latter half of the 1960s, strong professional interest groups began to emerge to strengthen the national efforts in the field of space research. In 1968, the Indian Rocket Society (IRS), a non-governmental professional body of space scientists and engineers, was formed. One of the important objectives of the IRS was "to promote and stimulate space flight activities to achieve scientific knowledge of outer space for peaceful purposes,... and to stimulate work on astronautical subjects by the national establishments engaged on space research, scientific

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[61] Balwant Bhaneja, *Science and Government: The Nehru Era: Accountability of Science in India* (New Delhi, 1992)., pp. 37-57

[62] At the !964 Indian Science Congress at Calcutta, the General President of the Congress, Dr. Humayun Kabir who was closely associated with science policy and planning in the country referred to Prof. Heisenberg's suggestion 'to build up effective scientific teams within the country, expand facilities for research in Universities and laboratories and improve conditions of service of scientists' to counter the phenomena of brain drain. *Proceedings of the 52nd Indian Science Congress*, Part I (Calcutta, 1964-65) p 18.

institutions, universities, commercial and industrial firms, individual specialists etc."[63]

Although the support base for the space programme expanded during the 1960s, it was not without critics. Both within the scientific community as well as among the various government departments that were the principal user agencies of space technology, there was resistance to the expansion of programme. Many scientists and engineers, not convinced of the economic or military relevance of space research, cautioned the government against taking up scientific programmes on prestige grounds.[64] Another section of the scientific community, led by the Noble laureate, C.V. Raman was critical of the policy of big science in big laboratories. The essence of science, they maintained, is independent thinking and handwork and not equipment. The media in general supported the avante grade scientific activity , but it too found "the place of space research in the complex pattern of the country's socio-economic priorities unclear".[65] Within the government itself, there were differences among the various departments on the relevance of space technology to development. While it was recognised that space communications would play a decisive and vital role in international communications, the role that it could play in domestic telecommunications and television was not that obvious to many. The principal user agencies of the space applications, the All India Radio and the Post and Telegraphs, for a long time did not accept satellite-based communication techniques, preferring terrestrial technology of microwave and television towers networking.[66]

5. SPACE TECHNOLOGY

Rocket Development

The indigenous development of sounding rockets can be traced to the creation of the SSTC in the mid-1960s. In early 1966, the DAE had begun to develop its own rockets under the guidance of a Japanese rocket expert, who was appointed as a consultant in his individual capacity.[67] The first Indian rocket, launched on 20 November 1967, was

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[63] 'International Facility for Space Research', n. 40.

[64] D.M. Bose, 'India's Recent Achievements in Atomic and Space Research', *Science and Culture*, vol. 34 (6) June 1968.

[65] *The Statesman*, 13 November 1968.

[66] B.D. Dhawan, 'Satellite TV Revisited', *EPW*, 20 April 1974, pp. 634-40.

[67] Prime Minister Mrs. Gandhi in the Lok Sabha on 9 May 1966.

typical of a pioneering effort. With a diameter of just 75 mm, the first indigenously fabricated solid propellant rocket, the Rohini-75, weighed only 10 kg. and attained an altitude of 4.2 km. But it proved the skill and confidence of the pioneers. The fundamentals of rocketry were understood. Making bigger rockets was only a matter of time, requiring the development of the essential infrastructure. Some of that infrastructure was already becoming available through the licensed production of the Centaure rockets.

In fact, after flight testing a few RH-75 rockets with indigenously developed propellants, Indian engineers were already thinking in terms of developing a launch rocket, equipped with guidance and control systems -a complex and sophisticated technology when compared to a sounding rocket.[68] In the mid 1968, the Indian engineers at the TERLS and SSTC prepared a preliminary feasibility study report for launching a modest scientific satellite of about 20-40 kg weight into the 400 km low earth orbit. Based on this report, Sriharikota, a place located on the east coast, was identified for development as satellite launching site. In the following year, a feasibility and optimisation study was done to finalise specifications for the design and development of a satellite launch vehicle having a capability of putting 70 kg payload into 400 km near circular orbit. A development programme for a minimal control guidance system, therefore, became an area of special emphasis. At that time, it was estimated that it would take five years to design and develop an indigenous control and guidance system for the Indian satellite launch vehicle. Until then, the Indian space programme had to consolidate its sounding rocket technology. In the next five years, the diameter and the launch weight of the Rohini series of rockets increased. These series consist of single and two-stage solid propellant sounding rockets. The smallest of these, the RH-125, is a single-stage rocket weighing 32 kg with a capacity to lift 7 kg payload to an altitude of about 10 km, while the two-stage 1.4 tonne RH-560 can carry multi-experiment payloads weighing nearly 100 kg to an altitude of over 350 km. The development of these rockets resulted in a fully indigenous capability in sounding rockets. These rockets were used by Indian and

[68] Sounding rockets can carry a variety of payloads, but they cannot impart the final velocity needed to orbit the payload. The final stage of a launch vehicle, on the other hand, is designed to inject in orbit, low or geo-stationary orbit, a payload or satellite. This is a complex operation requiring the incorporation of on board guidance and control systems.

international experimenters to conduct wide ranging scientific experiments like the study of the neutral and ionised parts of the upper atmosphere, the equatorial electrojet, x-ray astronomy and various meteorological studies. More important, the Rohini rockets directly contributed to the development of satellite launch vehicles. Larger rockets, such as the RH-560, were used for flight testing technological payloads and subsystems developed for use in the satellite launch vehicles and spacecraft.

The Central Workshop at Trombay which had taken up the licensed production of the Centaure sounding rocket, played a crucial role in the design, development and construction of components that go into the making of sounding rockets and payload systems.[69] The Centaure involved large number of special materials from aerospatial steel (for casings, fins etc.) to items like explosive belt, ignitor, thermal lining compounds, impregnated synthetic laminations, high temperature resistant electrical cables, vibration proof electrical connectors, special mechanical fastenings, a wide range of resins, electrometers and host of other items.[70] The handling and development of special materials and the high quality standards achieved boosted the confidence of the Indian engineers. The first Indian made Centaure carrying a 30 kilogram payload was test flown in February 1969. With the commissioning of the Rocket Fabrication Facility (RFF) at Thumba into service in 1971, the Trombay unit ceased the manufacture of the Centaure. The RFF became the main centre for the development and production of various sounding rockets, the Rohini, Centaure and Menaka series of rockets.

(a)Propellants and Propulsion Systems

Propellants provide the rocket with necessary energy to perform its single most important task, to move up against gravity. Studies on understanding the basic principles involved in making propellants were taken up by a group of chemical engineers at Thumba in 1964. It was difficult to get precise guidance on making propellants, a

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[69] Between 1965 and 1968, the Trombay Workshop fabricated and supplied almost all the major mechanical components of payload systems for different types of rockets at the TERLS. Among the items supplied were several types of nose cones, payload canisters for use with sodium, Trethylaluminium (TEA) and Trimethylalauminium (TMA), precision components for payload recovery systems and a unit for charging payload canisters with TEA and TMA fluids. *Nuclear India*, October 1967.

[70] *Nuclear Indian*, March 1967.

technology which was closely associated with missile development abroad. The agreement with the French firm, Sud Aviation, for the manufacture of Centaure rocket did not cover technology for producing the propellant resin and other chemicals but only the techniques and equipment necessary for making solid motor out of them.[71] As a result, research and development work on propellants assumed utmost importance. This was carried out at several centers simultaneously, notably at the SSTC, TERLS, BARC and in a defence laboratory.[72] As a result, by the time the first Indian manufactured Centaure was ready, Indian engineers had developed eight different propellants and had carried out over 500 static tests using indigenous propellants.[73] The indigenously developed Rohini (RH-75 and RH-100) and Menaka rockets, several of which were launched since 1967, were used to test these propellants.[74]

The Propellant Engineering Division at Veli Hills was strengthened with the addition of a chemical laboratory in April 1969. Housed in the Propellant complex, this laboratory, was meant to serve all units of the ISRO at the Thumba and Veli Hills. This laboratory developed the propellant resins, insulating rubber, inhibitors, adhesives and other chemicals needed for solid propellants. An indigenous PVC resin called Mrinal was developed as a substitute for the imported resin used in the Centaure rockets. Later on, needing better polymer binders, HEF 20 (high energy fuel) and IPP (ISRO Polyol Propellant) which could be made cheaply from castor oil, were developed. The HEF -20 was used in the upper stages of the SLV and the ASLV.[75]

(b) Guidance and Control System

Having decided to become a satellite launching nation, guidance and control systems became an area of emphasis in the expanding research and development activities of the Indian space establishment. A feasibility study of the control and guidance system of satellite launch vehicles was carried out in 1969 and a development programme for a

[71] Gopal N. Raj, 'Self-Reliance in Solid Propulsion', *The Hindu* (New Delhi) 8 September 1993.

[72] Propellants have several applications in the defence sector. In 1964, a propellant plant was set up at Bhandara, near Nagpur.

[73] India, DAE, *Annual Report 1968-69*, p.70.

[74] In 1967, eight RH-75 rockets were test fired and the following eleven more RH-75 rockets and five Menaka rockets were flight-tested.

[75] Raj, n. 71.

minimal control and system for such missions was initiated. This involved the design and development of optical, magnetic and inertial type sensors and control components of electro-mechanical, magnetic, pneumatic and hydraulic types and associated special electronics.[76] Within a year, the SSTC developed a prototype of a rate gyroscope, an instrument to measure the rates of angular motion of space vehicles in flight.[77]

Satellite Technology

In the mid 1960s, an important opportunity became available for carrying out a feasibility study in instructional television based on satellite technology. At that time, NASA of the U.S.A was developing a very large high power experimental three-axis stabilised communication satellite with high power transmitters operating in the ultra high frequency (UHF) band around 860 mhz and a large 30 feet diameter antenna that can be used for generation of narrow beam and pointed very accurately. Compared to the then available capabilities of communication satellites like the INTELSAT-3 for television transmission requiring large earth stations to receive reasonable quality of pictures, the capability of this satellite, Applications Technology Satellite-ATS-F, was expected to be such that using an inexpensive antenna of only 10 feet diameter and a relatively low cost, low noise receiver the television signal could be received in the area covered 'by the beam. The frequency allocations in the UHF region for use of space to earth communications were not available then but there was a possibility of using this frequency band in India and other developing countries where it was not in use for mobile communications or terrestrial television transmission.[78]

With the cost effectiveness of satellite-based communication systems established by the DAE-NASA study of 1966-67, INCOSPAR persuaded NASA to provide the ATS-F satellite for a year long experiment in instructional television in India. In 1969, the NASA and the DAE signed an MOU for conducting a communication experiment, called the SITE (for Satellite Instructional Television Experiment). To define the overall system configuration for the year long experiment using the ATS-F satellite, as well as for future

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[76] India, DAE, *Annual Report 1969-70,* p. 67.
[77] India, DAE, *Annual Report 1970-71,* p. 145.
[78] Pramod Kale, 'Development of Space Communications in India', in R.K. Varma, and others, eds., *Space-In Pursuit of New Horizons,* (Allahabad, 1992), p.239.

operational satellite-based systems for television and telecommunication services, a series of system studies were conducted (ISRO-General Electric Corp., ISRO-Hughes Corp., ISRO-MIT studies and NASA sponsored studies by TRW and GEC). Once the feasibility for a national satellite communication system was established, the INCOSPAR in 1970, drew a ten year time frame for acquiring not only the ability to build communication satellites but also the ability to launch them into synchronous orbit. A new area of space applications that gained ground in the late 1960s was the remote sensing of natural resources. In December 1969, the DAE convened the first interdepartmental meeting of the Members of Parliament, Departmental Heads, Planners and Policy makers for acquainting them with remote sensing and its applications. A few months later, ISRO conducted its first experiment in remote sensing in collaboration with NASA. Coconut plantations in parts of Kerala were photographed from a helicopter for an early detection of the coconut blight disease. In order to acquire indigenous competence in this technology, steps were taken to have an infra-red scanner constructed in France in Prof. Morel's Laboratory with the active participation of an Indian scientist and an engineer. Apart from the relevance of remote sensing technology for a developing country that had embarked on the path of planned development, an important factor that stimulated the interest of scientists in India was that this technology was new and India was almost on the on 'ground floor' as some of the advanced countries. "We can, therefore, hope that adequate technological skills will be developed locally, so that we will be able to use this powerful and sophisticated technology to the same extent as any advanced country, for the economic and social betterment of our people".[79]

Ground Support Systems

The establishment of the ESCES was a first step in the development of an extensive ground support equipment necessary for national satellite system. The center which became operational in August 1967, provided valuable experience in building and operating ground satellite communication terminal. In 1968, the DAE undertook the Arvi Satellite Communication Earth Station project for the Ministry of Communication. The

[79] P.R. Pisharoty, a senior scientist at the Space Application Centre, Ahmadabad. Quoted in K.P. Prakasham, Space Horizons (New Delhi, 1981), p. 42.

90 foot diameter parabolic reflector antenna and the servo control and drive system for the antenna were designed and fabricated by the BARC. Indigenous capabilities were also tapped in the field of Multiplex and terminal facilities sub system. The station which was handed over to the Overseas Communication Services in January 1971, came in to commercial operation when it got locked on to the INTELSAT-IV stationed over the Indian Ocean.

In the early 1970s, the UNDP allotted a sum of $1,068,900 towards the upgradation and expansion of the ESCES so that it can serve as a prime earth station for conducting the SITE experiment. Once again, the accent was placed on the indigenous development of the additional equipment required for the facility. The import content was limited to the components and hardware not available within the country.

6. CONCLUSION

The opening up of opportunities for international co-operation in peaceful uses of outer space accelerated the evolutionary process in outer space related scientific activities leading to the formal launching of the Indian space programme in 1961. It was clear at the outset that space research cannot progress without the simultaneous development of space technology. As satellite technologies of the space powers advanced, bringing out their economic potential, Indian planners became convinced of the relevance of space technologies for a developing country of the size and diversity of India. Recognising the potential of space technologies and their applications in the areas of communication, meteorological and remote sensing, to pitch fork the country into a higher level of economic and social development, the government made a firm commitment to the space programme in the latter half of the 1960s. This resulted in the establishment of the basic research and development infrastructure necessary for a self-reliant space programme. The sounding rocket experiments conducted since the early 1960s provided the focus around which an extensive science and technology base for space activities was set up. With the pace of space activities gathering momentum, a new organisation for the purpose of conducting programmes of space research and their utilisation was felt necessary. In 1969, the Indian Space Research Organisation (ISRO) was set up at Ahmedabad. ISRO was made responsible for the management and execution of space research activities undertaken of behalf of the DAE. The INCOSPAR was reconstituted as an advisory body under the Indian National Science Academy.

With the experience gained from the development and construction of scientific payloads, sounding rockets and complete ground support equipment required for rocket experiments, and with the basic strategy for achieving competence in space technology laid down, the Indian space programme decided to establish the country's capabilities to develop and launch application satellites aboard its own launch vehicles. The Ten-year development plan for the space programme in the 1970s entitled 'Atomic Energy and Space Research- A Profile for the Decade 1970-80,' spelt out the principal objectives of the India space programme thus: "to develop indigenous competence for designing and building sophisticated hardware involved in space technology including rockets and satellites for scientific research and practical applications, the use of these system for providing point to point communications and a national television hook up through a direct broadcast synchronous satellite; and the application of satellites for meteorology and for remote sensing of earth resources". With the space programme poised for a new phase of development, the Government of India established the space programme as a full-fledged and institutionalised programme under the newly constituted Space Commission and the Department of Space.

CHAPTER THREE

INSTITUTIONALISATION OF THE INDIAN SPACE PROGRAMME: INDIAN SPACE PROGRAMME 1972-1987

Space research which was initiated by a small community of physicists had registered a phenomenal growth by the early 1970s, with over 2500 scientists of some 18 major institutions, universities and organisations engaged in it. The pace of research had also gathered momentum. While a total of 205 sounding rockets were launched from the TERLS, in 1970 alone, some 75 rockets were launched.[1] Equipped with the basic capabilities of producing its own two-stage sounding rockets and sophisticated payloads, the nature of the programme was also undergoing a change, with space applications (communications and survey and management of resources) gaining prominence in the overall scheme of space effort. The ten-year plan entitled "Atomic Energy and Space Research-A Profile for the Decade 1970-1980", that was announced in May 1970 by the Atomic Energy Commission, then headed by Vikram A. Sarabhai, envisaged the development of an experimental launch vehicle, the SLV-3, within five years. This was to be followed by the development of more powerful launch motors with the objective of attaining capability for orbiting the country's communication and remote sensing satellites.

Keeping these factors in mind, the Government of India "in order to promote a rapid development of activities connected with space" considered it "necessary to set up an organisation, free from all non-essential restrictions or needlessly inelastic rules, which will have responsibility in the entire field of science and technology of outer space and their applications". In June 1972, the Government of India set up a new policy making body, the Space Commission and handed over the subject of space research and its utilisation (that was held by the Department of Atomic Energy since 1961) to a newly created Department of Space (DOS). The official resolution establishing the Space Commission stated that "the Government attaches the highest importance to the exploration of outer space and the development of space science and technology and their

[1] India, Atomic Energy Commission of India, *Atomic Energy and Space Research: A Profile for the Decade 1970-80* (Bombay, July 1970).

applications. The sophistication of this technology, the newness in the field, the strategic nature of its development and the many areas in which it has applications, have to be borne in mind in devising a suitable organisational framework".[2]

The newly established Space Commission was to be responsible for the formulation of the policy of the Department of Space for the consideration of the Prime Minister, preparation of the budget of the DOS for approval by the Government, and the implementation of the Government policy in all matters concerning outer space. The Department of Space (DOS), directly under the charge of the Prime Minister, was made responsible for the execution of space activities in the country through the Indian Space Research Organisation (ISRO) in space applications, space technology, and space sciences. The jurisdiction of ISRO was extended over all the establishments carrying out research and developmental activities of the Indian space programme. In 1975, ISRO, which had functioned as an autonomous agency since its establishment in 1969, was converted into a government organisation. The process of transformation from an informal activity into an institutionalised programme with an assigned budget, time-bound goals, and specific projects in space applications and technology was thus effected in the early 1970s.

The newly established DOS derived some of its policy guidelines from the Atomic Energy Commission under whose aegis the space activities were conducted until 1972. Other policy guidelines that governed space activity of the DOS are implicit in the Science Policy Resolution of 1958 which were made explicit and specific for space from time to time. The main elements of the overall policy guidelines shaping space activity under the DOS are:

(1) Application of space technology in the country must be firmly directed towards assisting the solution of large scale identified problems, exploring the unique capabilities of orbiting satellites where they hold out distinct advantages over other alternatives.

(2) The introduction and application of space technology must, while introducing a new dimension, essentially support and enhance the capabilities of other national systems, catalysing the modernisation process through injection of new technology, systemic analysis and definition approaches and forging linkages between agencies affected by the

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[2] Cited in M. S. Rajan, *Indian Spaceflights* (Delhi, 1985), p. 134.

programme.

(3) While remaining fully cognisant of developments elsewhere and encouraging international co-operation in space, the essential components of space technology must be mastered and grown within the country as speedily as practicable. Technology transfer to and utilisation of Indian industry is an important element in the task.[3]

In this chapter we will trace the evolution of the Indian space programme between 1972 and 1987, that is, from its inception as an institutionalised and full-fledged programme in 1972 to the year in which the Missile Technology Control Regime was established. Developments in the space programme since 1987 are examined in Chapter Six which focuses on the impact of the MTCR on India's space programme.

If the 1960s involved the setting up of infrastructure facilities to provide the necessary base and the training of sufficient scientific personnel, the period under consideration 1972 to 1987 saw the acquisition of technological competence in space technology through a series of experiments and the utilisation of satellites for communications, weather forecasting and remote sensing of natural resources. In fact, one can identify two distinct phases in the development of the Indian space programme during this period. The first phase, roughly covering the 1970s, was marked by a series of experimental missions, designed to acquire competence in the fields of satellite technology, launch vehicles and space applications. The second phase, beginning in the early 1980s, saw the operationlisation of space services. It was also marked by vigorous efforts to develop operational satellites, the second generation of multi-functional INSAT satellites and remote-sensing IRS satellites, and space launchers, Polar Satellite Launch Vehicle and the Geo-stationary Satellite Launch Vehicle.

1. EXPERIMENTAL PHASE

This phase was marked by a series of planned experiments in space technology and space applications. ISRO conducted major experiments in the area of telecommunications, television broadcasting, weather forecasting and remote sensing of natural resources. It

[3] Satish Dhawan, Aryabhata Lecture Delivered at the Indian National Science Academy, 2 August 1985 (Bangalore, 1985).

also carried out experiments in satellite technology such as the development of the Aryabhata, the Bhaskara satellites and the Ariane Passenger Payload Experiment. It also developed an experimental satellite launch vehicle (SLV-3). The basic objective of these experiments was to energise the user agencies with space applications, and strengthen the technological and organisational infrastructure for a self-reliant space programme.

Space Applications

In addition to the work in the area of weather monitoring and forecasting, communications and survey and management of natural resources, utilising satellite technology, had emerged on the Indian space profile in the 1960s. This was carried forward in the 1970s by conducting selected experiments in the area of communications, earth observation and meteorology. These experiments involved the use of indigenously built satellites (such as the Aryabhata, the Bhaskara, the APPLE and the Rohini satellites) and those procured from abroad (such as the American ATS-6 and the Franco-German Symphonie satellite).

A few months after the setting up of the DOS, various division of the ISRO dealing with space applications were integrated under the newly formed Space Applications Center (SAC) at Ahmadabad. These included the Audio-Video Instructional Division, Remote Sensing and Meteorological Applications Division, Satellite Communications System Division, the Electronics System Division and the Microwave Division. Responsible for planning and execution of the space applications projects of ISRO, the SAC became engaged in conducting a series of experiments in the fields of communications technology, natural resource survey and meteorology, and developing the hardware necessary for these applications.

A major experiment in satellite based communication systems that was carried out in the 1970s was the Satellite Instructional Television Experiment, SITE in short. SITE was essentially an attempt to try satellite television in India as envisaged by several studies made from the mid-1960. As we saw, in the late 1960s, the DAE and NASA had agreed to co-operate in a joint instructional television experiment, using the Application Technology Satellite, ATS-6, the first three axis stabilised communication satellite to be launched in early 1970s. Taking responsibility for the space segment of the experiment, NASA moved the ATS-6 satellite to an orbital location over the Indian Ocean in 1975. The year-long SITE project that began in August was the first of its kind to be undertaken anywhere in the world where television broadcasting directly to small rural community systems was attempted. Educational and general television programmes were delivered to more than 2,400 village communities located in different cultural, linguistic and agricultural regions of the country. These programmes addressed such development topics as agriculture, family planning, health and nutrition.

Although there is no unanimity on its developmental impact, the SITE was a managerial and technological success. Scientists, technologists, sociologists, educators, programme producers, engineers, artists and administrators worked together at all levels in remarkable harmony. On the technical side, the SITE promoted important research and development activities and stimulated the electronic industry. The entire hardware required for the experiment was built within the country. The Indian industry produced the standard solid state 23 inch black-and-white TV sets and manufactured Indian designed antennas and earth station components.[4] The high technical standards achieved and the project manager's demonstrated ability to cope with problems that arise from time to time, without excessive reliance on foreign technical assistance, boosted the confidence of the managers of the space programme.

Even as the SITE was under way, ISRO began preparations for undertaking another major experiment in utilising satellites for domestic telecommunications. In 1975, ISRO entered into an agreement with the CNES and signed an MOU with the Symphonie Council for the use of the Franco-German Symphonie satellite by the Indian scientists for conducting telecommunication experiments, under the Satellite Telecommunication Experimental Project (STEP). The STEP was to the telecommunication sector, what SITE was for television broadcasting. It was intended to enhance the country's capability in the design, development and operation of various ground systems required for space telecommunications and provide competence to choose the right operational system for

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[4] The augmented community television reception system was totally developed by the SAC at Ahmadabad and the technology was transferred to the Electronics Corporation of Indian Ltd. .See Promode Kale 'Development of Satellite Communications in India', in R.K. Varma and others, ed., *Space: In Pursuit of New Horizons* (Allahabad, 1992), p. 240.

satellite telecommunications.

During the two year experiment, beginning from June 1977, advanced techniques such as digital communication and multiple access were tried· The integration of satellite signals into a telephone network on ground was also tested. Other experiments consisted of radio networking (where several radio stations were linked by satellite) and television transmission with multiple audio channels. Besides networking the domestic communication system with space system, the STEP focused on remote area communications. During the experiment, techniques of multiple access communications such as Time Division Multiple Access, Digital Communications Multiple Access, Frequency Division Multiple Access, Single Channel Per Carrier Multiple Access etc. were successfully tried out. Experiments were conducted that resulted in the development of small jeep transportable Emergency Communication Terminals (ECT) and truck mounted Transportable Remote Area Communications Terminals (TREACT).[5]

Space Technology

During this phase, ISRO geared its efforts towards carrying out research and development in a variety of scientific and engineering disciplines of relevance to satellites and launch vehicles. ISRO gained experience in designing, fabricating, testing, integrating and using spinning as well as three-axis stabilised satellites by developing and lunching a series of experimental satellites, scientific (the Aryabhata), and application oriented (the Bhaskara series and the APPLE.). With that experience, a beginning was made in the indigenisation of the second generation satellites of the INSAT systems. In the sphere of launch vehicles, ISRO progressed from the regular production of the Rohini series of sounding rockets to the design and development of an experimental satellite launch vehicle, the SLV 3, capable of launching small scientific and technological payloads into the near earth orbit.

a) Satellite Technology

ISRO mastered satellite technology by building and launching six satellites, both experimental and technological, in a phased manner in the decade 1972-82. Indo-Soviet

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[5].ibid., p. 242.

co-operation played a vital catalysing role in the development of ISRO's capability in satellite technology Under the ISRO-USSR Academy of Sciences agreement of May 1972, the Soviet Union offered to launch a satellite that was to be designed and manufactured in India. A few months after the signing of the agreement, the Satellite Systems Division that was established at the Vikram Sarabhai Space Centre (VSSC) in 1970, was shifted to Peenya near Bangalore to take advantage of the availability of back up, both in the field of electronics and aeronautics and of the environmental test facilities at various institutions in and around Bangalore.[6] This laboratory soon developed into the ISRO Satellite Center (ISAC), the main R&D laboratory of ISRO for satellite technology. The design and the fabrication of the first satellite, Aryabhata, and other satellites were undertaken by this Centre.

In designing and fabricating the Aryabhata, Indian engineers and scientists worked with their Soviet counterparts in eight Joint Commissions set up for dealing with specific tasks such as power supply system, spin up system, flight dynamics, telemetry and satellite communication, temperature regime, equipment testing, flight control and scientific experiments. The Soviet Union also supplied some critical electronic components which could not be manufactured within the country. These included the sub systems such as the solar panels for the generation of electricity, special tape recorders for storage and transmission of data, and the spin up system to stabilise the satellite while in orbit.[7]

ISRO adopted a consortium approach for developing and building the Aryabhata. Instead of trying to build all the necessary infrastructure required for satellite fabrication, only those facilities which did not already exist within the country were set up at the ISAC. As a result, a large number of educational and scientific institutions, more than thirty organisations in the public and private sectors, came to be associated with the satellite development activities at ISAC. These included the Hindustan Aeronautics Limited (HAL), Central Instrumentation Laboratory (CIL), Bhabha Atomic Research Center (BARC), Bharat Electronics Limited (BEL), CMTI, Electronics Corporation of India (ECIL), Hegde and Goley Ltd., Indian Telephone Industries (ITI), National

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[6].It was largely on the suggestion of the Soviet experts that Bangalore was identified as a suitable place for satellite technology development, Vladimir Gubarev, *Aryabhata,: The Space Temple* (Delhi, 1976).
[7].K.P. Prakasam, *Space Horizons* (New Delhi, 1981), p. 33.

Aeronautical Laboratory (NAL), Electronics and Radar Development Establishment (ERDE), Indian Institute of Science (IIS) etc. Special test facilities to evaluate the satellite structure were set up with indigenous expertise (for instance the thermovac chamber was set up with the assistance of BARC and ECIL). A tracking system was designed and installed at Sriharikota.[8]

After extensive testing, India's first satellite was launched aboard an Intercoms rocket in April 1975. Weighing nearly 360 kilograms, the satellite designated as Aryabhata (after the famous fifth century astronomer and mathematician of Pataliputra, now Patna) carried three scientific payloads for carrying out experiments in aeronomy, solar physics, and X-ray astronomy. These experiments were really piggy back devices as the basic objective was to develop satellite technology and tracking and telemetry systems for gaining experience in on-orbit maintenance. Although the scientific experiments aboard Aryabhata functioned only for five days due to a malfunction in the power system, the satellite continued to provide its telemetry data for over four years. In addition to the scientific experiments mentioned, the satellite was also used to carry out some experiments in communication. In one of them, elector cardiograph data were transmitted from Sriharikota to Bangalore. In another experiment, weather information from a standard data allocation platform was transmitted.[9] The primary mission of Aryabhata, to acquire the ability to design, fabricate and launch a spacecraft and operate it for a long period, was thus fulfilled.

The Aryabhata programme created the necessary infrastructure for satellite fabrication and testing and in the utilisation of the satellite. This included special equipment and laboratories for the fabrication and testing of spacecraft, ground stations for telemetry reception and tele-command transmission and tracking of satellite. More important, a cadre of trained scientific and engineering personnel was created, capable of taking up future tasks with greater confidence. In the next five years, the material and manpower capability established by the Aryabhata programme were utilised for the construction of technological and application oriented experimental satellites.

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[8].Rajan, n.2., p.55.
[9] ibid., p.57.

Taking advantage of the Soviet offer to launch another satellite payload and of availability of infrastructure created during the Aryabhata project, ISRO concluded another agreement with the U.S.SR Academy of Sciences for the launching of a Satellite for Earth Observation (SEO) by 1978. The SEO, being the first application oriented experimental satellite, was more complex and sophisticated than the Aryabhata.

The experience gained in building the Aryabhata came in handy for the smooth organisation of the work connected with this second satellite. As in the earlier instance, eight Soviet-Indian mixed work groups were set up for the design and development of the satellite. While most of the components that went into the SEO were developed indigenously, ISRO had to obtain from abroad critical subsystems (such as the spin up system, the on-board data memory device, nickel-cadmium batteries etc.) indicating that the Indian industry had not yet attained the capability to manufacture space qualified components.

The SEO, designated as Bhaskara-I, was launched in June 1979 on an Intercosmos rocket. It was followed by another SEO of the same configuration, the Bhaskara-II, which was launched by the Soviet Union a couple of years later. The Bhaskara II was readied for launch in two years after making improvements based on the lessons learnt from the first remote sensing satellite. While Bhaskara-I took four years and 15 technical meetings between the Indian engineers and Soviet experts, the Bhaskara-II was finalised in just four meetings. Bhaskara-II was launched in November, 1981 aboard a Soviet launcher. Like its predecessor, Bhaskara-II was placed in a near earth orbit of about 525 kilometers.

Both these satellites provided valuable experience in integrated end to end systems development and application, from the configuration of the spacecraft to reception and processing of the remotely sensed data, generation of user oriented data products and their utilisation.

An opportunity for building and launching a communication satellite into geo-stationary orbit arose in 1976-77, when the European Space Agency offered a free flight for any payload aboard its experimental Ariane vehicle. ISRO decided to build a three-axis stabilised synchronous communication satellite in time for the scheduled launch of the Ariane. In June 1981, the satellite called APPLE (for Ariane Payload Passenger Experiment) was launched into the transit orbit by the first flight of the ESA's launch vehicle Ariane. The main goal of the APPLE mission was to gain indigenous capability in design and development, fabrication, test and evaluation, injection into geo-stationary orbit, in orbit management and utilisation of geo synchronous communication satellites. It was intended to help the Indian technologists to obtain experience for using geo-stationary satellites for domestic communication, radio networking, data relay etc.

Various subsystems for the APPLE, such as the transponder, graphite fiber, reinforced plastic antenna reflector, earth sensors, momentum wheel and apogee kick motors were developed indigenously.[10] But the APPLE also incorporated a number of components procured from abroad. Its solar panels came from the Spectolab, U.S.A., sensors from Lockheed, U.S.A., control systems from Hamilton Standard, U.S.A., microwave components from Hughes International, U.S.A., batteries from Saft, France, solar array drive from British Aerospace and one momentum wheel for body stabilisation from Teldix, West Germany.[11]

A variety of digital telecommunication/radio experiments and live television coverage/demonstrations were conducted with the spacecraft. The most important outcome of the APPLE was that it established ISRO's technological capability in building a three-axis stabilised geo-stationary communication satellite and established the necessary infrastructure to integrate, test, operate and utilise it.

In the latter half of the decade, ISAC took up the construction of Rohini series of technological/scientific satellites for launch aboard the SLV-3 launch vehicle. The Rohini satellite-1, that was injected in a near earth orbit by the SLV-3 in July 1980, was essentially a technological satellite. It was meant to evaluate the performance of the fourth stage of the launch vehicle and to test satellite performance in orbit. The satellite also carried two small Indian built solar panels with indigenous solar cells .

An important feature of the experimental satellites built in the 1970s was that they were not modelled after the early generation satellites of the space powers, but represented the state-of-the-art in technology. The first satellite, Aryabhata was as sophisticated as many satellites which were being flown by other countries at that time. Incorporating

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[10] Kale, n.4, p. 243.
[11] *Financial Express*, 29 July 1981.

more than 12,000 active and passive electronic components in addition to 20,000 solar cells and other structural parts, the Aryabhata was also the heaviest first lunch ever attempted by any country[12].The Bhaskara satellites were even more sophisticated than the Aryabhata. For Aryabhata, 35 different commands could be sent whereas for Bhaskara, their number was 200. Data from Aryabhata come at 2560 bits per second when the tape recorders played back the recorded information. In Bhaskara, data flow was as high as 91,000 bits per second. The experimental communication satellite, APPLE, up to date in some of its features, the most significant feature being that it incorporated the three-axis stabilisation technology that was mastered by America and Europe only in the mid-1970s.[13] In other words, India was steadily closing the gap with the leading space powers in the design and development of satellite technologies.

Work on designing an operational communications satellite began in the mid-1970s when the government decided that the communication network of the country will contain a satellite component. A high level committee was set up to work out the scope, time-frame and financial, organisational and technical aspects of the national satellite system. Studies on the possible configuration of the satellite showed that a multipurpose configuration which combined Fixed Satellite Service, Broadcasting Satellite Service and Meteorological Satellite Service capabilities into a single space platform was the most cost effective and optimum way of implementing a satellite system for India.

However, the enthusiasm of ISRO for establishing a satellite based communication system was not shared by the user agencies. Both the Doordarshan and the Ministry of Telecommunications had rejected the conclusion of the Indian space scientists that satellite communications was superior to their terrestrial plans and favoured terrestrial networks.[14]

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[12] U.R. Rao, 'A Overview of the Aryabhata Project', in U.R. Rao and K. Kastrurirangan, eds., *The Aryabhata Project* (Bangalore: Indian Academy of Sciences, 1979), p.13. See also P. Nandakumar, 'Space Research in India', *India and Foreign Affairs Review*, 1 November 1977, p. 15.

[13] It was only in 1974 that the United States and the European Space Agency had mastered this technology through their ATS-6 and the Symphonie satellites.

[14] The DOS's plans to play a major role in applications was also seen as undesirable. As one commentator argued "Space technology is one of the alternatives and development of unitechnology-oriented applications is a dangerous precedent". R.S. Ganapathy, 'Unspelled Objectives', *EPW*, 20 June 1974. For some of the issues involved in the introduction of communication satellites see, B.D. Dhawan, 'INSAT TV Plan: Questionable features and Parameters', *EPW*, October 1975. and Ashok Raj and Vishnu Mohan, 'INSAT: Evolution and Prospects', *EPW*, August, 1982.

Moreover, ISRO's satellite plans were also plagued by institutional problems. The SITE project from hardware and software to planning, implementation, and evaluation, was managed by ISRO rather than the telecommunication and broadcasting authorities. The user agencies felt that ISRO was invading their turf. The ministries of agriculture, education, health, and family planning considered the SITE project as a drain on their resources with little potential benefit for their bureaucracies. These institutional concerns were to some extent taken care of during the STEP programme which was a collaborative programme of ISRO and the Posts and Telegraphs Department. In the INSAT system that was finalised in the latter half of the decade, operational services were taken from the mandate of ISRO and placed with the principal user agencies, the Doordarshan, the Ministry of Posts and Telecommunication and the Meteorological Department. It was only when the government of India gave a go ahead to the INSAT system in 1977 that these agencies seemed to have seen 'the writing on the wall' and realised that a satellite was destined for India's future.[15]

Given the problems associated with the innovation and introduction of new technologies, the implementation of the INSAT system may have taken more time, but for some developments in the outer space regime. The INSAT system gained urgency in view of the crowding of the Geo-stationary Orbit (GSO) and the first-come-first-served principle of access to the GSO and frequency spectrum in vogue in the international radio regulatory mechanism of the International Telecommunications Union (ITU).[16] This is evident from the haste in which the government approved the INSAT-I satellite in mid-1977. Instead of waiting for all the user agencies of the multipurpose satellite system to get ready for the INSAT-1, the government approved only the telecommunications and meteorological ground segments of the multi-purpose satellite system. The radio and TV ground segment was approved four years later.

As a result of satellite construction and various experiments in satellite applications,

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[15] Even then, they viewed the technology solely as a means of filling the gaps in areas that were not to be served terrestrially, rather than as part of a national plan that would use the most appropriate mix of technologies to meet the country's needs. Heather E Hudson, *Communication Satellites: Their Development* and Impact (London, 1990)., p.204.

[16] V.S.P. Kurup, 'Space Programme Going Ahead: The Need for Urgency' *The Times of India* (New Delhi), 7 November 1978. Also see *The Hindustan Times* (New Delhi) 20 December 1976.

by the end of the decade, Indian scientists and engineers acquired the necessary expertise in designing and fabrication of remote sensing and communication satellites and had the necessary infrastructure to integrate, test, operate and utilise these satellites.[17] There were problems associated with the introduction of new technologies, but by the end of the 1970s, the government had made a firm commitment to satellite-based communications systems.

b) Launch Vehicles

As we observed in the last chapter, with the objective of attaining a capability to launch its own satellites, ISRO had identified a modest multistage launch vehicle for development in the late 1960s. A four-stage launch vehicle, designated as the SLV-3, was conceived as an experimental vehicle with the primary goal of establishing indigenous technologies relating to propulsion, aerodynamics staging, structural engineering, vehicle control and guidance and mission management. Although the basic configuration of the launch vehicle was finalised by 1970, it was only in 1973 that the government of India gave a go ahead by sanctioning Rs 15.60 crores for the SLV-3 programme.

The SLV-3 was configured as a four-stage solid propellant vehicle, weighing about 17 tonnes and having a length of 22.5 meters. It had 44 major systems and 250 subsystems. Its main subsystems are four solid propellant rocket motors to provide propulsive energy; the interstages connecting the forward skirt of a stage with a rear skirt of the next stage, and housing control, guidance, electronics and pyro subsystems; inertial guidance and control systems to steer the vehicle along a predetermined trajectory; and a heat shield to protect the fourth stage and the satellite from the aerodynamic heating during initial flight through atmosphere. The vehicles had a destruction system for the first three stages to destroy them in case they failed to follow the desired flight path. The vehicles carried an instrumentation package to measure its performance and to monitor the flight events.[18]

The first flight test of the SLV-3 took place in 1979, more than a year behind

[17] *Space*, vol. 8 (4), July-August, 1981.
[18] *Space*, vol. 3 (4) June, 1977.

schedule. That flight ended in failure due to a malfunction on the second stage control system which led to the loss of trajectory, and the payload along with the first stage fell into the sea. The second flight of the SLV-3 in July 1980 succeeded in placing a 35 kg Rohini scientific satellite(RS-1) into an elliptic orbit of 900 kilometer apogee and 300 kilometer perigee at an inclination of 41 degrees. Thereafter, two more SLV-3's were successfully launched in May 1981 and in April 1983.

The main development work on the SLV-3 was carried on at the VSSC. However, as in the case of satellite construction, ISRO adopted a consortium approach. Over 45 national industries and institutions were associated with the project. Over 85 per cent of the components were indigenous. The propellants for the lower stages and the high energy propellants for upper stages were developed and produced within ISRO.[19] The fourth stage of the vehicle was carefully tuned so that it could also be used as the apogee motor for the geo-stationary spacecraft APPLE. Imported guidance system used in the first two vehicles was replaced by an indigenous guidance system, a three-axis/ four gimbal, capable of keeping the rocket in its intended plane even when it is spinning.[20] The fourth SLV-3, incorporated an advanced rocket motor called the Kavlar motor (as it is enclosed in a very light Kavlar fiber casting) This reduced the weight of the vehicle, thereby enabling the addition of more fuel for injecting the satellite into higher orbit.

The sub-systems of the SLV-3 were flight qualified through Centaure and RH-560 sounding rockets. In addition, several specialised test facilities were set up. These included static test facilities for testing stage motors, kinetic heating simulator for testing heat shield, test facilities for testing control systems, components etc. Besides these, other national facilities, such as the wind tunnel available at National Aeronautics Limited was utilised for testing some of the SLV-3 systems.

The SLV-3 programme established a firm base for the development and fabrication of satellite launchers complete with solid propellants, rocket motor propulsion systems, control and inertial systems, electronics, test and checkout systems. The focus of the launch vehicle programme of ISRO now shifted to the development of some crucial

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[19] The industries and institutions involved in the development of the SLV-3 are listed in *Space*, vol. 17 (4), July-August, 1980.
[20] S.C .Gupta, Director of Avionics, Vikram Sarabhai Space Center in *The Times of India*, 1 June 1981.

technologies that go into the polar and geo-synchronous launch vehicles. In fact, even as the SLV-3 programme was in full swing, a blueprint was drawn to expand the infrastructure for realising the polar and geo-synchronous launch vehicle capability for orbiting operational satellites. A low cost launch vehicle, the Augmented Satellite Launch Vehicle (ASLV) was identified for development. It was essentially meant for proving the highly complex technologies that are used in operational launch vehicles. Another necessary requirement for satellite launch capability was the mastery over liquid engine technology. Work on developing a liquid rocket motor was already underway in ISRO laboratories. With the SLV-3 project nearing completion, ISRO speeded up the work on operational launch vehicles, by acquiring liquid fuel technology from France in 1978.[21]

2. THE OPERATIONAL PHASE

In the 1980s, the Indian space programme moved from the development phase to the semi-operational and operational phase. Space services in the form of space based telecommunications, television broadcasting, weather forecasting and remote sensing became available in this phase. As the Space Research and Development Profile for 1980-90 rightly noted, the Indian space programme was moving away from a course that ran adjacent to the national mainstream and was "in the process of identifying itself with the nation's day to day life".[22] With the indigenous development of the second generation INSAT satellites and the Polar Satellite Launch Vehicle underway, the Indian space programme had to grapple with new problems that are typical of high-cost and high-risk ventures. The expansion of space effort also increased the dependence of the space programme on domestic industry. ISRO made deliberate efforts to gradually move towards a system of organisation where it could concentrate on R&D by divesting the management and technical operations of selected production, technical and operational facilities to the Indian industry.

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[21] About 50 engineers were trained in France in 60 tonne liquid Viking engine The Viking was twenty times more powerful than the one developed by ISRO. Muthunayagam, Director, Propulsion Division (Vikram Sarabhai Space Centre) in *The Hindu*, 7 November 1978.

[22] 'Space Research and Development: Profile for the Decade 1980-90', Excerpts reprinted in *Space*, vol. 8 (2&3), March/June 1981., p. 2, 8.

Indian National Satellite System

India's first domestic satellite, the INSAT-I built by Ford Aerospace was launched by NASA in April 1982. However, due to the depletion of on-board propellants for station keeping, the satellite was deactivated and replaced with INSAT-1B in 1983.

It is not possible to detail the expansion of satellite applications during this phase. Each user agency had its own priorities and interests which accordingly influenced their use of the technology. There was a phenomenal expansion in television broadcasting which was not emulated or matched by the telecommunication sector. For more than twenty years after the introduction of television in India in 1959, the growth in the number of transmitters took place largely around major cities and towns. By 1982, there were only twenty five television transmitters in India covering just 25 percent of the population. By 1986, 180 transmitters fed by satellite covered 70 percent of the population. INSAT-I provides two television rebroadcast channels for nation-wide coverage: one for networking of terrestrial transmitters and the other for direct transmission from the satellite to augmented community TV receivers for rural areas .

During its operation, the domestic INSAT- 1B was used to capacity. Its customers included the Doordarshan, which uses the satellite for networking and for direct broadcasting of television to community receivers; All India Radio, for networking of radio programmes; the Post and Telegraph Department, for telecommunications traffic; and the Indian Meteorological Department, for meteorological warning systems. As one analyst concluded "despite formidable governmental and commercial barriers, India has done more with its domestic satellite system than any other developing country, and has at least tried to use its technology for developmental purposes".[23]

The 1980s were also marked by some important changes which had a bearing on the use of satellites. These included the growth of the middle class, a new commercial orientation in public television, the liberalisation of regulations, and increased support for enterpreneureship and joint ventures.

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[23] Hudson, *Communication Satellites*, n.15, p.207.

INSAT Technology

The space segment of the INSAT-I consisted of two identical multipurpose satellites in the geo-stationary orbit and a Master Control Facility for satellite orbit raising and for orbit control and management. One satellite was envisaged as a primary satellite providing all services and the other as a major path satellite providing certain additional Fixed Satellite Service utilisation and also certain on-orbit back up capability. In 1978, an MOU between DOS and NASA on the provision of NASA launch and associated services for the INSAT-I was signed. The same year, based on a competitive procurement process, the contract for the supply of the spacecraft and associated equipment was awarded to the Ford Aerospace and Communications Corporation (FACC), a subsidiary of the Ford Motor Company of the U.S.A.[24]

The Master Control Facility (MCF), forms the major element of the ground system employed to support INSAT-I satellite operations after separation from the launch vehicle. Established in the Hassan over 180 km from Bangalore, the MCF consisted of two independent satellite control earth stations and a Satellite Control Centre (SCC). All the earth station electronics, including up and down converters, and 3 kw, 6 GHz High Power Amplifiers were built by the SAC. The two 14-meter diameter fully steerable antennas for the earth stations were developed by TATA-DSMA, New Standard Engineering Co., Bombay, ECIL and BARC. The SCC is the focal point of mission operations. It houses two PDP-11 computes and related peripherals and equipment supplied by the FACC, the prime contractor of the INSAT satellites. The MFC was later augmented for the second generation INSAT satellites with the addition of two earth stations, each with a 11 meter antenna, redundant satellite control center for INSAT-2 including base band equipment and extended C-band earth station equipment for spacecraft checkout and on orbit checkout system for VHRR, Data Collection System and Satellite Aided Search And Rescue Payloads.[25]

In the mid-1980s, the indigenisation of the spacecraft to replace the imported first generation space segment of the INSAT, was speeded up with the sanctioning of the

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[24] .*INSAT-I*, (Bangalore: ISRO, 1982).
[25] *Space*, (126) October 1990.

INSAT Test Spacecraft (TS) Project. The aim of this project was to design, develop, test and qualify on ground, operate and test in space two identical INSAT-II spacecraft to establish and demonstrate indigenous capability to meet the space segment in the early 1990s. By the year 1987, the design phase of the project had been completed and the development and qualification phase of critical and new elements were nearing completion.[26]

Indian Remote Sensing Satellites

Following the experimental missions of Bhaskara-I and II, ISRO designed and developed an operational remote sensing satellite, the IRS-1A, the first of a series under the National Natural Resources Management System. The IRS mission was approved in 1982. The structural model and the engineering model were completed in the next couple of years. By 1987, the integrated spacecraft had passed through ground checkout, thermal vacuum, acoustic and other environmental tests and was readied for launch from Baikanour in the U.S.S.R. in March 1988.

The payload consisted of three Linear Imaging Self Scanning Sensors (LISS-I, IIA, IIB). LISS-I had resolution of 36.25 meters. LISS-II of 72.5 meters, compared to the 70 meters for Landsat-3 and 4, and 30 meters for Landsat-5 and 20 meters for SPOT in multispectral mode. The low resolution imagery of LISS-I, besides meeting application objectives, was intended to ensure continuity of data services to Landsat users when it gets phased out.

An important feature of the IRS-IA was that except for some very critical components, electronic items such as Charge Coupled Devices (CCDs) and lens systems for the camera,[27]and most of the high-tech precision devices that went into the satellite, were indigenous. These included the inertial guidance systems, dynamic and static sun-acquisition and earth-acquisition sensors, the solar panel drive and the power transfer assembly and the reaction control system. A major portion of the testing of the spacecraft was also done within the country. The only major tests carried out abroad were the

[26] India, Department of Space (DOS), *Annual Report 1987-88*, p. 16.

[27].K. Kasturirangan, Project Director in *Frontline*, April 1988.

thermal cycling tests on the solar panel modules at Estec (Holland) and the 14 day solar simulation test on the satellite's representative model at INTERSPACE, France.[28]

Launch Vehicles

The technological leap from the sounding rockets of the 1960s to the country's first launch vehicle, the SLV-3 in 1980 was only a small step in realising the ambitious goal of achieving indigenous operational launcher capability. Both the payload capability and the accuracy of the guidance systems of the launcher had to be increased before that goal could be realised.[29] In order to overcome these limitations, ISRO planned the ASLV, the Augmented Satellite Launch Vehicle capable of putting 150 kilograms class payloads in near circular orbits.

Basically derived from the SLV-3, the ASLV was a necessary intermediate step for reaching operational launch vehicle capability. It was intended to develop and qualify a number of indigenous technologies and subsystems relevant for future launch vehicles, particularly the Polar Satellite Launch Vehicle. These technologies ranged from the use of high energy propellants, canted nozzles, and new jettisoning mechanisms to application of state-of-the-art technologies such as closed loop guidance systems, automated vehicle checkout systems and S band TTC systems. The most important of this is the use of a closed loop guidance system to enable injection of the satellite payload into a precise circular orbit. The first developmental flight of the ASLV-DI took place in March 1987. The primary objective of the mission could not be accomplished due to non-ignition of the first stage motor. However, a number of new technology elements relating to the launch vehicle, SROSS spacecraft, the launch complex and the ground stations, were validated.[30]

Polar Satellite Launch Vehicle

Parallel to the ASLV, ISRO drew plans for developing a launch vehicle for orbiting

[28] N Sachitananada, 'A Giant Stride' *Frontline*, April 1988.
[29] The SLV-3's basic payload capability was merely 40 kilograms in near earth orbit. Moreover, it employed a open loop guidance system which meant that the vehicle followed a predetermined flight path which cannot be changed during flight—only corrected within certain bounds by the guidance system. This resulted in lesser accuracy in achieving the final orbit *Space India*, vol. 1, January 1987.
[30] India, DOS, *Annual Report 1987-88*, p. 3.

its IRS series of satellite within five or six years. The government formally approved the PSLV project in 1982 by sanctioning Rs. 311.67 crores.[31]

The configuration of the PSLV, a vehicle intended for injecting 1000 kilograms class satellites into sun-synchronous or polar orbit, was a logical outcome of the launch vehicle technology built on the established capabilities in solid propellant technologies and acquisition of liquid propellant technology from France. The basic configuration of the 275 tonne, 44 meter tall PSLV was (6 x S 8.7+ S 125)+ L 37.5 + S 7+ L 1.8). This meant that the launcher was a four-stage vehicle. The first stage is of 2.8 meter diameter, with a 125 tonnes of HTPB (Hydroxyl Terminated Pry Birtadiene) and Ammonium Percholrate solid propellant with six SLV-3 first stage motors (each with 8.7 tonne propellant) strapped on to it. The second stage, based on liquid engine technology, uses 37.5 tonnes of UDMH and N2O4 liquid propellant. The third stage is a seven tonne solid propellant motor and the fourth stage is again a liquid propellant stage with 1.8 tonnes of MMH and N2O4 liquid propellant. A closed loop guidance system with an on board processor was to be employed for the vehicle.[32]

By 1987, Indian engineers had overcome most of the technological problems associated with the PSLV project. The fabrication of the motor cases which used the M-250 material for the first time was taken up with a substantial R&D input from the private sector.[33] The new propellant for the first and second stages known as the HTPB, was developed in house and transferred to Messers NOCIL, Bombay for production. The oxidiser, Ammonium Percholrate was already available within the country (from the Ammonium Percholrate Experimental Plant set up in the late 1970s). Significant progress was made in the development of the second and fourth stages of the PSLV, where India for the first time was using liquid propellant for primary propulsion. Based on liquid engine technology of the European launch vehicle, Ariane, the second stage motor Vikas engine was fabricated within the country.[34] While the first two titanium tanks were fabricated

[31] *Hindustan Times*, 6 June 1982.
[32] U. R. Rao, 'Indian Launch Vehicle Development' Brahma Prakash Memorial Lecture on 21 August 1992 (Bangalore, 1992).
[33] *Countdown*, (103) November 1988.
[34] The Vikas engine was originally developed by Societe Europeeanne de Propulsion (SEP) of France. In 1978 France gave the complete liquid engine technology, Muthunayagam, Director, Propellant Division, VSSC, in The *Statesman* 7 November 1978.

abroad, fabrication of subsequent tanks was taken up at the HAL with technology from France. The development of the liquid propellant, a combination of nitrogen tetroxide and UDMH capable of developing over 72 tonne thrust, was done indigenously. The development of the fourth stage which was entirely a new technology posed a major challenge to the Indian rocket team. After overcoming problems related to thermal equilibrium, combustion efficiency, specific impulse etc., the final design of the engine was completed. A High Altitude Test Facility was getting readied at Mahendragiri for qualification testing of the engine.

The crucial system of the PSLV was the Inertial Navigation System. Engineering models of two versions of these systems-the RESINS (Redundant Strapdown Inertial Navigation System) and the SPINS (the Stabilised Platform Inertial Navigation System) went through system level tests. Some of the precision sensors used in the engineering models came from abroad. But efforts were on to replace these with indigenously developed ones. Some of the indigenously developed sensors: the Dynamically Tuned Gyros, Rate Integrating Gyros and Servo Accelerometers were already undergoing final qualification tests.[35] In addition to these, significant advances were registered in the development of control systems. Various mechanisms used for the separation of stages, jettisoning of strap-ons, heat shield etc. were developed and tested on scale down models.

3. SPACE AND INDUSTRY

Beginning in the mid-1970s, there was a gradual strengthening of the space programmes linkages with national institutions and universities on the one hand and with domestic industry on the other. When the space programme began in the 1960s, it had little or no industrial base to support it. Most of the work had to be done in-house, including the development of equipment and hardware fabrication. Only common materials, chemicals and simple hardware could be obtained from the industry. With the expansion of activities associated with experiments in space technology and applications, there was a much larger involvement of the Indian industry in the overall efforts required

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[35] *Countdown*, n. 33.

for the development of the space technology. During the 1970s, ISRO made deliberate and sustained efforts to promote the participation of domestic industry in the space effort. In 1976, ISRO instituted the technology transfer scheme to promote and support industries to meet the requirements of the space projects and R&D programmes through buy back of products and to service the expanding space applications market in the area of satellite telecommunications, television and radio broadcasting, meteorological observation and remote sensing. And as the space R&D generated new techniques and products, know-how for products and processes developed by the space programme began to be transferred for non-space applications as well.[36] However, only a few industries accepted major responsibilities and committed themselves for the space projects. Throughout the 1970s, industry's collaboration with the space programme was largely confined to the establishment of ground based facilities, although it took up some fabrication work related to satellites and SLV-3. The volume of orders placed by the ISRO on the domestic industry amounted to Rs. 10 crores in the 1970s.[37]

In the early 1980s, as the space programme moved to a new phase of providing space services and developing operational satellites and launch vehicles, ISRO's dependence on domestic industry began to increase. Almost all ISRO projects, the ASLV and the PSLV launch vehicles and the IRS and INSAT-II satellites, involved huge expenditures and were in the order of magnitude more complex compared to the previous projects, requiring gigantic facilities and new technologies as well as large industrial back up. In an effort to lower the costs of the programme and share the burden of hardware work with the industry, ISRO began to actively promote the indigenisation of space technology through its technology transfer schemes. However, the Indian industry with its preference for imported technology was unwilling to take up ISRO projects or absorb the know-how for

[36] Over 90 different products and process technologies were licensed to nearly 50 industries by 1987. The major sectors in which these technologies have been transferred are: special chemicals, polymers, materials and composites; electronics; telecommunications and TV systems; precision electromechanical, opto-mechanical and electro-optic instruments; microprocessor based systems; special purpose machines; computer applications software; electrochemical processes and systems. P. Sudarshan and K.R. Sridharamurthy, 'Emerging Dimensions of Space-Industry Linkage', *The Hindu*, 29 April 1987.

[37] U. R. Rao, *Space and Industry Partnership*, Lecture delivered at the 'Opportunities in Space' A joint seminar of the Association of Indian Engineering Industries (AIEI), Indian Rocket Society (IRS) and ISRO in December 1985 (Bangalore, 1985).

products and process generated by the space programme. The managers of the space programme responded by aggressively promoting technology transfers from ISRO laboratories and offering consultancy services to the industry and by discouraging the government from adopting liberal import polices. For instance, in January 1982, the DOS drew the attention of the Science Advisory Committee to the Cabinet to the impact of technology import polices on the generation and utilisation of domestic science and technological capabilities and called for checking technology dumping by foreign companies.[38]

Studies conducted by ISRO's research centers in the early 1980s identified the factors limiting the industry's participation in space projects as follows: the low volume and less repetitive jobs of ISRO, the rigorous quality and time standards set by the space establishment and hesitation of industry to experiment with new materials and processes.[39] Some of these issues were addressed in the intensified interaction between ISRO and the industry that began in the mid-1980s. Pointing to the export potential of space technologies, ISRO held the promise of big returns from exports.[40] ISRO itself began to design its products and services to meet not only the domestic requirements but also international market requirements. The Polar Satellite Launch Vehicle, for instance, although primarily meant for launching IRS satellites was also designed with international launcher requirements in mind.[41] With nearly a decade of experience in exporting precision tranducers to Europe, ISRO began to push the export of various high technology, precision electro-mechanical, electro-optic and polymers, special materials/chemicals through the industrial licencees of ISRO technologies. Export of some of these technologies themselves was also taken up.[42]

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[38] L. K. Sharma, 'Indigenous Efforts Get Raw Deal', *Times of India*, 26 January 1982.
[39] 'Indian Industry's Space Trek', *Business Standard*, 12 January 1986.
[40] Satish Dhawan, the former chairman of the Space Commission, for instance urged the industry to take part in the evolving space technologies by pointing to the growing interest of any developing countries in remote sensing technologies and the opportunities for export of know-how. The 18[th] Sriram Memorial Lecture.(Delhi, n.d.)
[41] The PSLV was planned to compete with the proposed Ariane-IV, a multi-mission launch vehicle of the European Space Agency set for launch in 1987. "With PSLV's economic cost, India can compete with Europe and even with the U.S.A, if our configuration design is linked with the Polar launching site and the development of cryogenic stage". A.P.J. Abdul Kalam, *Large Boosters for Space Missions* (Bangalore, May 1982).
[42] U.R. Rao, *Space and Industry Partnership*, n. 37.

Although the Indian industry did not match up to the requirement of ISRO, still several small, medium and large scale industries emerged as sub-contractors for the various satellite, launch vehicle and space application projects and associated ground systems. A number of industrial units in the public and private sectors established plants, production lines and divisions either with ISRO's know-how or on their own to cater to the programmes requirements of special chemicals/materials, propellants, launch vehicle/satellite hardware fabrication and electronic packages. The volume of orders placed by ISRO on industry which was around Rs. 10 crores during the 1970s, shot up to Rs. 100 crores during the Sixth plan period (1980-1985). While the volume of orders on Indian industry were expected to exceed Rs. 620 crores during the Seventh plan period (1985-1990), ISRO made efforts to overcome its dependence on imported components, material, equipment and services, which were estimated to cost around Rs. 360 crores during the Seventh plan period.[43]

In the mid-1980s, ISRO envisaged a major change in the role of Indian industry in the space programme-from being a mere supplier of goods and services to that of prime contractor with the capability of executing complete projects.[44] It offered a total systems job of developing a space simulation chamber to the Indian industry. Although the new role envisaged for the industry would take time, significantly four business groups set up consortiums to bid for the contract to make the Rs. 36 crore space simulation chamber, indicating the emergence of an expanding space business in India The contract was finally awarded to the Bharat Heavy Plate and Vessels (BHPV) of Vizag, which has enlisted the aid of Spectrolab and HVEC of the United States for the project.[45]

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[43] Ibid.

[44] Offering the industry to take the total systems job of building a space simulation chamber for ISRO, Prof. U.R. Rao, the head of ISRO and also the chairman of the Space Commission, made this clear when he said "We are now keen to gradually divest ourselves from the management and technical operations of selected production, technical and operational facilities". Quoted in 'Indian Industry's Space Trek', n. 39.

[45] Three private sector units, the Tatas, Larsen &Toubro, Walchandnagar Industries and a public sector undertaking, Bharat Heavy Plates and Vessels (BHPV) each set up a consortium to bid for the contract. Lincoln Kaye, 'Search for Cohesion', *Far Eastern Economic Review*, 27 August 1987.

4. INTERNATIONAL CO-OPERATION

In the 1960's, significant space programmes didn't exist outside the Soviet Union and the United States. Consequently only a very modest co-operation necessitated by the global reach and character of space technology was possible during the first decade of space. By the early 1970s, several countries, notably those endowed with a strong industrial base and/or scientific resources had launched their own space programs. Moreover, the monopoly of military over space technology ended in the latter half of the 1960s with civilian applications gathering momentum. Thus, both because of the increase in the number of actors as well as the expansion of space activities, co-operation in the field of outer space began to assume a truly international character. Equipped with the basic infrastructure and a strong commitment to the applications of space technology for national development, India was well placed in the 1970s to participate extensively in international co-operative programmes and undertake joint studies in space sciences, technology and applications.

In the early 1970s, the Indian space programme expanded its co-operation in space research by establishing ties with several national space agencies. In 1971, the ISRO signed its first MOU with the European Space Research Organisation. This was followed by an MOU with the Academy of Sciences of the U.S.S.R. in 1972. In 1974, it signed an MOU with the German Aerospace Research Establishment (Deutsche Forschungs and Versuchsanstalt fur Luft and Raumfaht e.v or the DFVLR). These co-operative arrangements led to exchange of scientists and a number of joint studies in space sciences, applications and technology.

In addition to sounding rocket research programme, bilateral co-operation expanded to other areas of space, notably technology and applications. Indian scientists and engineers while receiving training and technical assistance for enhancing the capabilities of the national space programme, were on the other hand carrying out studies and even fabricating technology for other space faring countries. Thus, for instance, the Indian Institute of Technology (IIT) Delhi, using equipment provided by NASA, investigated on the use of Mossbauer effect to control the relative velocity of space shuttle and space stations for docking purposes.[46] Under ISRO, the Nainital Observatory carried out important work related to Apollo Telescope Mount in Skylab of NASA.[47] The PRL, Ahmadabad and the Indian Institute of Technology, Kanpur, in collaboration with NASA, studied various samples of lunar material collected by the American lunar probes. During this decade, India also began to fabricate and supply certain items needed for the Ariane launch vehicle of the European Space Agency.

International co-operation played an important role in the enhancement of India's competence in space technology. In the 1960s, multilateral agencies had played an important role in equipping the country with basic infrastructure, especially in the area of sounding rocket research (TERLS) and satellite communications (ESCES). The 1970s saw an expansion of co-operation through bilateral arrangements. ISRO entered into co-operative arrangements on mutually beneficial terms with NASA, the ESA, CNES, the Academy of Sciences of the U.S.S.R., DFVLR and other space agencies. Space technology came mostly in areas that were not affected by commercial and security considerations. Where commercial interests had already emerged, such as in the area of satellite technology, the Soviet Union provided an alternative source. Launch vehicle technology was the monopoly of the Super Powers until the European Space Agency launched its Ariane in 1981. International co-operation in this area was limited due to strategic considerations. With several countries acquiring launch vehicle capability and the emergence of ESA as a competitor to the NASA, commercial considerations began to restrict co-operation in this area. In the 1970s, Indian scientists and engineers both within ISRO and outside were associated with the development of launch vehicles such as the Skylab and Ariane. India received technology and expertise from different agencies in the development of its launch vehicles. As we saw, the crucial component in a launch vehicle, the guidance system for the early SLV-3's, was procured from abroad. India acquired the liquid engine technology from France even before the PSLV design was drawn. And during the designing phase, experts from NASA, ESA, CNES and DFVLR participated in reviewing the preliminary design of the PSLV in some fields like the inertial

[46] *Report to the XVII COSPAR,* 1974 (Bangalore, March 1974), p. 29.
[47] Ibid., p.30.

navigation, tracking and telecommmand. But with the unveiling of the Missile Technology Control Regime in April 1987, co-operation in the area of launch vehicle technology came to a grinding halt. And as the PSLV was in an advanced stage, other launch programmes of ISRO became the target of the regime.

5. CONCLUSION

Through a series of carefully planned experiments in space technology and applications in the 1970s, India acquired the basic technological and managerial capabilities necessary for utilising space services. In the 1980s, the Indian space programme operationalised most of the space services. ISRO also began to transfer technologies, know-how and processes generated by the space programme to the Indian industry. The period is therefore described as the maximum spin-off stage of the Indian space programme.

As space services became operational and as the magnitude and complexity of the space projects increased, ISRO came to increasingly rely on the participation of the domestic industry in space projcets. Since the mid-1970s, domestic industry had been providing products and services for space projects mainly as sub-contractors. But by the mid-1980s, keen on shedding some of routine managerial and industrial operations to the Indian industry, ISRO began to encourage the industry to assume the role of prime contractors with a capability to execute complete projects. Towards this end it offered technology and consultancy services to the industry. However, the big engineering industry, which has been working in a oligopolistic market structure, found no incentive to upgrade its technological skill and take up major projects for ISRO. In this context, the managers of the space programme were confronted with two alternative routes to the strengthening of the technological base of the programme. One was to encourage the liberalisation of the economy to infuse competition into it. The other was to establish a consortium or international space agency which would permit the pooling of resources. The latter idea, favoured by those opposed to the commercialisation of space technology, gained some ground in 1986, when the Soviet President Gorbachev proposed the setting up of an international satellite launch facility in India. However, before these approaches could mature into policy responses, the Western industrialised countries unveiled the

Missile Technology Control Regime, restricting international co-operation in the peaceful uses of outer space. In the following chapters, we will examine how India's civilian space programme came to be associated with military oriented missile development programme and the impact of the MTCR on the Indian space programme.

CHAPTER FOUR

SPACE TECHNOLOGY AND SECURITY

As we saw in the earlier chapters, by the early 1980s, India had attained a fair degree of capability to design and develop satellites and small space launch vehicles and was well on its way to develop launch vehicles to orbit its application satellites. These capabilities had military implications. Satellites and, to an extent, space launch vehicles are dual-use systems. Communication and earth observation satellites have varied military applications and launch vehicles can be easily developed into ballistic missiles for delivering either conventional or non-conventional payloads by adding guidance and re-entry systems. The focus of this chapter is on the security implications of the Indian space programme with particular reference to its launch vehicle programme which bestowed India with ballistic missile capability.

When ballistic missiles emerged on the Indian policy agenda in the late 1950s, the focus was on disarmament and the objective was to mitigate the ills of nuclear weapons by eliminating ballistic missiles. Three decades later, India was poised to enter the select club of states having both a robust civilian space industry and viable missile based defences. A variety of missiles including ballistic missiles were flight-tested in the late 1980s. Why did this shift from disarmament to missile armament occur? What is the relationship between the civilian space programme and the missile programme? In this chapter, we seek to find answers to these questions. Before doing so, it is necessary to examine the international trends in the development and use of ballistic missiles and other surface-to-surface missiles (SSMs). This provides the broader context in which the Indian missile development efforts are being made and also help in identifying the level of technological abilities of missile forces of different countries.

1. MISSILE SYSTEMS

The current phase in the history of missiles began during the Second World War with the use of V-I and V-2 rockets by Germany. Since then, there has been a tremendous and rapid global advancement in this field. These missiles, which are described as 'guided missiles', come in a variety of sizes, designed to meet specific requirements, from the leviathans of inter-continental ballistic missile class to the tiny shoulder fired missiles, which fly only a few kilometres and weigh only a few kilograms. They provide both a defensive and offensive capability, giving pinpoint accuracy, high destructive power and minimum risk to the originator. Generally, missiles are classified on the basis of their features such as type of target, range, mode of launching, system adopted for control, propulsion or guidance, aerodynamics. etc. They are also classified in a broad sense as strategic or tactical, defensive or offensive.

On the basis of target, a missile is categorised as an anti-tank/anti-armour, anti-personnel, anti-aircraft, anti-ship/submarine, anti-satellite or anti-missile missile. On the basis of range, missiles are classified as short-range missiles; medium range missiles (MRBM), intermediate-range ballistic missiles (IRBM); and inter-continental ballistic missiles (ICBM). This classification is mainly used in the context of surface-to-surface missiles, the category of missiles, with which we are mostly concerned in this chapter.[1] Surface-to-surface missiles (SSMs) with ranges of 50 to 100 km are designated as short-range missiles and those with ranges of 100 to 1500 km are called as MRBMs. Intermediate-range ballistic missiles (IRBMs) are those that have a range upto 5000 km and Intercontinental Ballistic Missiles (ICBMs) belong to the class of long-range missiles which can travel a distance of 13000 km.[2]

Based on the type of trajectory, SSMs are categorised as ballistic and cruise missiles. While the former covers a major part of its range outside the atmosphere, the latter travels entirely in the atmosphere. The SSMs are augmenting artillery and substituting strike

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[1] Missiles are also classified on the basis of their launch methods, as surface-to-surface missiles (SSMs), surface-to-air missiles (SAMs), air-to-air missiles (AAMs), and air-to-surface missiles (ASMs). SSMs includes ship-to-ship and submarine launched missiles.

[2] This is the broad classification of ballistic missiles that is adhered to in the East-West arms control efforts. The Missile Technology Control Regime, however classifies missiles as short-range and long-range missiles on the basis of the 300 kilometer limit set for identifying missiles of concern.

aircraft in modern warfare. With ranges greater than those of conventional artillery and, in terms of kill ratio per round, SSMs are considered to be most cost-effective. As substitutes for strike aircraft, ballistic missiles possess unique capabilities that make them potentially useful as conventional military weapons. First, they are capable of delivering payloads over long distances in relatively short periods of time. A ballistic missile with a maximum range of 900 km requires only nine minutes to fly the entire distance, whereas a strike aircraft flying at a speed of 1000 km per hour would take nearly an hour. The Soviet SS-21, with a range of 100 km takes only three to four minutes to reach the destination whereas the striker would take six to seven minutes. Therefore, where speed is of critical military importance, ballistic missiles are an advantage. Secondly, existing air-defences are unable to intercept ballistic missiles, so that missiles are assured of penetrating the intended target. This assured penetration provides ballistic missiles a significant military advantage over manned aircraft. Finally, it may be easier for a country to operate a missile force than an airforce. In some cases, ballistic missiles might be the only practical means of attacking targets at long ranges. The increased capabilities of air-defences, the growing cost of acquiring and maintaining air forces, and the difficulties of operating modern fighter aircraft have all made ballistic missiles increasingly attractive.

Despite these arguments for the use of missiles over artillery guns and aircraft, there are obviously a number of drawbacks. They do not have the same flexibility of operation as manned aircraft. They cannot be recalled, for example, if fired at friendly forces. Then there is the accuracy and dependability of these systems. A gun or an aircraft is always immediately reusable; missile systems are more delicate, more prone to malfunction and, not always, as dependable for killing targets as the manufacturers make out.[3] Guns are also best suited for basic artillery requirements- bombardment duties against static targets, troop positions and supply dumps. Ballistic missiles when used to deliver ordnance against ground targets, have limitations over aircraft which are reusable, adaptable (useful for wide variety of missions) and flexible (pilot can react to changing circumstances). Finally, ballistic missiles, especially those in the Third World arsenals (such as the Scud-B, CSS-2, Condor-II, M-9 and M-11) suffer from one major technical weakness—insufficient

[3] Philip Birtles and Paul Beaver, *Missile Systems* (United Kingdom, 1985), p-1.

accuracy. As a result, they are more effective as terror weapons than against point military targets. All in all, it is the balance between effective use of guns/aircraft and missiles that leads to effective defence or offensive capabilities.

There is one area, however, in which ballistic missiles remain supreme: in the delivery of theatre and strategic nuclear weapons. Nuclear ordnance for guns and aircraft can be used tactically, but to maintain the nuclear deterrence the use of a missile delivery system is paramount, whether that system is land, air or sea based.

2. EVOLUTION AND ROLE OF BALLISTIC MISSILES

The origin of the present day ballistic missiles and space launch vehicles can be traced to the German A-4 rocket that was flight tested in 1942 and used in hundreds from September 1944 to the end of the Second World War. These rockets became popular as the V-2, the V standing for Vergeltungswaffe or 'revenge weapon'. Attaining an altitude of 80 kilometers and travelling 200 kilometers (with a one tonne high explosive warhead), the V-2 did not quite reach the top of the atmosphere, not, at any rate by today's definition of where this is. But nothing made by man had previously travelled further from the earth.[4]

The V-2 was essentially a product of the German efforts to overcome the limitations imposed on German armaments by the Treaty of Versailles at the end of the First World War. Anxious that the defeated country would not become a force in weaponry in the foreseeable future, the victorious allies stipulated in the Treaty of Versailles strict limitations on the artillery units that Germany could deploy. The Treaty was, however, silent about rockets to which the German armed forces turned in eagerness in the late 1920s. The development of new rocket weapons was placed in the hands of a small group of scientists at Artillery Testing Range near Berlin called Kaummerdorff-West. In addition to V-1 and V-2, some 138 different rocket projects were under development by the end of the Second World War. Some of the most important of these projects which, if put into actual operation, would have radically changed the entire course of the war were: A-10

[4] Peter Marsh, *The Space Business: A Manual on the Commercial Uses of Space* (London, 1986), p. 22.

rocket of 5000 km range, Amphibious V-2 for launching form U Boats, Natter (Adder), a vertical take off short-winged rocket carrier intended for use against invading bombers, Rheinbote, a four-staged fin-stabilised heavy powder rocket shell having a range of 220 km, an anti-aircraft rocket and Panzerblitz, an anti-tank rocket shell. At the end of the war, the designs and some experimental machines of these projects fell into the hands of the U.S. and the Soviet occupation armies.[5]

Germany's best scientists and captured V-2's provided the base for missile programme of the United States and to a lesser extent that of the Soviet Union. In total the U.S. gave jobs to some top 500 German rocket engineers and shipped across the Atlantic documents of thirteen years of rocket efforts and the parts for 100 V-2 rockets and machines of several projects that were in the advanced stage of development. In 1946, the defectors settled down at the U.S. Army's White Sands proving ground in New Mexico. The Soviet Union, which had considerable experience in rocketry also tapped the expertise of the German rocket technicians. When the Soviets overran the Peenemunde in May 1945, the Nazi dynasty's richest graves had already been robbed. All they got were the rank and file of the V-2 programme, engineers and minor technicians scattered over the eastern zone. France and Britain also scrambled to claim something from the German rocket work.[6] In the 1960s, France Egypt (United Arab Republic), Israel, and China launched missile programmes. France, China and Israel eventually succeeded in the 1970s and 1980s in breaking the monopoly of the Super Powers in the development of ballistic missiles. The Egyptian missile programme failed to take off because of lack of industrial and scientific resources. India, which initiated a ballistic missile development programme in the early 1970s, emerged as a missile power in the late 1980s.

In the evolution of SSMs, one can identify two broad categories of missiles; long-range missiles that are generally equipped with nuclear ordnance and short-range missiles meant for conventional missions. Historically, the development of long-range missiles took place in the context of nuclear weapons systems, when lightweight thermonuclear warheads became practical in the early 1950s. Both the Super Powers tested liquid-fuelled

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[5] *Indian Armed Forces Yearbook 1967-68* (Allahabad, 1968), pp. 385-87.

[6] Marsh, n. 4. See also, Walter A McDougall, *...the Heavens and the Earth: A Political History of the Space Age* (New York, 1985), p. 45.

ICBMs in 1957 and deployed modest numbers of them shortly afterward. Significant deployment began only in the 1960s, when reliable, quick firing solid propellants and inertial guidance systems became available. A family of nuclear missiles, of intermediate and long-range, were also deployed on nuclear submarines.

The other category of SSMs are those that are used as conventional weapons as anti-tank, anti-personnel and area weapons. In fact, the earliest ballistic missile, the German V-2 was designed and used with conventional warhead.[7] In the post-war period, both the Super Powers developed a series of conventionally armed ballistic missiles with varying ranges and accuracies. The tactical ballistic missiles developed by the United States in the 1950s and 1960s, such as the Honest John, Corporal and the Sergeant missiles were dual-purpose, armed either with nuclear warheads or large numbers of small conventional anti-personnel munitions. The Soviet Union also developed high explosive and chemical (VX) warheads for its short-range missiles such as the FROG, Scud, and even for the more advanced missiles of the 1970s and the 1980s, such as the SS-12 (900 km range) and the SS-23 (500 kilometer range).

It is possible to identify three distinct generations of conventionally armed ballistic missiles based on their performance. The first generation missiles developed by the United States in the 1950s are those that were derived from German technologies. These were the unguided Honest John (introduced in 1953) and Corporal missiles with a range of 40 kilometers and 130 kilometers respectively. These missiles were quite cheap to build but were clumsy, inaccurate and had slow rate of fire. Honest John, for example, required 15 vehicles to carry all its components, which weighed no less than 100 tonnes and when assembled, could only fire six rounds a day. Corporal took an hour to be fuelled, erected and armed and a further 15 to 30 minutes to be fired from the launcher. The Sergeant that remained in service till the late 1970s, was the last of the first generation missile. It had a better performance than the Corporal, having inertial guidance and a solid propellant, and could be deployed in 30 minutes. The Lance missile, that was inducted into the U.S.

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[7] The V-2 rockets carried a one tonne high explosive. From September 1944 to the end of the war, the Germans launched about 3000 V-2s. Although many of these failed to reach their targets, mainly the cities of London or Antwerp, they were hardly ineffectual. It is estimated that the V-1s and V-2s killed some 13,000 people and injured twice this number. In Greater London alone, they destroyed 23,000 homes and damaged 100,000 more. Marsh, n. 4, p. 24.

forces in the early 1970s, marked the advent of a new generation of short-range missiles. With a range of nearly 160 kilometers, the Lance was lighter and more mobile than the earlier generation missiles. The Soviet Union also developed comparable SSMs, the SS-12 and the SS-23, to replace its short-range missiles such as the FROG and Scuds.[8] In the latter half of the 1970s, advances in the area of micro-electronics, sensor technologies, and munitions led to the development of a new generation of conventionally armed SSMs that combined long ranges with precision guidance. Some of these came to be seen as effective substitutes for nuclear weapons in certain tactical roles. The United States which had a lead in these technologies, began developing long-range ballistic and cruise missiles for attacking fixed and mobile targets in the mid-1970s. The U.S. AXE project envisaged the use of ballistic missiles in hardened sites to deliver sub-munitions on runways and other fixed high value, time sensitive targets. Three missiles have been considered under this project. The first of these, the CAM-40 is a derivative of the U.S. Pershing II missile. A two stage version covering all Warsaw Treaty Organisation (WTO) operating bases and a single stage version covering 70 percent of the WTO bases were under development in the 1980s. The second missile, BOSS (Balanced Offensive Suppression System) is a delta wing glider launched by the booster of a Trident missiles into ballistic trajectory. Guided by stellar inertial type guidance, it has a range of 650 kilometers. The third missile is the Incredible Hulk also TABAS or TABASCO. Using booster components from the Thor/Delta or Saturn space rocket, it could carry a payload of 25 tonnes.[9] In order to attack mobile targets, the development of ATACMs for the Army and Cruise missile for the U.S. Air Force was taken up. The last mentioned missile, the cruise missile, was a born again Second World War delivery system whose efficiency had been enhanced by a number of technical advances, particularly the PGMs.[10] Partly because of the low cost

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[8] The technical aspects of the missiles described in this paragraph are from Guy Hartcup, *The Silent Revolution: Development of Conventional Weapons 1945-1985* (London, 1993). Hartcup is perhaps the first to classify SSMs based on range and performance, though he did not view precision guided SSMs as a separate or distinct category.

[9] Per Berg and Guinilla Herolf, '"Deep Strike": New Technologies for Conventional Interdiction', *Stockholm International Peace Research Institute (SIPRI) Yearbook 1984: World Armaments and Disarmament* (London, 1984).

[10] Essentially similar to the famous 'flying bomb' or the German V-1 rocket used against Britain in the latter part of the World War II, cruise missiles are pilotless jet aircraft which fly, by a combination of radar guidance and preset computer control, relatively slowly over ranges that can vary from less than a hundred to several thousand kilometers. They can be armed with either conventional or nuclear

and versatility of the cruise missile and partly because it was not limited by the initial Strategic Arms Limitation Talks (SALT) accords, the U.S. began to develop cruise missile systems in the mid-1970s.

The development of conventionally armed long-range SSMs basically took place in the context of East-West conflict. In the early 1980s, there were many proposals for the induction of these into the NATO forces to off-set the supposed superiority of the Soviet Union in conventional and theatre nuclear weapons. The new technologies improved the effectiveness of NATO's conventional forces. In certain cases, NATO began assigning to conventional systems, missions hitherto the exclusive domain of nuclear weapons. Whether they contributed to an effective and more robust conventional defence is not clear, as the bulk of the new systems were still at an advanced stage of development, but in the latter half of the 1980s, there were already proposals envisaging the use of the conventionally armed long-range missiles outside the European theatre. A prime example is the concept of discriminate deterrence expounded by leading American strategists that recommends the use of long-range missiles equipped with terminally guided munitions (in U.S. parlance, 'smart munitions'), in the Third World.[11]

3. BALLISTIC MISSILE CAPABILITIES AND MISSILE PROLIFERATION

Ballistic missiles are the most complex of the missile systems. The creation of a fully independent national capability to develop and produce ballistic missiles of intermediate range and greater has been a long evolutionary process. Even the most industrially advanced countries required periods of 15 years or longer to establish capability for design, production, testing, operation and management of missile systems and typically progressed from artillery rockets, air launched unguided rockets, aircraft converted to

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warheads, and used in either strategic or tactical role. They are capable of very great accuracy, but currently are relatively vulnerable to ordinary anti-aircraft defences. David Robertson, *A Dictionary of Modern Defence and Strategy* (London, 1987).

[11] "In the Third World, no less than in developed countries, U.S. strategy should seek to maximise our technological advantages. In some cases, technologies developed for fighting the Soviets will be enormously useful. Here too we will want to use smart missiles that can apply force in a discriminate fashion and avoid collateral damage to civilians...". United States Commission on Integrated Long-Term Strategy, *Discriminate Deterrence* (Washington, D.C., 1988), p.21.

drones, air-to-air missiles, air-to-surface missiles, surface-to-air missiles, aerodynamic cruise missiles and surface-to-surface missiles of increasing performance.

In order of their technical difficulty to indigenous development efforts, the principal missile technologies are guidance, re-entry, propulsion and airframes. *Guidance* is the most expensive and technologically most advanced subsystem in a ballistic missile. For developing long-range missiles targeted against military installations, highly sophisticated inertial guidance systems are virtually mandatory. For smaller weapons, targeted against cities, the requirements are not so severe. The second most difficult technology associated with ballistic missiles is the *re-entry_technology*. The difficult aspects of re-entry technology are in aerodynamic design of the body, heat sink or ablative materials, and advanced production technologies; shock tubes required for the testing program. Important requirements in the development of *propulsion* systems include the development of nozzle control mechanisms and propellant flow control systems; the development and production of both liquid and solid propellants; and the acquisition of adequate static test stands and test ranges. In the area of *airframe* development, important requirements are production methods and equipment (welding, wrapping, etc.) quality assurance, testing and inspection.[12]

Over a period of time, as a result of the general industrial and technological development, a few countries acquired missile development capabilities. Japan, India and Brazil, for instance, acquired such capabilities from their civilian space programmes. This is because, space launch vehicles are closely related to ballistic missiles in design and performance. The two differ in the payloads they can carry, their trajectories, and, to a lesser degree, the kinds of guidance and control they require. Although, there are attempts to stress on the similarities between the two in recent years, it should be noted that ballistic missiles are more sophisticated and incorporate advanced technologies-principally, re-entry systems and guidance systems- that are not deemed necessary for space launch vehicles. In a sense, the development of space launchers can be regarded as a necessary

[12] Browne and Shaw Research Corporation, *The Diffusion of Aircraft, Missiles and Their Supporting Technologies*, October, 1966, Prepared for the Office of the Assistant Secretary of Defence (International Security Affairs) under Contract DA-49-083 OSA-3117.

stage towards acquiring ballistic missiles. However, almost all of today's space powers (both the Super Powers and Western Europe) and Israel, an emerging space power, did not follow this evolutionary order. They acquired ballistic missiles before entering into civilian space activities. For instance, the Soviet Union used a modified military missile, the SS-6 to hoist the first artificial satellite, Sputnik, in 1957. It also converted the SS-5 missiles into space boosters. Similarly, the early models of ICBMs developed by the United States, such as the Titan-II, were, except for the re-entry vehicle they required, virtual duplicates of the space rockets used in the Gemini programme. Early West European efforts to develop a space launch vehicle centred around converting the British Blue Streak missile. China and Israel have also built military missiles before developing civilian space launchers.

Most Third World countries, lack the technological, economic and other resources, necessary for the indigenous development of ballistic missiles. The dominant mode of acquiring ballistic missiles in the Third World has therefore been by way of purchasing whole missile systems or major systems and technologies from the industrialised countries, principally the Super Powers. Both the United States and the Soviet Union equipped their allies and client states with a range of ballistic missiles, although neither of them transferred intermediate and long-range missiles to any Third World country. By the early 1980s, a total of 14 Third World countries possessed ballistic missiles supplied by the Super Powers. (See the Table-4.1). Of these, only three countries, Israel, Taiwan and South Korea, have indigenous missile development programmes which were largely based on the French and American missile expertise and technology.

Table 4.1. Ballistic Missiles in the Third World

Missile	Source	First Deployed	Range (km)	Recipients in the Third World
Jericho	Israel	1968	480	Israel
Ching Feng	Taiwan[(a)]	1980	120	Taiwan
FROG 4/5	USSR	1957	50	Algeria, Egypt North Korea
FROG 7	USSR	1965	70	Algeria, Egypt, Iraq, India,[(b)]Kuwait, Libya, North Korea, Syria, South Yemen, Yugoslavia
SS-1/Scud-B	USSR	1965	300	Egypt, Iraq, Libya, Syria, South Yemen
SS-12 Scaleboard	USSR	1969	900	Iraq, Libya
SS-21	USSR	1978	120	Syria
Honest John	US	1953	37	Greece, South Korea[(c)], Turkey
Lance	US	1972	160	Israel

[(a)] Ching Feng, is similar to the U.S. Lance missile and is suspected to be of US origin. In the mid-1970s, a large number of Taiwanese engineers were trained in the United States in missile technologies. See Edward Schumacher, "Taiwanese Program at MIT Ended", *Washington Post*, 16 July 1976. There are also allegations of Israeli assistance. See Melinda Liu, "Propping Up a Fading Friendship" *Far Eastern Economic Review*, 27 October 1978.

[(b)] India is reported to have FROG-7s on order. SIPRI, World Armaments and Disarmament Yearbook 1983 (London: Taylor and Francis, 1983), p. 316.

[(c)] South Korea has adapted the U.S. Nike Hercules, a surface-to-air missile for SSM roles. The SSM was first tested in 1978. Seth Carus, *Ballistic Missiles in Modern Conflict* (Praeger, 1991), p. 17.

Sources: *The Military Balance 1983-84* (London: IISS, 1983) and *Jane's Weapon Systems 1983-84* (London: Jane's Publishing, 1983).

It is in this broader context of the diffusion of missile technologies and spread of short-range ballistic missiles that in the early 1980s, a few Third World countries launched ballistic missile programmes. While India launched an indigenous missile programme in 1983, Argentina, Egypt and Iraq initiated a joint programme to develop ballistic missiles in 1984.

4. THE NEED FOR INDIAN BALLISTIC MISSILE CAPABILITY

Indian armed forces, particularly the Indian Air Force, evinced interest in guided missiles in the early 1960s and called for establishing research facilities in rocketry and missiles[13]. Although the importance of conventionally armed surface-to-surface missiles (SSMs) was recognised,[14] the IAF was primarily interested in surface-to-air missiles (SAMs) and air-to-air missiles (AAMs).[15] However, with the emergence of China as a nuclear power in the mid-1960s, the need for a nuclear-capable ballistic missile capability arose. Although the Chinese nuclear explosion of October 1964 did not pose an immediate threat, its growing nuclear capability became a 'matter of careful and continuous study'. In 1966, the chief of the army staff made a categorical statement that 'we should go in for missiles; there is no question about that'.[16] The DRDO began its serious efforts to acquire basic knowledge in rocketry and missilery during this period. It was, however, in the early 1970s when China demonstrated its capability for developing long-range missiles by launching a satellite into orbit in April 1970 that the demand for a nuclear deterrence vis-à-vis China gained in stridency. The Chinese space venture rejuvenated the bomb lobby in the country. In parliament, the demand for India to go nuclear in its defence preparedness found wide-spread and persistent expression on more than one occasion. At a symposium in New Delhi called to review China's success in space in May 1970, scientists, defence experts, economists, political analysts and members of parliament decided by a overwhelming majority that the government should revise its nuclear policy and produce the bomb immediately.

In response to the pressures generated by the Chinese space venture, the Indian government outlined to the public a ten-year nuclear energy and space development programme which would give the country a balanced nuclear infrastructure wedded to a modest space programme. At the same time, a separate and distinct missile development programme called the Devil's Programme was launched in 1970-71. However, with the

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[13] Flying Officer K.S. Tripathi, 'The IAF in the Space Age', *Journal of the United Services Institute of India (hereafter, USI)*, January-March, 1961, p. 3-6.
[14] Wing Comm. P.C. Santra, 'Guided Missiles or Manned Aircraft?', *USI*, April-June, 1960, p. 125-31.
[15] See for instance, Maj. R.S. Rawat, 'Case for Anti-aircraft Defence', *USI*, July- September, 1962, p. 250-53 and Col. R.C. Jetley, *Rockets, Guided Missiles and Satellites* (Bombay, 1964).
[16] *The Indian Express* (New Delhi) 13 June 1966.

demand for the bomb losing some of its edge after the emergence of India as a pre-eminent power in South Asia,[17] and lack of any significant break-through in the development of liquid propulsion technologies, the Devils programme lost its importance. The programme was finally wound up in 1978. The dominant thinking in the ruling party and in the bureaucracy in the 1970s was that it would be wiser and more prudent and practicable to stabilise and further develop India's status as a major non-nuclear power.

Even as the Devils programme was getting wounded up, interest in ballistic and cruise missiles was revived by the introduction of a new range of precision guided weapons systems that became available in the 1970s. With the advent of the Precision Guided Munitions (PGMs) long-range ballistic missiles became popular as conventional weapon systems and in the European theatre began to take on roles which were previously assigned to nuclear weapons. The transformation of ballistic missiles into dual-purpose systems enhanced the attraction of these systems for India which sought to maintain ambiguity on nuclear issue as a part of its strategic posture. Secondly, the extraordinary changes in the battlefield brought by the PGMs stimulated the interest of the Indian armed forces in SSMs. PGMs had a major impact on the tactics and logistics of warfare. Given the diffusion of military technology that takes place with greater or lesser degree of time lag, Indian armed forces felt the need for acquiring PGMs and evolving suitable doctrines for their use.[18] The Indian Air Force (IAF) which was seeking to acquire a capability to retaliate against Pakistani targets in depth since the Indo-Pakistan conflict of 1971, evinced interest in conventionally armed precision guided long-range missiles. However, because of difficulties in acquiring cruise missiles from foreign sources, the IAF decided to go for deep-strike aircraft as an interim arrangement.[19]

The demand for establishing Indian ballistic missile capabifity that had risen in response to the emergence of China as nuclear power thus got reinforced by the advent of PGMs. The PGM revolution which blurred the distinction between conventional and

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[17] When the question came up causally in the Lok Sabha on 15 December 1972, only one member, belonging to the Old Congress called for an Indian nuclear deterrence to counter the thereat from China.
[18] Lt Col., J.K. Dutt, 'Precision Guided Munitions', *USI*, January-March, 1977. Not willing "to discover its reality as target end recipients of these munitions" Dutt called for evolving doctrines and developing an embryonic PGM weapon system to begin with.
[19] *Military Yearbook 1977-78* (New Delhi, 1978)., p. 42.

nuclear weapons increased incentives to acquire ballistic missiles. Moreover, as a developing country that was sensitive to the defence-development debate, ballistic missiles became all the more attractive because of the predominance of dual-use technologies. In the early 1980s, confronted with the military modernisation programme of China, the massive arming of Pakistan as a front line state, and the threat of nuclear proliferation in the subcontinent, the Indian government decided to establish independent capacities for the design and production of guided missiles, including ballistic missiles.

5 INDIAN MISSILE DEVELOPMENT EFFORTS

Although the Defence Science Organisation was set up in the immediate years after independence to create an indigenous defence scientific and technological capability, systematic defence R&D began in the late 1950s when the Defence Research and Development Organisation (DRDO) was set up. Established in January 1958 with a mandate to "enable the nation to become self-reliant in weapons, weapon systems and equipment through research in wide-ranging areas of modern technology",[20] the DRDO initiated research in missile systems in the early 1960s. The objective of these early efforts was to acquire basic knowledge in rocketry and to increase awareness among service personnel of missilery and its military applications. The focus was on the air-to-air, anti-tank missiles and surface-to-air missiles. In 1962, under a Indo-Swiss agreement, the DRDO decided to design and manufacture intermediate range surface-to-air missiles(SAMs). This project, known as "Project Indigo" never took off. When the Soviet Union agreed to the sale of SA-2, SAMs in 1962, the project Indigo was cancelled.

Although it never came to fruition, project Indigo did provide impetus for a more broad based Indian missile research programme. At the "special weapons establishment" in Hyderabad, a group of scientists "to study missilery so that they could advise the services at the appropriate time", was created under the direction of Air Commodore V Ganeshan, (Director, Armaments). This project began by launching experimental rockets to study their ballistic behaviour. In 1963, a "number of two stage rockets" were fired

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[20] India, Ministry of Defence (MOD), *Annual Report 1982-83.*

from Hyderabad and "work on the development of rocket propellant was carried out at the DRDO explosives laboratory.[21] The following year, a three stage high altitude rocket was test fired for the first time from Chandipore sea range, at Balasore.[22]

The impetus for sustaining these early developments was provided by the changing nature of the Chinese threat to India. As we saw in chapter two, following the Chinese nuclear explosion in October 1964, India revised its nuclear policy. The immediate threat from China was a conventional one, but its growing nuclear capability became 'a matter for careful and continuous study'. It was in this context that the need to develop expertise in ballistic missiles arose. In 1965, the Electronics Committee headed by Vikram Sarabhai made it clear that India did not as yet have the required industrial base to undertake the production of missile systems, and suggested that if Bharat Electronics and other undertakings were strengthened, the development of missiles could be taken up.[23] With the armed forces making its requirement for ballistic missile capabilities clear, efforts commenced to update the technical and professional competence of the scientists and technologists of the defence R&D. The Ministry of Defence instituted a Masters course in Rocketry and Missiles at the Indian Institute of Science, Bangalore. However, only seven officers attended the course in the 1960s. In addition, defence scientists were detailed for attending various short-term courses instituted on an ad hoc basis in various institutions in the country. The DRDO also began to farm out projects to the various national laboratories and universities in order to conserve R&D potential. These included the Tata Institute of Fundamental Research, the Physical Research Laboratory and the Bhabha Atomic Research Centre.[24]

It was, however, only in the early 1970s, when China demonstrated its ICBM capability by launching a satellite into orbit, that the DRDO began to focus on ballistic missile systems. In response to the pressures generated by the Chinese long-range missile capability, the Indian government initiated the Devils programme under the DRDO. The

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[21] India, MOD, *Annual Report 1963-64*,.p.75.

[22] While the first two stages of the rocket were designed and developed in India the third stage was an imported one. *Radio Times of India* April, 1964.

[23] Raju G.C. Thomas, *Defence of India: A Budgetary Perspective of Strategy and Politics* (Delhi, 1978)., p. 165-66.

[24] These three institutions handled six defence projects by the end of the decade. India, MOD, *Annual Report* 1970-71.

Devils programme was the first serious effort of the DRDO to acquire ballistic missile capability. It involved greater concentration of manpower and financial resources than previous research efforts. According to one source, it reportedly involved over 880 experts and between Rs 2 to 3 crores per year was devoted to the project. Under this programme, attempts were made to convert the SA-2, a surface-to-air missile (SAM) into a SSM. There were also attempts at reverse engineering the SS-11 wire guided anti-tank missile.[25] The project developed two liquid propulsion rocket motors by 1974. However, following the failure of several prototype systems, the project was cancelled in 1978. Although the Devils programme failed due to insufficient funding and lack of support from the military bureaucracy,[26] research on missilery did not cease. With the expertise and know-how in the field of unguided rockets being well established, work on a number of projects of relevance to guided missiles- inertial guidance, lasers, infra red ramjet and dual thrust propulsion was taken up. By the early 1980s, having completed the task of building the infrastructure within which R&D could flourish, the DRDO was poised to the "harnessing of this infrastructure in to meeting the challenge of major multidisciplinary efforts involving a large financial outlays".[27]

The Integrated Missile Development Programme

In the early 1980s, India decided to establish design and production capabilities in guided missiles, including ballistic missiles. In July 1983, the Government of India authorised a sum of Rs 380 crores for the Integrated Guided Missile Development Programme (IGMDP) that was set up under the DRDO. The programme involved the development of four missile systems: Trishul, a short-range SAM; Akash, a medium-range SAM; Nag, a "fire-and-forget" anti-tank missile, and Prithvi, a battlefield support surface-to-surface missile. Concurrently, the programme was to develop Agni, an intermediate-

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[25] Manoj Joshi, 'Dousing the Fire? Indian Missile Programme and the United States' Non-Proliferation Policy, *Strategic Analysis*, vol. XVII (5), August 1994., pp. 557-75.

[26] The money devoted to the project was not sufficient to create the critical mass of a technical and manufacturing infrastructure to develop a missile. See Timothy V McCarthy, 'India: Emerging Missile Power' in William C Potter and Harlan W Jencks, eds., *The International Missile Bazaar: The New Suppliers Network* (Boulder, 1994), p. 203.

[27] India, MOD, *Annual Report 1981-82.*

range ballistic missile, and to establish long-range ballistic missile capability.[28]

Reasons for the Launching IGMDP

Security considerations were the dominant factor that persuaded the India to establish a missile production base in the country. The Indian armed forces perceived an immediate and future need for a number of types of guided missiles as essential prerequisites for the defence of the country. As we saw, ATMs and SAMs were already in the inventory of the armed forces since the early 1960s and that the need for SSMs which originally arose in the context of the emergence of China as a nuclear weapon state, got reinforced due to the changes in the warfare brought about by the advent of the PGMs. The first indication of a shift towards the acquisition and induction of new weapon systems, i.e. SSMs, into its armed forces became available in 1980, when India sought to acquire FROG-7 missiles from the Soviet Union.[29]

In the early 1980s, defence preparedness both in respect of conventional defence planning and nuclear deterrence called for ballistic missile capability. Conventional defence planning in the late 1970s had to reckon with 1) the military modernisation programme that China embarked upon, and 2) the rapid development of new weapons systems in the West and the possibility of earlier generation weapons finding their way in India's immediate neighbourhood. There was a strong possibility of China getting financial and technical support for the military modernisation programme and Pakistan's arms purchases from the United States being financed by the oil rich Arab states.[30] The fears expressed over the transfer of Western arms and related technologies to China and Pakistan soon became a reality. The nature and extent of military collaboration between China and the United States underwent changes in the early 1980s. In 1981, the U.S. Secretary of State announced that from now on China's requests for lethal weapons would

[28] Many analysts include Agni as one of the systems being developed under the IGMDP. However, one official Indian source mentions that "Under the IGMDP development of four types of missile systems has been undertaken...", India, MOD, *Annual Report*, 1987-88, p. 63

[29] *SIPRI Yearbook 1983: World Armaments and Disarmament* (London, 1983), p.316.

[30] The then Defence Minister, C. Subramanyam expressed these concerns at the National Defence Academy in 1979. *Hindustan Times*, 2 November 1979.

be considered on a case-by-case basis.[31] The same year, the Reagan Administration, seeking to use Pakistan as a conduit for supporting anti-Soviet Afghan resistance, initiated a six year $ 3.2 billion programme of assistance for Pakistan, much of it to be used for the overall strengthening and modernisation of Pakistan's armed forces. The sale of forty F-16 aircraft, which were even more modern than the A-7 aircraft that was disallowed in the mid-1970s, was authorised as a part of the new relationship.

Apart from the conventional threats, the spread of nuclear weapons in the neighbourhood of South Asia, the threat of nuclear proliferation in the Indian sub-continent and the growing evidence of strategic partnership between Pakistan and China added a new dimension to the Indian security calculus. With two of the nuclear powers adjoining the subcontinent, and the United States stationing a permanent carrier task force, presumably with nuclear weapons on board, in the Arabian Sea and preparing to operate B-52s from Diego Garcia, in the latter half of the 1970s, South Asia became a crossroad of strategic interaction among the three nuclear powers-the U.S., the U.S.S.R. and China. Although China's nuclear capabilities were limited when compared to that of the Super Powers, it began to supplement its land-based nuclear missiles with sea-based missiles. It was reportedly engaged in constructing a nuclear powered ballistic missile submarine (SSBM) for deployment in the Indian Ocean.[32] While these developments in the immediate neighbourhood had implications for the security environment and balance of power in South Asia,[33] the threat of nuclear proliferation in sub-continent heightened India's security concerns. The disclosure of Pakistan's Kahuta enrichment plant in 1979 and revelations of Pakistani nuclear smuggling operations exacerbated India's concerns. The reports of Pakistan's efforts to design nuclear arms and test their components revived the demand for India exercising the nuclear option. In 1980, two influential Congressmen and ex-ministers, V.N. Gadgil and H.K.L. Bhagat called for a review of military strategy in view of Pakistan's efforts to go nuclear. The latter, who had headed the Department

[31] K. Subramanyam, 'Modernising Indian Defence' *The Times of India*, 27 June 1981.
[32] The optimal area for the deployment of China's SSBMs in second strike mode against the U.S.S.R. is the Arabian sea and the northwest quadrant of the Indian Ocean. See *Jane's Fighting Ships, 1981-1982* (New York, 1981)
[33] K. Subramanyam, 'Nuclear Proliferation and the Balance of Power in South Asia' in Adam M Garfinkle, ed., *Global Perspectives on Arms Control* (New York, 1984), pp. 96-7

of Defence Production for several years, wanted India to go nuclear and opt for a 'strategy of uncertainty' or the 'Israel syndrome' of manufacturing the bomb but 'keeping the last wire unconnected'. It is in this context that India expressed concerns over the U.S. decision to supply nuclear-capable F-16 aircraft to Pakistan.

Indian concerns were heightened by the permissiveness that had crept into Western strategic thinking on the nuclear issue. In the latter half of the 1970s, the idea of using theatre nuclear weapons in actual conflict began to gain legitimacy in the West. The United States began the development of a new generation of nuclear weapons, stealth bombers and air-launched cruise missiles, for fighting limited nuclear wars. Already, the Carter Administration had unveiled the PD-59, a doctrine to fight prolonged but limited nuclear war. These developments led to a new arms race between the Super Powers and raised concerns over the use of nuclear weapons outside the European theatre. The research, development and testing of ballistic missile defence (BMD) systems under the Strategic Defence Initiative (SDI) programme launched in 1983 confirmed the Western complacency over nuclear matters. The new defence systems had the 'potential to drastically enhance the usability of present nuclear arsenals...because of the reduced fear of retaliation and because of the general uncertainty and instability that the development of these weapons will create'.[34] Reflecting such complacency was the efforts to de-link economic and military assistance from nuclear proliferation considerations. This became evident from the Reagan Administration's moves in 1982 to seek an unlimited waiver of the Symington Amendment, freeing it from having to impose an automatic cut-off of conventional arms transfers consequent to any nuclear test by Pakistan.

It is in this security environment that the Government of India set up the IGMDP to develop a range of guided missiles, including a short-range SSM, the Prithvi. In addition, the IGMDP was asked to establish indigenous capabilities for long-range ballistic missiles. The thrust on establishing SSM capabilities was not driven by a specific country or concern, but from an assessment of the prevailing military-security environment-rapid advances in military technologies stimulated by Super Power rivalry, and the diffusion of

[34] Muchkund Dubey, 'SDI from the Viewpoint of the Non-aligned Nations', in Bhupendra Jasani, ed., *Space Weapons and International Security* (Oxford, 1987), p. 301.

these technologies in the immediate neighbourhood of India. However, given the range parameters of the Prithvi missile (150 to 250 kilometers) it came to be regarded as a Pakistan-specific weapon and as a counter to that country's F-16 aircraft.

Security considerations apart, there is evidence to suggest that the setting up of the IGMDP was a product of the technological momentum arising from the autonomous growth of science and technology personnel in the country. The growth of Indian nuclear and space scientists and engineers 'has been particularly spectacular in number and quality'. The availability of the expertise and industrial capabilities within the country itself generated pressure on the government to go for the indigenous production of guided missiles in the early 1980s. For instance, in 1980, the leader of the opposition, A.B. Vajpayee, was highly critical of the absence of progress in defence sector, especially in the area of missiles and lamented the fact that scientists in the defence laboratories had no work although they were highly competent.[35] Keeping up the pressure on the government, the following year, he called for a high level probe into the functioning of the defence laboratories.

Support for establishing indigenous design and production capabilities in guided missiles came from the country's defence planners for a number of reasons- the high costs of purchasing even a few types of missiles from abroad, the difficulties in obtaining the required missile systems from abroad and the difficulties encountered in integrating the imported missile systems in the armed forces. By the early 1980s, most of the missile systems that were in the inventory of the armed forces were ready for phase out. The SSII-B-I wire-guided ATM produced under license from France, was of the 1960s vintage and had been replaced everywhere by the new generation of ATMs, the U.S. TOW and the French Milan. Similarly, in the air-defence artillery, India had SA-2 and SA-3 Soviet missiles while the industrialised countries were already replacing their modern and lighter second generation SAMs that were in service (such as the U.S. Blowpipe, Chaparrai, the Swedish RBS-70, the Soviet SA-7 and SA-8 and the French Roland and Crotale) with

[35] The opposition leader attributed the lack of progress in defence sector to the unholy alliance between corrupt politicians and dishonest bureaucrats in the defence establishment who were interested in the purchase of military hardware form abroad for the 'flush money' *The Indian Express*, 20 April 1981.

even more advanced laser guided systems.[36]

If technological upgradation of missile systems was necessary, their indigenous production became attractive to the Indian armed forces. For one thing, this enabled them to design and develop weapon systems to suit their requirements. There were serious limitations to importing these missile systems. For instance, the logistics of the armed forces was made difficult by the different mix of ATMs (Entac and SS-B1). Each systems required different spares, ground equipment, simulators etc. for training and maintenance.[37] Moreover, the armed forces found that there was very little stretch potential in the imported missiles. Once they were purchased, hardly any improvement could be affected in the existing weapons. Secondly, there were difficulties in obtaining new generation missiles and their technologies. Foreign arms suppliers were often reluctant to supply the kind of missiles demanded by the Indian armed forces. In case of some types of missiles, for example, the Akash missile of the Patriot class, it was known that India would be denied these missiles. Even the country's foremost arms supplier, the Soviet Union, had refused to sell some of its more advanced and larger missiles.[38] Obtaining even technologies for missile systems from abroad was difficult. The informal discussions on ad hoc export controls on missile related technologies that commenced among the G-7 countries in the early 1980s also played an important role in the decision to set up the IGMDP.

IGMDP: Features

The IGMDP represented a clear departure from the earlier missile development efforts in several respects. The IGMDP was the first Indian attempt to develop several missile systems simultaneously. In the earlier phase, the development of missiles had been hampered because the missile requirements of the army, navy and the air force differed in shape and size. The demand for some of the missiles needed by individual services was not enough to sustain a highly costly programme of R&D. Integrated development of

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[36] K. Subramanyam, 'Updating Defence Equipment', *The Nagpur Times*, 28 April 1981.
[37] Dr. S.S. Srivastava, *The Hindustan Times*, 2 February 1983.
[38] Indranil Banerjie, 'The Integrated Guided Missile Development Programme' *Indian Defence Review*, July 1990, pp. 99-108.

missiles enabled the programme to avoid duplication and save resources. It also enabled the IGMDP to save time. Within a short span of six to seven years, the programme was able to develop and test all the guided missiles that it took up. The guided missiles developed under the IGMDP and their features are given in Table 4.2.

TABLE 4.2 Guided Missiles Developed under the IGMDP

Name, Type & First Test Flight	Propulsion	Guidance	Range	Other Features
Trishul, SAM, 1985	Solid HTPB composite dual thrust motor	Command to Line of Sight	500m-9 km	Radar LOS guided weapons. Can be used against aircraft as well as helicopters. Has sea-skimming capability when used from ships.
Prithvi, SSM 25.2.1988	Twin gimballed engines using storable liquid propellants	Strap-down inertial navigation	40-250 km	Comparable in propulsion and range to Scud missile but more accurate. Controlled and guided all the way.
Angi, Reentry technology demonstrator, 2.5.1989	Three stage vehicle (two propulsion stages and payload)	Strap-down inertial navigation	Long range capability	The flight demonstrated the capability of re-entry vehicle. Only re-entry vehicle based on totally composite material.
Akash,SAM, 14.8.1990	Integrated rocket solid propellant system	Command Guidance followed by active homing.	30 km	Has phased array radar for multi-target acquisition, tracking and guidance. Mounted on tracked vehicles.
Nag, ATM	...igh ... ages.	Imaging infrared and millimetric wave radar	4 km	Third generation fire-and-forget type. Can defeat any armour of the day.

...apoor, Guided Missiles (Delhi: DESIDOC, 1991).

...pted by the IGMDP was unique to the DRDO. While the ...opment Laboratory (DRDL) at Hyderabad and its sister ... Centre Imarat (RCI) are the principal agencies in the ... a total of 19 other defence research laboratories, seven ...stitutions, like the Indian Space Research Organisation, the ... Research and SHAR have been involved. Similarly, in the ... public sector units, 11 ordnance factories, nine private ...ganisations were involved.

Organisationally, the IGMDP adopted the mission mode approach under which the 'mission', the development of a particular missile, was made paramount. Everything else, the organisation, procedures, personnel, finances etc. was made subservient to the mission. Review teams for every missile met once a month not only to review progress but also to take on-the-spot decisions without the need to refer to any higher body. With the review teams being composed of representatives of Ministries of Defence, Finance, DRDL and other outside agencies, financial clearances too were given at such meetings

The IGMDP was marked by high degree of support from the armed forces. As we noted earlier, the Indian armed forces had considerable difficulties in importing the type of missiles it required and in operating those missiles. As a result, the Indian armed forces were left with no option but to back fully the efforts of the Indian scientists and engineers. One senior scientist at DRDO, Dr M Krishnamuthi has written about the difference in the attitude of the armed forces to the regular defence projects and to the IGMDP. The Main Battle Tank and the Light Combat Aircraft, the two important projects taken up by the DRDO did not get the backing of the armed forces. Once the Germans offered the main battle tank (MBT) engine or wherever foreign collaboration was possible in the development of the light combat aircraft (LCA), the services opted for foreign supplies. "[I]n many cases a foreign source was preferred to indigenous development. In each case, the Services questioned the competence of Indian scientists to achieve their targets within the time frame specified. This at a time when the same people were willing to entrust the same Indian scientists with such an ambitious and technologically advanced effort as the IGMDP".[39]

The strong backing for the indigenous missile development efforts also led to close co-operation between the services (especially the Indian Army) and the R&D institutions. Clear cut specific system development goals were established at the onset of the project. Therefore, apart from the missiles that are developed within the programme, an enduring legacy of the IGMDP may well be its creation of a vast missile design and production establishment within the country that is more integrated with and responsive to the needs of the armed forces.

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[39] 'Self-Reliance: The Lessons of Agni', *The Hindu*, 5 July 1989.

6. SPACE PROGRAMME AND SECURITY

Given the close association of launch vehicles with nuclear delivery vehicles, some attribute a military intent behind the origin of the Indian nuclear and space programmes. They generally cite the hawkish disposition of Homi J Bhabha, the founder of India's nuclear and space programmes, in contrast to Nehru's strong preference for abjuring nuclear weapons.[40] However, as we saw in Chapter Two, the formal launching of the Indian space programme in 1961 preceded the awakening of strategic concerns that was characteristic of the period after the Sino-Indian war of 1962 and in many ways was a natural outcome of the scientific activities that were being undertaken in different parts of the country. The establishment of the sounding rocket programme under the auspices of the United Nations in 1962-63, and the 1964 decision of the INCOSPAR to go in for the indigenous production of sounding rockets did not represent a new trend. A strong desire to keep abreast with the latest developments in science had led to the development and use of the advanced and latest techniques for carrying out research and to strong ties with the international efforts in understanding the phenomena encountered in upper atmosphere. Second, there is some evidence which disproves the widespread impression that Bhabha was a nuclear hawk. The distinguished French nuclear scientist and former chairman of the French Atomic Energy Commission, Bertrend Goldschimdt records an interesting incident in his book *Atomic Complex*. At the time when Bhabha was presiding over the meetings in Vienna for the formation of the International Atomic Energy Agency (IAEA), he suggested to Prime Minister Nehru that he might be authorised to renounce nuclear weapons on India's behalf or the Prime Minister should do so. Nehru, who knew international relations better, laughingly told him: "Homi, come back to discuss this when we are in a position to make such weapons". Bhabha became an advocate of the Indian nuclear option only after the Chinese attack and Chinese nuclear test.[41]

However, security considerations began to impinge on the nascent space programme in the mid-1960s. The nuclear explosion in October 1964 did not pose a immediate military threat, but the altered security environment led to the revision of India's nuclear

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[40] Amit Gupta 'Fire in the Sky', *Defence and Diplomacy*, 1990

[41] This evidence is provided by Nehru's biographer, S. Gopal, who also studied Dr. Bhabha's papers. See K. Subramanyam, 'Nuclear Policy Perspective', *World Focus*, November-December, 1988.

policy. The Indian government did not deviate from its long standing emphasis on peaceful uses of nuclear energy but reserved an option to go nuclear. This policy implied that India would not make nuclear weapons but would constantly threaten to do so. It was a posture that avoided the vulnerability that existed in a unilateral renunciation of nuclear weapons, on the one hand, and the increased security dangers that would arise from embarking on a nuclear arms race with China, on the other. It is in this context that the establishment of a technological base in rocketry became important-as a foundation for the nuclear option. It was felt that "even without a bomb but with well developed indigenous rockets and missile technology, electronics and radar technology, we can to some extent claim a feeling of adequacy in future situations that may arise".[42] As in the area of atomic energy, the response of the Indian government was to strengthen the civilian space programme rather than go in for a military-oriented missile development programme. As a result, those who favoured a military-oriented space programme were disappointed. They felt that the emphasis on space science and technology was due to political and prestige considerations.[43]

The emphasis on self-reliance in space technology, that is particularly evident after Chinese nuclear explosion, must be seen in the broader context of the defence-development equation prevailing at that time. After the reverses suffered by India in the Sino-Indian war of 1962, there was a awakening of strategic concerns. The defence versus development equation that was characteristic of the period prior to the 1962 war, underwent a change. In the earlier years, the perceived inverse correlation between defence and development requirements and Nehru's own critical disposition to military oriented security, a Gandhian legacy, had led to the emphasis on development over everything else, including defence. After the war, the inverse correlation between defence and development continued to dominate the planning process, but at the political plane, defence requirements acquired high priority resulting, in greater co-ordinating between the civilian development programmes and defence requirements. The Indian elite remained

[42] 'China Joins Atomic Club: What Should India Do', *Science and Culture*, vol. 30 (10) October 1964.
[43] D.M. Bose, argued that unlike the atomic research (basic and applied) which is based on prestige and economic grounds, space research had been taken up mainly for prestige considerations. "How much of the results obtained may find applications for military use is still obscure" D.M. Bose, 'India's Recent Achievements in Atomic and Space Research', *Science and Culture*, vol. 34 (6), June, 1968.

convinced that the main thrust of Indian planning directed towards making the country self-reliant as far as possible, must remain undisturbed and indeed receive even greater attention than before. After all, defence preparedness did not merely mean collection of armaments, but "a solid and broad based economy and population increasingly trained to make full use of the resources of modern science and technology".[44] This belief that development is a perquisite of sound defence combined with the high priority that defence matters acquired after the reverses suffered in the Sino-Indian war of 1962 led to greater co-ordination of the defence and development requirements in the planning process. Not allowing for cuts in the development outlays, Nehru made deliberate efforts to co-ordinate the defence needs with economic planning and development by setting up a new ministry along with the Defence Ministry, known as the Ministry of Defence and Economic Co-ordination. It was intended to synchronise defence planning with economic development and private industrial production so as to optimise the allocation of resources. It was however in the later half of the decade that these efforts gathered momentum. In September 1965, the National Development Council gave a directive that a plan for defence requirements from the civilian sector be prepared for incorporation in the Fourth Five Year Plan (for the period 1969-74) that was being given shape. In 1966, the Electronics Committee headed by Homi J. Bhabaha recommended that

> the Electronics industry has to be...developed in an integrated and interlocked manner. In the interest of the tax payer....it is essential that all equipment, whether for civilian or military use, should be produced in the most economical manner possible, and this requires that the production of this equipment should be organised according to the technologies and economies of production, as is done in the highly industrialised countries. If the separation of civilian and military production is not required by security considerations even in the technologically most advanced countries, it clearly cannot be justified in India. It also follows from technological considerations that production in the public sector cannot be separated from the production in the private sector, and for the optimum development of the industry it is necessary to plan it on an integrated

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[44] Jawaharlal Nehru, 'Changing India', *Foreign Affairs*, (New York), April 1963. This perspective of regarding development as a prerequisite for defence was shared widely. See D.K. Sukla, 'Economic Implications of Defence and Development', *AICC Economic Review*, vol. XVII (113) January 1966. pp.-16-8., S.S. Khera, *India's Defence Problem*, (New Delhi, 1968)., pp.-258-66., A.L. Venkateswaram, *Defence Organisation in India* (New Delhi, 1967)., p. 398, P.V.R. Rao, *Defence Without Drift* (Bombay, 1970)., pp.-307-310.

basis taking the public and private sectors together.[45]

Dual-purpose technology programmes, such as the space programme therefore acquired importance in the context of the new defence-development consonance that emerged in the context of the new security situation in the 1960s. In the wake of Chinese nuclear explosion, many external observers were quick to note the military potential of the nascent space programme.[46] Within the country, the belief that space activity is an important element in the technological base for not only economic security but also military security gained ground[47] and became a driving force for the expansion of the space programme in the latter half of the decade. It is in this context that India's interest in U.S. Scout rocket technology came to be seen as a move in the direction of acquiring ballistic missile capabilities. The United States declined the technology and became cautious in its co-operative ventures with the Indian space programme-guarding against any potential contribution to space launch capabilities.

In the early 1970s, the military potential of the space programme attracted wide attention and a section of the bomb lobby called for realising that potential. In April 1970, when China hoisted a satellite into space, it was widely seen in India as an evidence of growing nuclear muscle of China, equipping that country with an IRBM capability. In the Indian parliament that was in session at that time, the Defence Minister drew attention to the military potential of the country's space programme and informed the members that the civilian space programme will have to be reviewed.[48] The demand for the nuclear deterrent capability vis-à-vis China was revived and gained widespread support. Amongst the advocates of the bomb, two schools of thought crystallised in the early 1970. One

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[45] India, Electronics Committee, 'Electronics in India'(New Delhi, 1966), p.80. Set up in 1963, the committee submitted its report after the untimely death of its chairman Bhabha in January 1966. The other members of the committee were S. Bhagavantam, Science Advisor to the Ministry of Defence, A. S. Rao, Director of the Atomic Energy Establishment, Trombay, and Vikram A. Sarabhai, Chairman of the ISCOSPAR. The report was submitted

[46] For instance, Alastair Buchan of the International Institute for Strategic Studies (IISS), London observed that India does "have the beginning of a missile program in high altitude meteorological rockets which were obtained from France, and these could be gradually developed into a series of medium and large range ground-to-ground missiles" Buchan, 'The Dilemma of Indian Security', *Survival*, vol. 2 (5) August 1965, p.204-7.

[47] For instance see, 'China Joins the Atomic Club...' n. 42.

[48] *Hindustan Times*, 29 April 1970.

group favoured an immediate crash programme of weapons consisting of plutonium warheads and a crude delivery systems of liquid fuelled missiles of 1500-3000 kilometers range, or alternatively, purchase of bomber aircraft of adequate range on one way mission. The other group which gained considerable ground stood for a balanced nuclear weapons development programme. This group did not call for an immediate commitment to the bomb but pleaded for embarking upon an accelerated effort for an integrated programme of research and development of peaceful uses of nuclear and space technologies so that a weapons threshold capability is acquired. They believed that once the country actually acquired that capability, the decision to take the plunge would be the logical, almost inevitable, next step.

In July 1970, when the Government of India outlined to the public a profile of a ten-year nuclear energy and space development programme, the bomb-for-security lobby came to regard it as a firm step towards nuclear weaponry. The SLV-3 launch vehicle programme that was envisaged in the Profile, therefore received strong support. Although a separate missile development programme, the Devils programme, was initiated in the defence sector in 1970-71, it was the space programme that had already established a modest infrastructure in rocketry, which continued to attract the bomb-for-security lobby.

The emergence of the space programme as an institutionalised programme accountable to the Indian parliament in its own way contributed to the perception that space activity is a civilian oriented but defence related activity. Emerging out of the protective wing of the Department of Atomic Energy, the space programme found itself in a not too comfortable environment. With satellite-based communications yet to acquire wider acceptance, both among the user agencies and planners, and the space projects taking a huge portion of the space budget, both because of the inherent complexities of the technology and the economic environment in which the country found itself, the managers of the space programme found it necessary to highlight, among other things, the military potential of its projects. For instance, at the Parliament's Consultative Committee on Atomic Energy and Space Research in mid-1974, the Chairman of the Indian Space Commission, Dr. Satish Dhawan, referred to India's capability for producing medium range ballistic missiles with locally developed solid fuels and guidance systems.[49] In other words, if pressures generated by external developments drew attention to the military potential of the space programme, the managers of the space programme reinforced that image to gain support for a high technology programme in the context of scare resources.

In the context of the space programme emerging as a civilian oriented but defence related programme, there emerged two broad approaches to the exploitation of space technologies for military purposes. Those who wanted an immediate or early establishment of nuclear deterrence vis-à-vis China called for accelerating the space launch vehicle project, the SLV-3, so that it could be developed into an IRBM with the addition of improved guidance system.[50] Others who wanted a balanced development of rocketry, called for close co-ordination between the missile development efforts in the defence sector and the civilian space programme. According to this school of thought, an important reason for the lack of progress in rocketry in the defence sector was the absence of a regular or sustained relationship between the civilian and military programmes. They were highly critical of the formal separation being maintained between the civilian space and military missile programmes which was a potential obstacle to realising India's strategic objectives. As one analyst argued "If... national security goals someday dictate a reconsideration of strategy, then it is clear that the potential of the space programme can be tapped if, and only if, the activities of the two (the Space Department and Defence ministry) are co-ordinated".[51]

In the early 1980s, strong pressures emanating from security and economic considerations led to the establishment of close though not integral relationship between the civilian space and military missile programmes. After the civilian space programme demonstrated its satellite launch capability (the SLV-3 was launched in July 1980, May 1981 and in April 1983), there was a mounting pressure on the government to utilise that technology for military purposes. The hawks became highly critical of the government's

[49] Cited in Onkar Marwah, 'India's Nuclear and Space Programs: Intent and Policy', *International Security*, Fall, 1977.
[50] For instance see, Ravi Kaul, *India's Nuclear Spin-off* (New Delhi, 1975).
[51] R.R. Subramanian, 'Military Potential of India's Space Program', *Strategic Analysis* 1978, pp. 387-88.

reluctance to derive the military potential of the space programme. One of them argued that "there is something pathetic about the weak attempting to save the world ...In the world of realpolitik, it is the more powerful that determine the fate of the world. They also establish the fundamental patterns of international politics and one can avoid these only at the cost of one's independence. Until the more powerful are able to develop a new self enforcing international morality regarding violence, the less powerful should be more forthright about using all necessary means to protect their independence".[52] The advocates of the military use of space had a upper hand in a world moving towards the deployment of space weapons, the breakdown of arms control efforts and the proliferation of advanced weaponry. They weakened political restraints on utilising the technologies available within the country for military purposes.

At around the same time, strong economic-industrial pressures began to impinge on the civilian space effort. As we saw in Chapter Three, given the magnitude of the space projects envisaged for the decade, the civilian space programme became increasingly dependent on domestic industries. Although, ISRO instituted a technology transfer scheme to strengthen the industrial base of the programme, the Indian industry was unwilling to take up space projects, not only because of the rigorous quality and time-schedules set by ISRO, but also because of the non-repetitive and low volume nature of the orders. It is in this context that the belief that the industrial base of rocketry could be strengthened by taking up military missile development gained ground. The argument that 'without explicit military backing , ISRO's rocket programme will not gain sufficient momentum to achieve its aims' was advanced by a section of the scientific community.[53]

The decision of the Indian government to acquire design and production capability for a variety of guided missiles, including the Prithvi and Agni, was thus based on security considerations, not only in the narrow sense of the term, to meet the military security requirements but also in the broader sense of strengthening the base of high technology in the country.

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[52] Baldev Raj Nayar, *India's Quest for Technological Independence*, (New Delhi, 1983), vols. I & II.
[53] Amalendu Das Gupta's report in the Statesman (Calcutta) cited in Lincoln Kaye, 'Step by Step Towards Eventual Self-Reliance, *Far Eastern Economic Review*, 27 August 1987. A similar assessment was made by the U.S. Embassy in New Delhi in December 1987. See MaCarthy, n. 26, p. 205.

The two programmes-ISRO's space launcher programme and the DRDO's missile programme- evolved as distinct programmes. Although solid propulsion technologies were well established in the civilian space sector, the IGMDP's ballistic missiles were based on liquid propellant technologies that have been developed in the defence sector. Nevertheless, both the programmes shared a common development and production base- public sector undertakings, both in the civilian and defence sectors, private industrial corporations, universities and research institutions. There has been collaboration between the two programmes in the manufacture of certain key rocket components. For instance, the defence public sector undertakings, the Bharat Electronics Ltd (BEL), Mishra Dathu Nigam Ltd (Midhani) Hindustan Aeronautics Ltd (HAL) have contributed to the civilian space programme, while several public and private sector units in the civilian sector have contributed to the missile programme. In early 1980s, ISRO signed a memorandum of understanding with BEL for "technical co-operation in the field of development and production of electronic equipment and components for space applications" Apparently, the agreement established a separate and dedicated production division within BEL.[54] Midhani produces maraging steel (M250) for the first stage of the PSLV.[55] The HAL has designed and supplied systems for the SLV-3 and has a ISRO funded facility to manufacture alloy structures and tankages for the Polar SLV[56]. Similarly, the missile production effort has benefited not only from the defence public sector undertaking and ordnance factories, but also from public and private sector units in the civilian sector. In addition, the IGMDP has utilised ISRO's test and tracking facilities for the development of ballistic missiles, reflecting the close, though not integral, relationship between the two programmes. Six of the first eight Prithvi tests took place at the SHAR (Sriharikota) range, which is under the control of ISRO's Vikram Sarabhai Space Centre. The Agni was however flight tested at the interim test range facility located at Baliapal in east Orissa. Several of the facilities which form ISRO Telemetry, Tracking and Command

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[54] India, DOS, *Annual Report 1982-83*, pp. 60-61. Also see P. Sundarsan, "ISRO and Indian Industry-A Growing Partnership" in R..K. Mishra, ed., *Indian Industries: Problems and Prospects, 1986-87* (New Delhi, 1987)., p.247.

[55] ibid., p.245.

[56] C.V. Gopalakrishnan, 'HAL Gears for Dynamic Phase', *The Hindu Survey of Indian Industry*, March 1990, p.35.

Network (ISTRAC) such as those at SHAR and Car Nicobar Islands, were used to monitor Agni's maiden launch. The INSAT satellites , which fall under ISRO's control, were used to transmit Agni launch data.

7. CONCLUSION

The above analysis of the security concerns and the evolution of the space and missile programme shows that the civilian space programme came to be regarded as defence related programme only in the 1970s . In the earlier phase, the driving forces of the space programme were economic development and scientific advancement. Thereafter, security concerns arising from developments in the country's immediate neighbourhood generated the demand for the military use of space technology, particularly, rocketry. This did not however, lead to the conversion of the civilian programme into a military one as in the case of Argentinean space programme. Instead, the industrial and technological competence that emerged out of the civilian space effort was utilised by the defence sector. The use of ISRO's test and tracking facilities and its expertise, reflects the close, though not integral, relationship between the civilian space programme and the missile programme initiated by the DRDO.

CHAPTER FIVE

EXPORT CONTROL POLICIES: THE MTCR

At the on set of the Space Age, it was the military potential of space launchers and the satellites that they hoisted into orbit that attracted foremost attention. Both, the United States and the Soviet Union had acquired the capability to deliver nuclear weapons across the continents and place weapons in the outer space. In an effort to mitigate the evil consequences of nuclear weapons, some countries, including India, called for serious efforts to eliminate long-range ballistic missiles. In the late 1950s, efforts were made to put in place arms control measures, such as monitoring the deployment of missiles and banning further testing of missiles. Neither the disarmament efforts nor the more limited arms control efforts had any impact. Both the Super Powers were reluctant to accept controls on missile/space technology whose military potential was yet to be fully exploited. It was generally recognised that with the passage of time arms controls would become increasingly difficult. However, for the United States, freeze proposals meant controlling space activities and giving up the pursuit of what it thought to be a more stable deterrence.[1] For the Soviet Union, ballistic missile disarmament and arms control proposals meant disclosing the actual status of its technological capabilities[2] and giving up its best means (inter-continental ballistic missiles) of reaching the United States.

Although no meaningful co-operation between the Super Powers was possible until the

[1] Arms expert Norman Rathjens argued that" any measures which can contribute to an improvement in stability are of very great importance- so much so that they may be worth implementing even if, from the longer point of view, they make controlled disarmament more difficult. Probably continued testing and development are among such measures". Quoted in Peter J Roman, "Eisenhower and Ballistic Missiles Arms Control, 1958-1960: A Missed Opportunity?", *The Journal of Strategic Studies*, vol. 19 (3), September 1996, pp. 365-380.

[2] "I believe at that time the U.S. might have been willing to cooperate with us, but we weren't willing to cooperate with them. Why? Because while we have been ahead of the Americans in space exploration, we were still behind them in nuclear weaponry....Our missiles were still imperfect in performance and insignificant in number. Taken by themselves, they didn't represent much of the thereat to the United States. Essentially, we had only one good missile at the time: it was the Semyorka, developed by the late Korolyov. Had we decided to cooperate with the Americans in space, we would have to reveal to them the design of the booster for the Semyorka...In addition to being able to copy our rocket, they would have learned its limitations; and form a military standpoint, it did have serious limitations. In short, by showing the Americans our Semyorka, we would have been both giving away our strength and revealing our weakness". Krushchev, S. Nikita, *Krushchev Remembers: The Last Testament*, Strobe Talbott, trans.(Boston, 1974), p. 54.

Soviet Union achieved some parity in the early 1960s, both U.S.S.R. and U.S. shared a common interest in non-proliferation of nuclear weapons. As a result, both of them enforced some kind of informal control on the diffusion of rocket technology which was considered as vital for the development of a independent nuclear force. This control was exercised with respect to the transfer of the whole rocket systems or its technology.

1. PROLIFERATION CONCERNS AND POLICIES

The Super Powers concern over the proliferation of nuclear weapons was awakened in the late 1950s itself when France and China decided to establish their own nuclear deterrence force. Both the United States and the Soviet Union sought to discourage the nuclear and missile development efforts of their respective allies. In the late 1950s, the United States declined to assist France in the development of solid-propellant technology. Later, the U.S. attempted to impede the French development of the thermonuclear warheads by prohibiting French military aircraft from flying over or landing in the U.S., if their destination was the Pacific Test Center and denying high-performance computers or other devices which would be useful in weapons development effort.

The Soviet Union, after the initial technical assistance to China in the mid 1950s, withdrew all such assistance once it became clear that China was seeking to emerge as an independent nuclear weapon state. One of the important reasons for the widening Sino-Soviet gulf in the late 1950s was the Soviet refusal to share nuclear and missile technologies with the Chinese.

In the mid-1960s, following the Chinese nuclear explosion, there were heightened concerns over the proliferation of nuclear weapons. It is in this context that the United States began to bestow greater attention on the spread of aircraft and missiles which could deliver nuclear payloads. The nascent missile race that had developed in the Middle East, between the United Arab Republic (UAR) and Israel, in the early 1960s attracted lot of attention.[3] In 1960, the UAR had initiated a ballistic missile development programme in

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[3] See Lewis A. Frank, "Nasser's Missile Program", *Orbis*, vol. XI, (3) 1967, pp. 746-58. For the early concerns over the transfer of sophisticated military hardware, particularly, aircraft and missiles and their related technologies to the Middle East See, J. H. Hoagland and J. B. Teeple, "Regional Stability and Weapons Transfer: The Middle Eastern Case", *Orbis*, vol. IX, (3), 1966.

response to the Israeli sounding rocket programme. But the UAR's programme was indigenous only in the sense of being under domestic management and financing. The entire rocket design team was composed of experts drawn from abroad, mainly Germany. Although, it carried out development flight testing of two missiles in June 1962, it was evident that the UAR faced serious technical obstacles in the development of missiles and that it would take several years to develop an operational missile system. But the mere existence of the programme raised Israeli concerns about Arab-Israeli balance of power. It therefore launched its own missile programme with French assistance. At the same time, it used a variety of pressure tactics ranging from public appeals in the United Nations to physical violence to induce the German scientists to leave the UAR and thereby impede its missile programme.[4]

A study conducted for the U.S. Department of Defence (DoD) in the mid-1960s, *The Diffusion of Combat Aircraft, Missiles and Their Supporting Technologies*,[5] noted that the diffusion of ballistic missiles that had begun in the Middle East, along with the Chinese missile effort, could serve as bellwethers for the Third World. It noted that ballistic missile development in the Third World could have several adverse effects:

(a) the procurement of missiles can heighten interest in and accelerate planning for weapons of mass destruction;

(b) the success of one Third World country in its missile programme may provide the basis for co-operation with other countries which are successful in nuclear programme;

(c) the introduction of ballistic missiles into regional environment will introduce new and unfamiliar strategic concepts among adversaries; and

(d) the cost of indigenous missile programmes will divert allocations of human and financial resources from other pressing national needs.[6]

The study noted that some diffusion of missile-relevant technologies had already occurred in the form of surface-to-air missiles and sounding rockets. Table 5.1 is an abridged version of the comprehensive survey done by the study on the missile and

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[4] Israeli Foreign Minister, Golda Meir, accused the UAR of developing weapons of 'mass destruction' in a speech before the United Nations General Assembly on 2 October 1963.

[5] Browne and Shaw Research Corporation, The Diffusion of Combat Aircraft, Missiles and Their Supporting Technologies, Report prepared for the Office of the Assistance Secretary of Defence (Mass, 1966).

[6] ibid., p. B-39.

missile relevant technologies that has occurred is unlikely to help Third World countries in making rapid progress in developing accurate and sophisticated missiles. Indigenous development, production, and operation of large and sophisticated guided missile systems placed severe strains on the resources of the Third World countries seeking to emerge as missile powers. The options for these countries were limited to importing sophisticated systems from the relatively few suppliers, developing the weapons indigenously with a great deal of outside help, or procuring lower performance missile systems. The study noted that apart from China which has benefited from its earlier alliance with the Soviet Union, India was the only Third World country capable of missile development affecting to varying degrees, the major power strategic balance.[7] A continuation of prevailing controls on technology transfers and restraints on the transfer of whole missiles seemed sufficient to deal with the problem of Third World ballistic missiles, if any.

Table 5.1 Countries with Missile and Missile-Relevant Programmes by 1965

Albania	Operating Chinese supplied SAMs.
Algeria	Soviet Union has supplied unknown number of SAMs.
Argentina	Sounding rocket programme. NASA supplied the rockets, launcher and launch training.
Brazil	Sounding rocket programme. NASA supplied the rockets, launcher, training and advice.
Indonesia	Navy has short-range sea-to-surface 'Styx' missiles from the Soviet Union in 1965-SAMs were also supplied at that time- Sounding rocket programme with Japanese supplied rockets, launcher and training in launch operations.

[7] ibid., p. 5.

Iran	The U.S. Hawk SAMs were being supplied since 1964-UK has agreed to supply Tigercat SAMs.
Israel	French firms and expertise being used for developing two-stage medium-range vehicle-also sounding rocket programme.
Kenya	Italian Space Commission in collaboration with University College of Nairobi is launching sounding rockets off the coast of Kenya.
North Vietnam	SAMs and training crews have reportedly been supplied by the U.S.SR.
Pakistan	Launching sounding rockets since 1961. Rockets, launchers and training provided by U.S. -United Kingdom provides payloads and ground equipment.
Saudi Arabia	In late 1965, it placed orders for Raytheon Hawk SAMs from US. Training in air defence part of the deal- UK also involved in the air defence deal.-It has supplied anti-aircraft Thunderbird missiles as an interim arrangement.
Syria	Received short-range Styx SSMs from USSR for use with Komar-class motor torpedo boats.
United Arab Republic	Development and production of SSM since 1964 with teams of West German aerodynamicists, electronics and guidance engineers and propulsion specialists- Development and production equipment procured through Swiss intermediaries.-Some U.S. men were also secretly in Egypt to assist in the program-Cairo sources say in 1965 that precision instruments for the programme were purchased from East Germany because of difficulties in procurement from the West- Received Styx SSMs from USSR for use with Komar class motor torpedo boats.

It is clear from the above, that the concern over ballistic missiles in the Third World arose primarily from the impact that they would have on major power strategic balances. Neither the United States nor the Soviet Union were concerned with weapons systems whose impact would be intra-regional. In fact, beginning in the mid-1960s, both the Super Powers even while enforcing informal national controls on the transfer of missile technologies, began to transfer outdated short-range SSMs to a number of countries in the Third World, mainly in the Middle East. The Soviet Union took the lead in transferring SSMs. Beginning in 1967, it transferred different versions of FROG (free-rocket-over-ground) missiles to North Korea and a number of countries in the Middle East. Some of these countries also received the 300 kilometer range Scud missile. The United States transferred Honest John missiles to South Korea, Greece and Turkey and deployed a number of SSMs in the Third World theatres. For instance, it deployed the advanced Lance missile in South Korea for a short time in 1971. Although the United States showed restraint in transferring SSMs to the Middle East, it however, transferred the off-the-shelf Lance missile to Israel in early 1972. Thus, we notice a peculiar situation in which the Super Powers, while discouraging indigenous development of ballistic missiles through national controls on missile technologies, began transferring less sophisticated and short-range missile systems to their Third World clients. Both Israel and Egypt, which had initiated missile development programmes in the early 1960s, began receiving short-range SSMs from United States and the Soviet Union. Israel, in addition, benefited from French and U.S. technical assistance in developing its indigenous missile capabilities.

The U.S. Technology Transfer Controls in the 1960s

Non-proliferation considerations had already a strong imprint on the U.S. policy in the field of international co-operation in outer space. In the late 1950s, the United States encouraged co-operation in the outer space for scientific, political and economic reasons. The necessities of operating a programme that was inherently global in character, the desire to gain propaganda advantage in the context of the Super Power competition, and tap the expertise available in the allied countries dictated the U.S. programme for co-operation in outer space. But keeping non-proliferation considerations in mind, the United States had excluded co-operation in the tools of space research, that is, rocket technology.

The NASA, as the agency charged with co-operation in space for the United States, avoided the missile related security difficulties by stressing co-operation in scientific payloads and spacecraft. When European nations formally established two regional organisations, ESRO and ELDO in 1964, NASA saw it as an opportunity for sharing scientific and technical resources. But given the non-proliferation concerns, this called for new regulations. The Department of State stated that the general policy governing space launchers was that co-operative undertakings, including the export of technology, would depend upon the differentiation of civil from strategic applications and would preferably move through the multinational channel of ELDO rather than bilaterally.[8] Thus, the official position of the United States was that a valid dividing line would be drawn between technical exchanges that are civilian and those that contributed to military applications. The NASA made it clear that such a distinction could be drawn. Rejecting the 'superficial view' that a missile is a missile and technical assistance for a scientific satellite booster will not preclude the use of that booster for military purposes, the Head of the NASA's International Programme, Arnold Frutkin wrote that this will

> depend upon conditions and circumstances. Generally speaking, missiles using cryogenic fuels, for example, do not commend themselves for use with deterrent forces since it is too difficult and expensive to keep them in standby status; storable propellants are much to be preferred. Thus, fuels and other missile elements requiring the use of cryogenic equipment are unlikely to be used for weapon systems. Similarly, certain guidance systems are adequate for space application but do not command themselves for targeting applications. It is perhaps sufficient here to say that the matter is most complicated but that distinctions appear possible and have in fact been made.[9]

However, with the awakening of nuclear proliferation concerns in the mid-1960s, differences over the transfer of rocket technologies widened within the U.S. Administration. The DoD became increasingly concerned over the diffusion of missile technologies and cautioned the U.S. government against entering into co-operative programmes in the tools of space research, including sounding rockets. Referring to the Indian sounding rocket programme, especially the licensed production arrangement with

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[8] Address by Chief, Outer Space Affairs Section, Department of State (25 October 1962) before the Export Committee of the American Aerospace Industries Association. Cited in Arnold W Frutkin, *International Co-operation in Space* (Delhi, 1967), p. 136.

[9] ibid., p 136-7.

CNES of France, the DoD study noted that although the Centaure rocket was too small to have direct military utility, the production experience gained by India through licensed production arrangement could be useful in the future development of larger rockets.

> First, such an agreement permits continuous discussions under official auspices between missile engineers and scientists in the supplier and recipient countries. Second, an agreement can have the effect of establishing a cadre of rocket personnel in the recipient country whose interest in further rocket or missile activity is aroused, and whose talents may be drawn away from the needs of the national economy. Third, it is obvious that development and production experience can be gained, even though in a very basic form. Fourth, the teams at the launch site become familiar with test procedures, have a reason to acquire increasingly more sophisticated test instrumentation, and acquire a practical engineering and operational knowledge of rocketry which cannot be duplicated merely at the scientific level. Finally, the existence of a sounding rocket program may, in some cases, be taken by an adversary as an expression of military intentions and thus contribute to an existing arms race.[10]

While the DoD expressed concern over the diffusion of missile-relevant technologies and called for restricting co-operation in outer space, the NASA, on the other hand, saw the emerging space programmes as an opportunity of tapping the resources of the co-operating countries in space technology. In addition, co-operative space ventures were seen as providing economic benefits to the U.S., albeit small.[11] These differences combined with the absence of an immediate threat from Third World missile programmes, precluded a consensus on dealing with the diffusion of missile technologies. The United States began to adopt a case-by-case approach, denying assistance to some (as in the case of India[12]) and aiding others (Israel). This phase lasted for about a decade, that is, until the mid-1970s, when the subject of conventional arms limitations and nuclear proliferation acquired prominence in the security policies of the United States.

The 1970s

In the 1970s, the advent of Precision Guided Munitions (PGMs), the use of ballistic missiles in the Middle East conflict and the threat of nuclear proliferation brought ballistic

[10] *The Diffusion of Combat Aircraft, Missiles...*, n. 5, p. 8.

[11] Frutkin, n.8, pp. 77-8.

[12] According to one report, NASA and the Department of Commerce were willing to sell the Scout rocket technology but were prevented from doing so by the Department of State. See, William E. Burrows and Robert Windrem, *Critical Mass* (Simon and Schuster Ltd., 1994).

missiles into focus and created an intellectual and psychological climate against Third World ballistic missiles.

In the late 1960s, in response to reverses in Vietnam, the United States attempted to shift some of its global defence responsibilities to 'surrogate gendarmes' in the Third World, a policy which came to be known as the Nixon doctrine. This resulted in accelerated arms transfers to the Third World. International economic environment arising from the increase in the OPEC oil prices in the early and mid-1970s further fuelled the arms transfers as Western arms producing nations attempted to improve their trade balances vis-à-vis the oil producing nations in the Middle East. The dramatic increase in the arms transfers to the Third World, both in terms of the quantity and quality of the weapons traded, raised concern over 'uncontrolled arms trade'. While arms transfers served important political, strategic[13] and economic interests of the Western arms producing nations, an unrestrained pattern of arms transfers threatened to ultimately disrupt international security (read U.S. security interests) as well as undermine efforts at economic development, non-proliferation, and control of terrorism. The Carter Administration, therefore, drafted new guidelines for the U.S. arms transfers in 1977 and contacted allies to begin negotiations on a multilateral arms control initiative.

The Carter Administration's efforts to restrain conventional arms transfers aimed at addressing the fundamental problem of the rapid acquisition of relatively sophisticated

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[13] For instance, since the mid-1960s, arms transfers have served a range of U.S. policy objectives. The U.S. Secretary of State, Cyrus Vance, in his 30 June 1977 report to Congress, summarised these as follows:

To support diplomatic efforts to resolve major regional conflicts by maintaining local balances and enhancing our access and influence vis-à-vis the parties;

To influence the political orientation of nations which control strategic resources;

To help maintain regional balances among nations important to us in order to avert war or political shifts away from us;

To enhance the quality and commonalties of the capabilities of major allies participating with us in joint defence arrangements;

To promote self sufficiency in deterrence and defence as a stabilising factor in itself and as a means of reducing the level and automaticity of possible American involvement;

To strengthen the internal security and stability of recipients ;

To limit Soviet influence and maintain the balance in conventional arms;

To enhance our general access to and influence with government and military elites whose political orientation counts for us on global or regional issues;

To provide leverage and influence with individual governments on specific issues of immediate concern to us; and

To secure base rights, overseas facilities, and transit rights to support the development and operations of our forces and intelligence systems.

weapons by Third World countries in volatile regions of the world. Controls came to be predicated not only on considerations of volume and distribution of arms transferred but on their effect on regional military balances. Another important consideration that came to shape arms transfer policies of the United States, was their effect on the proliferation of nuclear weapons. On both these counts, ballistic missiles came to be singled out as the weapon systems for control. As conventional weapon systems, ballistic missile transfers came into sharp focus as a result of two important developments: the use of these weapon systems in the Middle East and the advent of precision guided long-range missiles. Concern over their proliferation was reinforced by the fact that these were the so-called threshold weapon systems which could be used to deliver nuclear payloads.

In the early 1970s, both the Super Powers had supplied their allies in the Middle East with 'beyond the battlefield' weapons such as the Lance and the Scud missiles. The actual use of these missiles by Egypt and Syria during the Yom Kippur war in 1973, perhaps for the first time since the Second World War, awakened concerns over conventional ballistic missiles of the Third World. The Egyptian and Syrian attacks on Israel with Scud and FROG missiles, towards the fag end of the war were too small (involving no more than a few dozens) and inaccurate to have any tactical effect on the outcome of the war. Nevertheless, they created terror among the Israeli population and had a profound political impact. A prominent Israeli analyst later argued that the Scud missiles were 'the most significant weapon system sent to Egypt', that they greatly inhibited Israeli strategy in the war and made Israeli leaders more willing to accept U.S. diplomatic initiatives that brought the war to a close after three weeks.[14] The political effectiveness of these missiles as weapons of terror is evident from the fact that soon after the war, Israel proposed an agreement through the International Red Cross under which it would join Syria and Egypt in a pledge to refrain form striking at each other's population centres if another war erupts.[15] Drawing their conclusions from the experience of arms and conflicts in the Middle East and Europe, advocates of arms control in the U.S. called for a complete ban on trade in systems whose primary mission is attack against cities, such

[14] Evron, Y, *The Role of Conventional Arms Control in the Middle East*, Adelphi Paper 138, (London, 1977), pp. 6, 11.
[15] 'Israel Seeks Pact on Sparing Cities in Any Future War', *New York Times*, 5 April 1975.

as long-range SSMs and area weapons.

The focus on long-range SSMs was reinforced by the advent of the PGMs, a range of new generation of guided missiles that became available in the 1970s. Although there was no consensus on the ultimate military impact of the new weapon systems, it was widely believed that the PGM warfare would stimulate the interest of Third World in SSMs and air-to-surface missiles (ASMs) which combined long-ranges with precision terminal guidance.[16] The deployment of PGMs for certain missions, for instance, to improve air defences (hand-held and radar dependent surface-to-air missiles) would make military aircraft vulnerable, forcing an adversary to acquire long range, stand-off defence suppression weapons such as air-to-surface missiles and glide bombs with terminal guidance, SSMs with ranges in excess of 60 kilometers.[17] Moreover, precision guided long-range missiles were expected to become attractive as conventional strategic weapons for several reasons. In the first instance, these were becoming versatile weapon systems. For instance, conventionally armed cruise missile could be used like a bomber with many bombs, to scatter weapons over a target area or could be used like a aircraft armed with terminally guided homing missiles, to launch several sub-missiles with each sub-missile capable of acquiring and homing on the target.[18] They could carry nuclear as well as conventional warheads. Secondly, in sharp contrast to weapons of mass destruction or area weapons, precision guided warheads had no stigma attached to them as they did not violate the existing norms of warfare.[19]

If the PGM warfare increased the incentives to acquire long-range SSMs, the enlarged supplier base of PGMs and the falling costs of production, seemed to create the objective conditions for their widespread proliferation. The technologies of PGMs were more

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[16] SSMs in the Third World arsenals, including the Scud missiles, were characterised by low accuracy. The CEP or Circular Error Probability of the Soviet Scud missiles was estimated to be several hundred meters. CEP is the most commonly cited measure of the accuracy of a missile or other long-range weapon .It is the radius of a circle within which 50 percent of all warheads fired at the same target will fall.

[17] Steven J. Rosen, 'The Proliferation of New Land Based Technologies: Implications for Local Military Balances', in Stephanie G. Neuman and Robert E Harkavy, eds., *Arms Transfer in the Modern* World (New York, 1979).

[18] C. I. Hudson, 'The Impact of PGMs on Arms Transfers and International Stability', in Neuman and Harkavy, ibid.

[19] The quality of indiscriminateness of weapons of mass destruction or area weapons had acted as a taboo against their acquisition and use.

diffuse. According to one estimate, some 15 to 20 countries were capable of producing their own PGMs, and thus of marketing first generation PGMs.[20] With many first time suppliers entering the arms market, most analysts projected a vigorous trade in PGMs in the years ahead.[21] Another noticeable trend was that PGMs were increasingly becoming affordable as a result of reduced costs. The unit cost of PGMs being developed by major weapon producing states began to fall as the R&D outlays were spread over longer productions runs and also because economies of scale were achieved in production by adopting modular guidance and propulsion systems to a multiplicity of weapons.[22]

The spread of newer and more efficient SSMs was of concern because of their adverse effects on regional military balances. Having a capability to penetrate defences, SSMs in the hands of peaceful states or strategic allies such as Israel could help deter aggression but in the hands of other states or aggressors, these could facilitate conquest and international blackmail. Long-range missiles therefore came to be categorised as 'destabilising' weapons or weapons which upset the regional military balance. Among other 'destabilising' weapons, such as the attack aircraft, and other weapons designed for offensive purposes, SSM came to be singled out not only for their capability for assured penetration but also because they were the so-called threshold weapon systems, systems capable of delivering nuclear weapon payloads. Although the advent of PGMs had blurred the distinction between strategic and tactical, and between nuclear and non-nuclear, many U.S. analysts continued to classify long-range SSMs as 'nuclear adjunct' systems.[23]

In the mid-1970s, concerns over nuclear proliferation were awakened by the acquisition or suspected development of nuclear weapons by India, Israel and South Africa. Following the nuclear explosion conducted by India in 1974, efforts to strengthen

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[20] Anne Hessing Cahn and Joseph J. Kruzel and others, *Controlling Future Arms Trade* (New York, 1977), p. 91.
[21] Ibid. Also see: Neuman and Harkavy, n. 17, Geoffery Kemp, R. Pfaltzraff and U. Ra'anan, eds., *The Other Arms Race* (Mass; 1975).
[22] Some of the weapon systems whose unit cost was expected to fall are buzz bombs, glide bombs, tactical range cruise missiles, expendable attack RPVs and kamikaze drones with ranges of up to 300 kilometers, unguided rocket assisted artillery projectiles, cannon launched guided projectiles. Rosen, n. 17.
[23] Peter Dawkins for instance argued that unlike other threshold weapons such as bombers and attack aircraft that had broader utility in the non-nuclear context, ballistic missiles had limited utility in non-nuclear roles. Cahn and others, n. 20, p. 148.

the non-proliferation regime had already begun. In 1975, the 'London Guidelines' or the Nuclear Suppliers Group was established to control the *nuclear capabilities* of Third World countries. These guidelines did not constitute an international treaty, but rather an agreement between seven states (France, Canada, West Germany, Japan, the United Kingdom, the United States and the Soviet Union) to adopt a common policy for nuclear exports, especially enrichment and reprocessing technology.[24] In this context, the U.S. began to adopt policies designed to affect the *nuclear intentions* of emerging nuclear states. Although the policy implications of the relationship of conventional arms transfers to nuclear proliferation was not always clear, especially with the PGMs blurring the distinction between strategic and tactical and nuclear and conventional, the U.S. began using conventional arms transfers to achieve non-proliferation goals.[25] It is in this context that the U.S. policy makers became sensitive to the transfer of the threshold weapon systems, aircraft and missile. For instance, the U.S. provided South Korea with sophisticated military equipment, including F-5 fighter aircraft and production rights for American weapon systems in its efforts to dissuade Seoul from producing long-range missiles.[26] In a proposal to the Committee of the Conference on Disarmament in 1976, the U.S. representative singled out missiles and manned aircraft for conventional arms-control purposes and stressed that the U.S. opposed the transfer of systems which could cause large-scale damage to population centres. Asking other suppliers to support such restraints, the U.S. called on the recipient states "to forgo acquisition of destabilising systems not yet introduced into the area, particularly surface-to-surface missiles systems having a long range beyond any defensive need and aircraft having a long-range strike

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[24] The London Guidelines were additional to the so-called 'Zangger Suppliers Guidelines' established under the auspices of the IAEA to interpret Article III (2) of the NPT. These guidelines had established criteria for evaluating exports of key components, equipment and materials use in the nuclear fuel cycle which would 'trigger' nuclear safeguards. These guidelines did not specifically cover the export of key nuclear technologies like enrichment and reprocessing components, neither did they require IAEA full-scope safeguards as a condition of supply.

[25] For instance, under a provision of the 1976 Arms Export Control Act, the U.S. military and economic aid was formally linked to constraining the use of nuclear technology by the recipient states.

[26] Janne E Nolan, 'Ballistic Missile Proliferation in the Third World' *Arms Control Today*, November 1989, p. 11.

role".[27]

It is significant to note that the concern over the proliferation of high-technology conventional weapons was not limited to the United States. The Soviet Union shared the American concern over non-proliferation and international trade in sophisticated weapon systems. In fact, the earliest agreements between the two were in the nuclear field, as is evident from the Partial Test Ban Treaty, Nuclear Non-Proliferation Treaty, the Strategic Arms Limitation Talks (SALT) accords, the Threshold Test Ban Treaty and collaboration in nuclear suppliers conference. In the mid-1970s, the Soviet Union evinced interest in "the problems of international arms trade" and participated in the Conventional Arms Transfer (CAT) Talks in December 1977 to decide on the general principles of mutual restraint of conventional weapons. At these talks, there emerged a consensus on prohibiting the export of long-range SSMs, naval mines and arms of particular use to terrorists.[28] Apart from the nuclear proliferation concerns which it shared with the West, the Soviet concern over ballistic missile proliferation was awakened by the activities of a private firm, Orbital Transport und Raketen Aktiengesellschaft (Otrag), formed by a group of West German engineers and technicians in 1976 to develop cheap space launchers at a test site in Zaire. The Soviet Union came to regard Otrag's activities as a NATO ploy to equip West Germany with long-range ballistic and cruise missiles.[29]

Thus, the conventional arms limitation efforts, on the one hand, and nuclear non-proliferation concerns, on the other, combined to create an intellectual and psychological environment against acquisition of long-range missiles by Third World countries. As a general problem of dealing with the issue of the transfer of military technology to the Third World, several proposals ranging from dividing the regional markets among different arms producers,[30] the establishment of a conventional arms supplier cartel to

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[27] Statement by ACDA Director Ikle to the Conference of the Committee on Disarmament: Arms Transfers, Nuclear Cooperation, and Non-proliferation, July 29, 1976. Cited in Martin Navias, *Ballistic Missile Proliferation in the Third World*, Adelphi Papers 252 (London, 1990), p. 49.

[28] The year long CAT, however, ended in failure, when the United States after persuading the Soviet Union of the necessity of discussing regions, did not agree to the Soviet proposal to discuss Middle East and Far East regions. Andrew J. Pierre, *The Global Politic of Arms Sales* (New Jersey, 1982), pp. 286-7.

[29] The Soviet Union denounced Otrag as 'spear in the heart of Africa' intended for use against 'progressive countries' *Comsat Digest*, 23 August 1978.

[30] Andrew J. Pierre, n. 28.

the establishment of a supplier code for arms exports,[31] came to be debated. These proposals in general centred round producer restraints because of the belief that supply is more susceptible to regulation than demand. However, with arms transfers continuing to serve important and often divergent strategic, political and economic purposes of the major powers, multilateral efforts failed to take off. Moreover, the advent of the PGMs complicated the debate on the arms transfer restraints. No consensus could be reached on the nature of the new weapons systems and their ultimate military impact. Some believed that these new weapons would favour the defence over the offence and would improve the prospects of deterrence.[32] Others argued that the claims made on behalf of the new weapons were greatly exaggerated and that PGMs could be used effectively by both sides, and therefore might diminish the chances of deterrence.[33] Thus, the belief that long-range SSMs are primarily designed and most likely to be used as offensive tactical weapons pointed to the need for strict controls of their transfer. But given that these systems can also be used defensively, or to deter aggression meant that strictly enforced controls on their transfer were not appropriate. From the nuclear perspective, the impact of conventional strategic weapons (SSMs and ASMs equipped with fuel air explosives and advanced point munitions) on nuclear behaviour of states was not clear. Most policy analysts concluded that there was merit in banning trade in nuclear-capable ballistic missiles and support systems, but with the emergence of dual-capable long-range missiles, a suppliers group arrangement, akin to the London Group or the Nuclear Suppliers Group, not only appeared politically not feasible, but also undesirable. Withholding them could stimulate indigenous production, heighten the general sense of discrimination felt acutely in the Third World and could increase the incentives to go nuclear.

Nevertheless, a tacit agreement between the Super Powers emerged on controlling the international transfer of SSMs. Although the Soviet Union equipped Egypt with Scud missiles during the 1973 war, it did not supplement them with newer, more sophisticated

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[31] Cahn et al, n. 20.
[32] James Digby, *Precision Guided Weapons*, Adelphi Paper 118 (London, 1975). Also, Kenneth Hunt, 'New Technology and the European Theatre' in Kemp and others, n. 21, p109-23.
[33] Richard Burt, *New Weapons Technologies: Debate and Directions*, Adelphi Paper 126 (London, 1976), Uri Ra anan, 'The New Technologies and the Middle East: Lessons of the Yom Kippur War and Anticipated Developments', in Kemp and others, n.21.

systems. The United States in turn, resisted repeated appeals by Israel during and after the 1973 war for Pershing missile systems.[34] At the CAT talks, as we noted earlier, both the Super Powers agreed to prohibit trade in nuclear capable long-range SSMs. However, before a formal agreement could be concluded the talks broke down. The deterioration of East-West relations in the late 1970s, especially after the Soviet invasion of Afghanistan in 1979, foreclosed the revival of CAT talks.

By the end of the 1970s, the need for controlling the transfer of long-range SSMs, both as conventional weapon systems and as nuclear delivery systems, had taken strong roots in the U.S.. The search for effective means for regulating arms transfers to the Third World, national and multinational, had begun. It was at this stage that two developments in the civilian space sector- the test launch of a rocket from Libya in March 1980 and the successful launch of India's SLV-3 vehicle in June 1980- shifted the focus on the diffusion of missile development capabilities in the Third World. The commercialisation of space technology that had gathered momentum around that time fuelled concerns over the diffusion of missile technologies which ultimately led to the establishment of a supplier cartel, the Missile Technology Control Regime.

The 1980s

The commercialisation of space technology combined with the growing participation of private firms in space launcher activities, particularly in the United States, played an important role in shifting the focus on the developing threat from indigenous missile development programmes in the Third World. With space technology and services becoming a proven necessity, commercialisation of space technologies gathered momentum in the late 1970s. With some space enthusiasts projecting abundant commercial uses of space, including full-scale manufacturing operations in space for drugs and other materials in the near future, many private firms became interested in owning and operating space launch services.[35] Otrag, a German firm set up in 1976 was perhaps the first private venture that sought to develop cheap launch vehicles for orbiting satellites

[34] See *Nuclear Threat in the Middle East* (Washington D.C., 1975), p.31.

[35] A study conducted by McDonnell-Douglas Corporation in 1977 on future commercialisation of space, predicted full-scale manufacturing operations in space by 1984. McDonnell-Douglas Corporation, *Feasibility of Commercial Space Manufacturing* (St. Louis, 1977).

on commercial basis. Otrag operated a test facility in Zaire but following opposition from the Soviet Union, shifted the facility to Libya, a country relatively immune to political pressures. But U.S. pressure forced Otrag to leave Libya to begin operations in Sweden. The controversy surrounding the operation of Otrag's test facilities in the Third World were mainly generated by its possible contribution to missile development capabilities in the Third World, although economic and commercial considerations were not entirely absent.[36]

In the United States itself, many private firms began to evince interest in entering the growing market for satellite launch services in the late 1970s. Several government contractors began vying to privatise launch systems previously operated by NASA and the U.S. Air Force. Major government contractors such as the General Dynamics, Martin Marietta and McDonnell-Douglas either sought to establish their own launch services or offer their rockets-Atlas-Centaur, the Titan and Delta series of rockets respectively-for private launchers. In addition to these established players, several new firms made a bid to develop new launch vehicles of their own design. Some of these were based on older, proven subsystems and components.[37] By the mid-1980s, some eleven private launch ventures were active in the United States.[38] The U.S. government played an important role in strengthening the thrust towards the privatisation and in 1984 it established a new Office of Commercial Space Transportation to aid entrepreneurs to develop private space launch capabilities.

With the market for space launch technology evolving into an orthodox market with a multiplicity of buyers and sellers, instead of being controlled by government agencies, NASA and the U.S. Air Force, there were growing concerns over the potential diffusion of missile/space technology. To many observers, the entry of private sector into space

[36] Otrag's offer to launch satellites at half the rates of the U.S. Space Shuttle posed a threat to the latter, that was being developed as the future launch vehicle for commercial and defence purposes. While the cost of one flight for the reusable Shuttle has gone up to more than $ 30 million from the original $ 10.5 million, Otrag offered to launch two tonnes into the GSO for about & 15 million. *New Scientist,* 8 June 1978.

[37] In 1982, the most advanced of these firms, the Space Services (based in Houston) succeeded in developing and testing its launcher, the Conestoga in a short span of two years.

[38] Edward Ridley Finch Jr. and Amanda Lee Moore, *Astrobusiness: A Guide to Commerce and Law of Outer Space* (New York, 1985), pp. 30-34.

launch services signalled unrestricted transfer of space technology. Like the French Aerospace firm, Marcil Dassault (then privately owned) that had developed the Jericho missile for Israel in the late 1960s, the emerging private firms could transfer sensitive technology and equipment to Third World countries.[39] In fact, according to a U.S. Arms Control and Disarmament Agency (ACDA) study in the early 1980s, several countries in the conflict prone regions of the Third World such as Libya, Pakistan, Saudi Arabia and Syria had already initiated missile programmes utilising the services and technologies of private industrial firms.[40]

Concern over the diffusion of missile relevant technologies were heightened by the perceived weakening of restraints on nuclear proliferation.[41] The potential spread of weapons of mass destruction-chemical, biological and nuclear- emerged as a major preoccupation of Western policy analysts in the early 1980s. While the technical obstacles to nuclear proliferation are greater than those of chemical and biological (CB) weapons,[42] nuclear proliferation trends were more visible than those of CB weapons. To the non-proliferation analysts, nuclear proliferation restraints, by some indications, were eroding in South Asia and Middle East. In both the regions, the belief of weaker states (e.g., Pakistan and Iraq) that the dominant regional powers (India and Israel) have already acquired nuclear capabilities, seemed to have become a driving factor.[43] The technical

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[39] Milton Leitenberg, 'Satellite Launchers-and Potential Ballistic Missiles-in the Commercial Market' *Current Research on Peace and Violence*, (2), 1981, pp. 114-28; Judith Miller, 'U.S. Uneasy Over Military Potential of Commercially Produced Rockets', *New York Times*, 12 September 1981.

[40] An MIT project on behalf of the U.S. Arms Control and Disarmament Agency suggested that some private companies have already shown willingness to develop IRBM programs in these countries. A company known as Intereac has been working with Pakistan towards the development of IRBMs and in 1979, Otrag signed an agreement with Intereac involving this programme. Gerald M Steinberg, 'Two Missiles in Every Garage', *Bulletin of Atomic Scientist*, October 1983, pp. 43-48.

[41] See for instance Rodney W. Jones, 'SNF Delivery Systems' in Rodney W. Jones, ed., *Small Nuclear Forces and U.S. Security Policy: Threats and Potential Conflicts in the Middle East and South Asia* (Lexington, 1984), Steinberg, ibid., and Aaron Karp, 'Ballistic Missiles in the Third World', *International Security*, vol. 9 (3), 1984/85, pp. 166-95.

[42] Concern over CB weapons were raised by the evidence of their use by the Soviet Union in Afghanistan, by Vietnam in Laos and Kampuchea, and by Iraq against Iraq.

[43] See Rodney W. Jones and Steven A. Hildreth, *Modern Weapons and Third World Powers* (Boulder, 1984) which summarises the proceedings of the conference on 'Modern weapons and Regional Powers' organised by the Center for Strategic and International Studies (Georgetown University) in 1983., p. 10. This assessment is however incorrect, at least in the case of South Asia. There is evidence to suggest that the Pakistani nuclear ambitions are driven by the need to offset India's overwhelming conventional force superiority.

lead time for actual proliferation was seen as being a few years in the case of South Asia and a little longer in case of the Middle East. In this context, non-proliferation community in the U.S. became concerned that almost all the countries which had ballistic missile capability (India) or were interested in acquiring it (Pakistan, South Africa, Iraq, Taiwan, South Korea and Israel) were "precisely those which have detonated or were believed capable of testing nuclear weapons".[44]

The importance and urgency that nuclear proliferation issue acquired in the early 1980s is very well reflected in the increasing focus on the strategic and military challenges that it posed to Western interests. This was in sharp contrast to the earlier proliferation concern that was mainly centred around the challenge that it posed to the non-proliferation regime. Proliferation in the context of prevailing regional rivalries in the Third World was seen as posing new threats to the West. In the first instance, local nuclear rivalries threatened Western economic interests. Like the diffusion of advanced conventional weaponry, nuclear proliferation enhanced the prospects for regional conflicts,[45] threatening Western access to Third World that was important 'for trade, investments, resources, transit and other similar benefits'.[46] At the strategic level, nuclear proliferation weakened the Western option for military intervention in the Third World by raising the risks. In addition, regional nuclear rivalries and conflicts posed the risk of escalating into Super Power nuclear exchange. Proliferation, especially in the Middle East posed direct threats to NATO members in the southern flank. Although these threats would be more notable for their political content than fighting potential, they could tempt these states to develop nuclear counters of their own, undermining in the process the sorts of alliance relations and capabilities on which East-West stability had rested in the past. Thus, proliferation of nuclear weapons that was expected to take place in the next couple of decades was more than a challenge to the non-proliferation regime, it was seen as posing a specific threat to the Western interests, jeopardising its economic health, defence

[44] ibid. Also see Aaron Karp, 'Ballistic Missiles in ..., n. 41.

[45] Western analysts and policy makers discount the possibility of nuclear balances in the Third World and believe that such balances are unlikely to be stable because of the political and technical weaknesses in the military command and control systems of the Third World states. See for instance, Jones and Hildreth, n. 43.

[46] Ibid., p. 12.

capacity and alliance commitments.[47]

The Western response, under the initiative of the Unite States was two pronged: controls on the international trade in ballistic missiles and relevant equipment, materials and technologies, on the one hand, and developing defences against ballistic missiles in the form of anti-ballistic missile systems, on the other. While these are two distinct approaches, one aimed at limiting Third World missile capabilities, and the other aimed at developing counter weapon systems, they are closely related. Technology controls are a subordinate part of force planning aimed at slowing or delaying the introduction of ballistic missiles by a potential adversary until after theatre and local area ballistic missile defences have been developed and deployed. However, the linkage between the two was made explicit and spelt out only in 1993 when the U.S. announced its counter-proliferation strategy.[48] It is for this reason that at the policy level, both the responses came to reinforce each other. The limitation of export controls became a major justification for the development of missile defences in the post-cold war era, while the delays in the development of defences against missiles became a justification for expansion and tightening of export controls. Significantly, both the responses, technology controls and development of defensive weapon systems, had their immediate origin in the East-West conflict that had revived in the late 1970s.

2. EXPORT CONTROLS

Since the beginning of the Cold War, the United States had used export controls as weapons of national security and foreign policy. These were mostly directed at the Soviet Union and its communist allies. In the late 1940s, the U.S. enlisted the support of other members of the North Atlantic Treaty Organisation (NATO) for a multilateral effort

[47] Jones, ed., *Small Nuclear Forces*...n. 41. See particularly the essays, Brad Roberts, 'NATO and SNF Proliferation: A Speculative Inquiry' and Stephen M. Meyer, 'Small Nuclear Forces and U.S. Military Operations in the Theater'.

[48] The U.S. National Security Council has defined counter-proliferation as "the activities of the Department of Defence across the full range of U.S. efforts to combat proliferation, including diplomacy, arms control, export controls, and intelligence collection and analysis, with particular responsibility for assuring that U.S. forces and interests can be protected should they confront an adversary armed with weapons of mass destruction".

to prevent the transfer of critical technology to the Soviet Union. The Co-ordination Committee on Multilateral Export Controls (COCOM) that was established in 1949 aimed at checking trade in items which could strengthen the Soviet economic, technological and military war-making capacity. In the late 1960s, with the emergence of a rough strategic parity and détente between the Super Powers, there was a relaxation of controls, both national and those imposed through the COCOM. As economic relations between the East and West multiplied, the embargo list was narrowed to include items of purely military significance. In the latter half of the 1970s, the U.S. became convinced that the intensified East-West economic interaction had befitted the Soviet Union more than the U.S. or the West and that trade had enabled Soviet Union to continue a substantial military build up, maintain a minimally acceptable rate of economic growth, and secure critical technologies required in certain key areas. The 1976 report of the Defence Science Board, known as the Bucy Report called for a shift in focus of controls away from end products to arrays of know-how, keystone equipment, and turnkey manufacturing facilities. The report thus introduced the concept of 'critical technologies' to be identified by the DoD, giving to the military for the first time a direct role in the control over exports. The report also suggested that the U.S. allies should be 'prohibited from receiving further strategic know-how' if they violated the U.S. restrictions on re-export of U.S. technology to the Soviet bloc, thus introducing the principle of the extraterritorial application of U.S. law. The Carter Administration introduced two laws accepting the recommendations of the Bucy Report.[49]

These rules were not applied strictly and did not have a major impact on international technology flows until the Reagan presidency. In the climate of a new 'cold war', the conservative U.S. government quickly and with thoroughness reversed the policy direction on technology flows to restrict the Soviet access to anything, including advanced technology, that would help it achieve its allegedly imperial ambitions (i.e., the Reagan

[49] According to the revisions of the Export Administration Act in 1979, the Commodity Control List (CCL, a list of technologies that were administered by the U.S. Department of Commerce) was complemented by the Militarily Critical Technologies List (MCTL), a 700-page document drawn up by the Department of Defence. More comprehensive than the CCL, the MCTL defined the militarily critical technologies in a broad manner to include an array of know-how, keystone equipment, and turnkey manufacturing facilities (including technical data)

notion of an "evil empire"). A variety of actions were taken, mostly by the executive order, to expand the range of technologies and end products subject to control, to bolster the role of DoD in export licensing decisions and to restrict the flow of technical information and, in some cases, people. In addition to its tightening and increased use of foreign policy and national security controls, the administration also moved to reinvigorate COCOM by pouring substantial human and financial resources into modernising COCOM headquarters in Paris and by using its political resources to pressure the other COCOM countries into abiding more closely by the Industrial List of controlled items.

The technology transfer issue gained prominence because of the fragile East-West military balance and the development of new weapons based on the so-called 'emerging technologies' (advanced sensors, microprocessor electronics etc.). Not that the Soviet Union lagged far behind in technology, but the overall sophistication of the emerging technologies made even marginal improvements they offered to both production capabilities and military systems, important. With the United States beginning to explore the use of exotic technologies for space-based defence weapon systems, export controls acquired even more importance. NASA tightened its restrictions on the transfer of data in the fields of aeronautics and space technology.[50] And the DoD was empowered to withhold even unclassified data that could be subject to export controls.

The DoD and intelligence officials cited evidences of the leakage of advanced technologies to the Soviet Union and Soviet application of Western technology in several of its weapons projects to support such extensive controls. In 1984 one U.S. Defence official informed that "SS-20 and, indeed, most Soviet missile systems contain Western technology, along with aircraft, communications systems, and surface-to-air missiles".[51] In a similar vein, the 1985 update of a DoD document, indicated that the Soviet Union had adapted numerous Western technologies in several areas, including in the area of strategic missiles, space and anti-satellite weapons.[52]

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[50] 'NASA Issues Technology Transfer Procedures' *Aerospace America*, April 1985.

[51] Quoted in *Strategic Survey 1983-84*, 'Technology Transfer: A Balance of Interests' (London, 1984)., p. 18.

[52] *Soviet Acquisition of Militarily Significant Western Technology: An Update*, September 1985. This document updated the 1982 version that was based on the so-called "Farewell affair", which was the code name for a Soviet double agent who provided the French intelligence service with the actual Soviet shopping list for Western technology from 1979-1981, including targets and rouble allocations for each

Western Europe, whose economies had become dependent on trade with the East during the détente years, resisted the U.S. efforts to expand and tighten export controls. Differences between the two came into open in 1982 over the construction of the 'Siberian pipeline', a civilian project whose only strategic aspect was that it allowed Europe to buy natural gas from the Soviet Union. The U.S. government not only forbade U.S. firms to supply parts for the project but it extended the prohibition to four European companies that had already signed contracts with the U.S.S.R. for the delivery of electric engines that incorporated U.S. technology. The Reagan administration invoked the extra-territorial authority of U.S. law over the resale of U.S. technology, and when European firms refused to obey its orders, it banned them from further access to U.S. technology.

The U.S.-Europe conflict over technology transfer issues lasted until the mid-1980s, when the U.S. coopted its allies with the Strategic Defence Initiative (SDI) programme, a programme that aimed to research, develop and test a new generation of high-technology weapons to be deployed in outer space and on earth. When the United States formally invited NATO members and other allies to participate in the SDI in early 1985, it stimulated the interest of many industrial firms and research institutions in Europe. Many governments, lured by the promise of technology joined it. Other governments that were highly critical of the SDI, soon found it 'virtually impossible' to stop their companies from participating either directly or indirectly through joint ventures with the American companies. By mid-1987, Great Britain (1985), West Germany (1986), Israel (1986), Italy (1986) and Japan (1987) signed accords with the United States which gave their industrial firms and research institutions a role in the SDI. France, Canada, Australia, Denmark, Greece, the Netherlands and Norway, refused to participate in the SDI on a government-to-government basis, but authorised their private firms and universities to undertake SDI research on contract.[53] While the details of the agreements were kept confidential, they ensured that the allied participation in SDI research was "consistent with

targeted item.

[53] For a detailed discussion on the evolution of allied participation in Strategic Defence and Anti-Tactical Ballistic Missile Defences, see *The 1990 Report to the Congress on the SDI*, SDIO,(Washington. D.C, May 1990), pp. B1-B6. For a comprehensive and technical study on West European defence against ballistic missiles, see Jurgen Altmann, *SDI for Europe: Technical Aspects of ATBMDs*, PRIF Research Report: Bochum (3), 1988. See also 'SDI', *Report to the Congress on the Strategic Defence Initiative*, (Washington DC:, 1987).

U.S. laws, security interests in protecting sensitive technology".[54]

It is in the context of the progressive tightening of national export controls on space and other high-technology items by the participating countries of the SDI, that they reached an agreement to restrict the export of space technologies necessary for the production of nuclear-capable missiles. Technology controls, which were essentially part of the East-West conflict, assumed a North-South dimension. In the early 1980s, when there were still differences between Europe and the United States on technology transfer issues, European nations seemed to be taking an independent line in international affairs. At the Versailles summit of the G-7 in 1982, the French President, Mitterand proposed the launching of a 'concerted programme' of international research and development in fields of advanced technology, specifically mentioning space and satellite technologies and that the developing countries should participate in it. Proposals for co-operative action on dual-purpose technologies also began to take shape among the neutral countries in Europe.[55] However, with East-West conflict remaining a dominant preoccupation and yielding to the U.S. pressures and temptations, they joined the U.S. in strengthening export controls and extending them to Third World countries.

The U.S. efforts to establish multilateral controls on the international transfer of missile/space technology to the Third World countries began in 1982 when the National Security Decision Directive (NSDD-70) called for investigation of ways to control ballistic missile proliferation in the Third World. The U.S. Administration initiated a series of secret negotiations with the G-7 countries (Canada, France, the Federal Republic of Germany, Italy, Japan, the United Kingdom) to evolve common guidelines for the transfer of missile/space technologies. At these meetings, the U.S. officials presented a proposal for the establishment of a missile technology supplier cartel as the next logical step in efforts to control the proliferation of nuclear weapons. In 1985, an agreement was reached among the G-7 regarding an international mechanism for controlling the spread of missiles

[54] James Abrahamsons, *The Strategic Defence Initiative*, Statement before the Subcommittee of the House of Representatives on Economic Stabilisation. (Washington, D.C.: 10 December 1985), p.16. The German tabloid, the Cologne Express which published the text of the secret agreements on 11 April 1986 made it clear that it curtailed West German trade with the Eastern bloc involving sensitive technologies.
[55] Anthony L. Dolman, 'Disarmament, Development, Dual-Purpose Technologies and the Like-minded Countries', *Conflict and Cooperation*, XIX, 1984, pp. 1-13.

and related technologies. However, it was in April 1987 that the guidelines "to limit the risks of nuclear proliferation by controlling the transfers that could make a contribution to nuclear weapons delivery systems other than manned aircraft" were formally announced. These guidelines, properly called the 'Guidelines for Sensitive Missile-Relevant Transfers', have come to be widely referred to as the Missile Technology Control Regime or the MTCR.

The Missile Technology Control Regime

The MTCR was launched as an adjunct to the nuclear non-proliferation policy. The formal announcement of the regime in April 1987 depicted it as the next phase in the progression of policy moves that had helped establish the International Atomic Energy Agency in the 1950s, the Non-Proliferation Treaty in the late 1960s and the nuclear suppliers cartel, the London Suppliers Group (or the Nuclear Suppliers Group) formed in the mid-1970s.

Neither a treaty nor an international agreement in the strict sense of the term, the MTCR is essentially an attempt to establish identical sets of national export policies aimed at controlling the diffusion of missile hardware and technologies. The regime is administered on a decentralised basis, subject to no international body; each of the adhering governments is responsible for its own actions.

The regime is primarily concerned with nuclear capable missiles which are defined as vehicles capable of the unmanned delivery of a 500 kilogram payload to a distance of 300 kilometers. The parameters correspond to the weight of a relatively unsophisticated nuclear weapon, to the strategic distances in the most compact theatres where nuclear armed missiles might be used. The 500 kilogram parameter determines the system of concern regardless of the type of payload-nuclear, chemical, advanced conventional, conventional or even scientific. The framers of the guidelines believed that payloads can be changed once a missile capability exists.

The regime defines in technical detail the items to be controlled and lays down ground rules for dealing with export applications for those items. All the items that are to be controlled are listed in a 12 page "Equipment and Technology Annex" to the Guidelines. The Guidelines and the "Equipment and Technology Annex" of the MTCR are reproduced in the Appendix to this study. The controlled items are grouped into two categories:

Category I covers items of highest sensitivity and include complete nuclear capable ballistic missile systems, space launch vehicles and sounding rockets or their subsystems, as well as production facilities and the technology to produce these systems. The term 'technology' is defined in a broad sense to mean specific information which is required for the development, production or use of a product. Category II consists of items of less critical nature, and cover a large number of dual-use space equipment, such as propulsion components, structural materials, launch support equipment and facilities, computers and converters as well as the technology necessary for the production and operation of this equipment. The items that fall under the 'Equipment and Technology Annex' were upgraded and listed in great detail in January 1993.

The export of facilities for the production of items in Category I are not to be authorised at all. The export of all other items in Category I are to be authorised only on rare occasions and only when certain well defined conditions are met. The supplier government is responsible, in the words of the Guidelines, for "taking all steps necessary to ensure that the item is put only to its stated end use". There is, as the Guidelines explicitly underline, a strong presumption to deny the export of these items. The presumption of denial is an extraordinary provision and has no precedent in the international nuclear non-proliferation regime except with respect to complete nuclear explosive devices. The export of items in Category II are less severely restricted. However, even for these items, export licenses are to be granted only after a careful evaluation of all relevant factors, among which the following are mentioned:

*nuclear proliferation concerns;

*capabilities and objectives of the missile and space programs of the recipient state;

*the significance of the transfer in terms of the potential development of nuclear weapon delivery systems other than manned aircraft;

*the assessment of the end-use of the transfers, including the potential for retransfer; and

*the applicability of relevant multilateral agreements.

The decision to grant or deny a license for the export of Category I and II equipment and technology is the sole and sovereign judgement of the government of the supplier country. However, in order to further the effective implementation of the Guidelines, the participating governments are expected to exchange relevant information on critical export applications.

An important feature of the regime is that it is not directed at all international transfer of missile hardware and technologies. As one official involved in the discussions leading to the establishment of the MTCR explains, 'the regime is aimed not at particular nations, but at specific missile and rocket projects that exceed the defined parameters. It is therefore essential to distinguish between projects with which supplier nations may co-operate and projects of concern'.[56] In other words, there are no restrictions on the transfer of missile hardware and technologies among the member countries as well as between the member countries and other nations as long as those transfers do not contribute to 'projects of concern'. It is under this provision that the MTCR member countries participate in collaborative defence projects such as the Strategic Defence Initiative and ATBMs and engage in the transfer of hardware and technologies for ATBMs.

Since it was formally announced in 1987, the regime has undergone some important changes partly as a result of the operational experience of the regime as well as changes that have occurred in the international environment. Some of these changes are related to the principle of extra territorial jurisdiction of the leader of the regime, reduction in the threshold of the missile capabilities to include all SSMs irrespective of the payload capabilities and more stringent interpretation of the norms. These are discussed in the next chapter which will focus on the impact of the MTCR on India's defence and development programmes.

3. MILITARY OPTIONS

Technology controls are but one dimension of the Western efforts to deal with the emerging problem of Third World missiles. Another dimension of these efforts was the search for a 'technical fix' in the form of anti-missile systems. Development of defences against ballistic missiles had re-emerged as an official objective of the United States in

[56] Richard H. Speier, 'The Missile Technology Control Regime', in Trevor Findlay, ed., *Chemical Weapons and Missile Proliferation With Implications for the Asia/Pacific Region* (Boulder, 1991), p. 117.

March 1983 when the U.S. President, Ronald Reagan, made an appeal to the U.S. scientific community to research, develop and test a new generation of high-technology weapons that could "intercept and destroy strategic ballistic missiles before they reached our own soil or that of our allies".[57] The SDI or the Star Wars programme, that was launched then differed from the traditional ballistic missile defences that were limited to attacking the enemy missile in the last minute or two of its flight. The SDI envisaged repeated attacks on an enemy missile throughout it trajectory by deploying space-based and earth-based defence systems. While the President's vision was for developing an ultimate anti-weapon, a weapon to end all weapons, the goals and research priorities of the SDI have underwent several changes. Even before the SDI research was formally organised under the SDI Organisation (SDIO) in 1984, it was apparent that the goal of developing leak-proof defences against strategic ballistic missiles was too ambitious, or unlikely to be ever realised. In one of the reports that laid the foundation for the SDI programme, a panel chaired by Fred Hoffman in 1983 advocated "intermediate options" that could be deployed earlier than space-based defences. These ground-based defences would address "the pressing military need to protect allied forces as well as our own...from either non-nuclear or nuclear attack".[58] The focus on intermediate options led to high priority being given to the development of anti-tactical ballistic missiles (ATBMs) against Soviet short- and intermediate-range ballistic missiles.

While capability to deal with accidental launches and attacks by 'third nations' or terrorist groups had been a strong selling point of the SDI,[59] the North-South dimension of SDI became operational with the development of the ATBMs[60]. The first indication

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[57] President Reagan's speech on 'Defence Spending and Defence Technology' on 23 March 1983. Reprinted in Robert M. Lawrence, *Strategic Defence Initiative: Bibliography and Research Guide* (Colorado, 1987), pp. 295-8.

[58] An unclassified version of the Hoffman panel's report was published as 'Ballistic Missile Defenses and U.S. Security', *Future Security Strategy Study* (Washington, DC, 1983), p. 3.

[59] Supporters of the SDI were highly critical of the security edifice built on deterrence. They drew attention to its inability to protect against accidental and other "small" nuclear attacks. Kenneth Alderman, Director of the U.S. Arms Control and Disarmament Agency, for instance, asked "Would we not all be better off if we did not have to accept that form of nuclear terror no matter how remote it might appear". Adelman, 'The Impact of Space on Arms Control', *Defense Science*, April/May 1985., p. 41-48.

[60] The North-South dimensions of the SDI, particularly the threat it posed to the independence and sovereignty of the Third World nations were first articulated by the Indian representative, Mujkund Dubey at the SIPRI conference on Space Weapons and International Security, Saltsjobaden, 5-7 July 1985.

of this came in 1986 when Israel became a participating country in SDI programme. While European leaders presented the case for their country's participation in the SDI programme by suggesting that research underway in the SDI could provide opportunities for European defence against Soviet missiles, Israel made it clear that it was interested in ATBMs for defence against increased deployments of SS-21 in Syria. Defences against Third World missiles thus emerged as an important element in the SDI. This dimension acquired prominence as the threat from Soviet missiles began to recede, first after the signing of the Intermediate Nuclear Forces (INF) treaty in December 1987 and later due to the break-up of the Soviet Union and the dissolution of the Warsaw Treaty Organisation (WTO). The developing threat from Third World missiles is being increasingly used as an argument for maintaining the SDI and its scaled down version, the Ballistic Missile Defence programme. Proponents of missile defence programmes in the United States[61] and Europe[62] argue that Third World missiles can pose a direct threat to their territories.

4. U.S. CONCERNS OVER INDIAN MISSILES

It was the Chinese progress in the nuclear field which drew the attention of the United States to a possible missile race between India and China. In early 1964, a few months prior to the Chinese nuclear explosion, the U.S. estimated that China would have nuclear missiles by the end of the decade. It was reasoned that India ultimately would be forced either to develop its own nuclear deterrent or to go under the nuclear umbrella of the U.S. or the Soviet Union.[63]

The demand for nuclear weapons that arose in India after the Chinese nuclear explosion in 1964, awakened U.S. concerns over nuclear proliferation. In early 1965, when India approached the United States for Scout rocket technology, the U.S. saw it as a step in the direction of acquiring ballistic missile capability. Denying the Scout rocket

An edited version of his address is printed as ' SDI from the Viewpoint of the Non-aligned Nations' in B. Jasani, ed., *Space Weapons and International Security* (Oxford, 1987).

[61] James T. Hackett, 'The Ballistic Missile Epidemic', *Global Affairs*, Winter 1990. "Monahan Examines the Future of SDI", *SDI Monitor*, 16 March 1990.

[62] The potential of North African missiles to threaten Western Europe was pointed out by a French study. 'U.S. Allies Concur on "Southern" Threat', *Military Space*, 12 March 1990.

[63] Cable, U.S. Ambassador in India, Chester Bowles to Secretary of State, Dean Rusk, 20 February 1964.

technology, the United States made a series of efforts to influence the pace and direction of the Indian space programme. It ceased all assistance to the Indian sounding rocket programme despite its being an international facility. Since then, Indo-U.S. co-operation in space became largely confined to space sciences, and in promoting satellite based communication systems in India.

In the mid-1970s, the Peaceful Nuclear Explosion conducted by India in 1974 and Pakistan's efforts to purchase a large plutonium extraction plant from France awakened the U.S. concerns over the proliferation of nuclear weapons in the sub-continent. Adopting a strategy of using conventional arms transfers to influence the nuclear intentions, the Ford Administration offered Pakistan 100 advanced A-7 fighters if it would abandon the nuclear deal with France.[64] While the linkages between conventional arms transfers and nuclear proliferation are complex, the very fact that an offer establishing such a linkage was made showed that the U.S. had become sensitive to the possible acquisition of threshold weapons by India and Pakistan. At the Committee of the Conference on Disarmament in 1976, the U.S. made an appeal to the arms recipient states "to forgo acquisition of destabilising systems not yet introduced in the area, particularly surface-to-surface missile systems having a long range beyond any defensive need and aircraft having a long-range strike role"[65].

Among the threshold weapon systems, it was the advanced aircraft rather than SSMs that attracted most attention in the 1970s. With the Soviet Union sharing its concern over the nuclear-capable missiles and India having no significant breakthrough in the development of a liquid-fuelled SSM, there appeared to be no cause for alarm over missile proliferation in South Asia. The focus was on the introduction of deep penetration strike aircraft in which both India and Pakistan evinced interest. The Carter Administration, implementing a broad policy of restricting sales of advanced conventional weaponry, withdrew the A-7 offer in early 1977. When in 1978 India began to consider the French Mirage, the Swedish Viggen and the Anglo-French Jaguar deep penetration strike aircraft to replace the aging Canberra and Hunter aircraft, the United States

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[64] Report of the Task Force on Non-Proliferation and South Asian Security, *Nuclear Weapons and South Asian Security*, Carnegie Endowment for International Peace, 1988.
[65] Statement by ACDA Director Ikle to the Conference of the Committee on Disarmament, n. 27.

expressed concern that it would 'introduce higher level of technology' in the region. India resented the U.S. efforts to dictate the level of aeronautical technology to be introduced in India and caused it to be known that it "(India) cannot possibly concede to the U.S. the right to decide what technology this country ought to have at a given time".[66]

Indo-U.S. differences over technology transfers in general and missile technology in particular gained prominence in the early 1980s. Following the success of the SLV-3 launch in mid-1980, the U.S. became increasingly concerned with India's growing technological capabilities and their security implications. Although a civilian venture, the satellite launch bestowed India with a capability to develop strategic delivery systems for nuclear weapons and employ sophisticated data processing and sensors for guidance and targeting of those weapons. With the evidence of Pakistan's determined bid to acquire nuclear and ballistic missiles becoming available at around this time, non-proliferation debate in the U.S. came to center around the growing availability of weapons development capabilities in South Asia. As a result, non-proliferation policies came to be designed not only to deal with the international transfer of ballistic missiles but also with trade and transfer of space/missile technologies.

In the early 1980s, partly in recognition of India's technological capabilities and potential and partly to weaken the perceived Soviet influence over India, the U.S. sought to establish close relationship with India. The U.S. became accommodative to Indian requests for sophisticated technology, subject however to export controls. The Reagan-Indira Gandhi Science and Technology Initiative of 1982 which led to the signing of the MOU on technology transfers in November 1984. The MOU introduced substantial changes in Indo-U.S. relations in the area of defence co-operation and sales of military and dual use equipment and technology, which seemed to mark the beginning of a new security relationship between the two countries. The MOU was followed by another significant agreement that set up 'mission area discussion' between the defence establishments of the United States and India "with the goal of increasing military co-

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[66] Statement issued by the Indian Embassy in Washington in response to the U.S. Ambassador, Robert Goshen's criticism of the Indian decision to acquire deep-penetration strike aircraft. Full text quoted in *The Hindu*, October 1978.

operation and sales of military equipment and technology".[67] In the next couple of years, defence delegations from both countries, led by their secretaries of defence, exchanged visits to explore specific areas of co-operation. [68]

The U.S. technology transfers to India under the MOU were impressive both in terms of volume and in terms of the nature of the items traded. Some of the items transferred included those that were almost never transferred to countries outside the COCOM group. In particular, the sales of Cray XMP-14 supercomputer for India's Meteorological Department, the advanced "Silicon-on Saffire" microprocessor chip for India's INSAT-2 satellite, and 16 General Electric F-404 engines to Hindustan Aeronautics for development of Light Combat Aircraft, constituted major leap forward in Indo-U.S. technological co-operation.

Liberal as the U.S. technology transfer to India may seem, it was a small sop in comparison to American military aid to Pakistan and even the growing Sino-American technological co-operation. Whereas in the case of Pakistan, assistance took the form of military end items, the U.S. agreement with China placed India's other traditional adversary on an extremely favourable footing for receiving high technology exports from the West and Japan.

Moreover, technology co-operation was not problem free. The U.S. concerns over the leakage of its technology to the Soviet Union on the one hand and diversion of its technology for nuclear or offensive weapons remained the main obstacles in Indo-U.S. technology co-operation. The U.S. imposed certain conditions and sought assurances from India on U.S. technologies which did not go well with India's objectives of technological autonomy and self-reliance. In fact, since the early 1960s, when India first sought to acquire American military assistance, the U.S. concern over the retransfer of U.S.

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[67] U.S. Secretary of Defence, Caspar W. Weinberger in a report to the 99 the Congress, 1986. Cited in Raju G.C. Thomas, 'U.S. Transfers of "Dual Use" Technologies to India', *Asian Survey*, vol. XXX, September 1990.

[68] Except for the brief period in the aftermath of the 1962 Sino-Indian war when some American light arms and ammunition were rushed to India and an Indo-U.S. joint air-naval exercise was conducted, there has been virtually no U.S. weapons transfer to India, or any other form of military co-operation between the two sides. This was in sharp contrast to the large scale transfer of American weapons to Pakistan in the 1950s under the SEATO and CENTO defense pacts, and then again in the 1980s, following the Soviet invasion of Afghanistan.

weapons, reflected in the demand for a General Security Military Information Agreement (GESOMIA), had prevented the forging of close defence ties between the two countries.[69] This continued to bog closer co-operation between the two countries in the 1980s. As we saw, in the climate of new cold war of the 1980s, the U.S. had expanded and tightened export controls directed at the Soviet Union and its communist allies citing evidence of technology haemorrhage from the U.S. to the U.S.S.R. via third countries.

Expressing concerns over the diversion of its technologies for the development of nuclear and offensive weapon systems, the U.S. remained unwilling to transfer military and dual-use technologies to India. With the exception of the sale of F-404 engines, no significant high-technology which might contribute to Indian weapons capability was transferred in the 1980s. The U.S. defence team that visited India in 1986 identified development of the Light Combat Aircraft (LCA), National Test Range and Anti-Armour capability in India with American technology but later retracted by linking security considerations with the transfer of 'sensitive' technology to India. By then, the U.S. became convinced that India was seriously committed to the development of a indigenous ballistic missile capability.[70] It approved the transfer of range instrumentation radar for the test site but only after down grading the system.[71]

In the latter half of the decade, India sought to alleviate the U.S. concerns over technology leakage and diversion. The public document released by the Ministry of External Affairs (MEA) in 1989 showed a streamlined procedure for issue of Import Certificates for Indian importers along with an undertaking not to export without due authorisation. It also has a system for issue of 'assurances' via the MEA, for a few particularly sensitive technologies.[72] In view of its technology protection performance

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[69] The U.S. Department of Defence demands a GESOMIA so that American weapons transferred to other countries do not leak to the U.S.S.R. or any other country considered to be hostile to the U.S.. India has not accepted GESOMIA to date as it conflicts with its policy of self-reliance in its defence production.

[70] The Indian government's efforts to establish the test range in the face of local opposition in 1986 was interpreted as a serious commitment to acquire ballistic missile capability. See Arthur F. Manfredi, Jr., Robert D. Shuey and others, *Proliferation of Ballistic Missiles in the Third World,* CRS Report to the Congress, 1987. Adapted and reprinted in James J. Frelk and Glen E. Tait, eds., *Defending Against Ballistic Missile Attacks, The Concept of Defensive Deterrence* (Washington D.C., 1990).

[71] James A. Russel, 'U.S. firms to Aid Indian Jet Efforts', *Defence Week*, May 4, 1987., p. 7.

[72] India, Ministry of External Affairs, *Implementing Procedures under the Indo-U.S. MOU* (New Delhi, 1989).

and self-imposed restraint on the export of indigenously developed sensitive technologies (nuclear, space and military) India called for liberalisation of technology restrictions and recognition on par with countries like Singapore, Hong Kong, South Korea, Sweden and Switzerland that have been conferred a set of benefits under the Third Country Co-operation Initiative of 1990.[73] No progress could be made in this direction as India was identified as a country of proliferation concern in 1989, after it test fired the Agni missile.

[73] These benefits have been provided under the revised Export Administration Act of 1988, Section 5(K) of which says that "in case of ...agreements on export restrictions comparable in practice to those maintained by the Co-ordination Committee (COCOM), the Secretary (of State) shall treat exports to countries party to such agreements in the same manner as exports to members of the Co-ordination Committee."

CHAPTER SIX

MTCR AND INDIA'S SPACE PROGRAMME

Directed against the proliferation of delivery systems for relatively unsophisticated military forces, the MTCR is concerned with the levels of technology lower than those in other arms control areas. Most of the technologies that are controlled by the regime are thirty or more years old and although most of these 'bronze medal technologies' have had their military origins, they have found diverse civilian applications. Today the modern industrial world is dependent on precision machining, high strength and high temperature alloys, sophisticated avionics, and other technologies that collectively constitute "space launch/missile technologies". Restrictions on such dual-use technology has therefore had a severe impact on development programmes in the Third World. The adverse impact of the MTCR has been further reinforced by the ad hoc character of the regime. Being administered on a decentralised basis by the participating governments and subject to no international body, the regime has flexibility for selective application technology controls. As the self-appointed leader of the regime, the U.S. has, in fact, used MTCR restrictions to realise diverse foreign policy, national security and economic objectives. India became a country of proliferation concern when it tested its 'experimental' intermediate-range Agni missile in 1989. With one of the targeted programmes of the regime, the Argentinean-led Condor II ballistic missile programme project collapsing at around this time, India, the only country other than Israel that had a broad-based missile programme, became the prime target of the regime.[1] Both, because of the dual-use character of the technologies controlled by the regime as well as the implementation strategy adopted by the regime, the MTCR impacted not only on its military missile programmes but also on its civilian programmes in diverse areas. This chapter examines the impact of the MTCR controls on civilian space projects that are an integral part of the country's socio-economic development programme. Before doing so, it will be useful to briefly examine some of

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[1] Despite the development and deployment of Jericho I and Jericho II missiles, Israel never became a target of the regime because of its close strategic ties with the leader of the regime, the United States. On the other hand, the U.S. aided Israel in the design and production of anti-tactical ballistic missile system, the Arrow.

the features and important developments in the evolution of the regime since it was unveiled in 1987.

1. THE MTCR: EVOLUTION AND FEATURES

As we saw in the previous chapter, the MTCR is a set of identical policies announced by the seven governments to be implemented in parallel. However, the United States plays a key role in co-ordinating the regime and in collecting and assessing intelligence on the subject. It has been in the forefront in strengthening the regime and has made all efforts to correct and update the list of technologies that are to be controlled and in roping in more countries into the MTCR framework. In the early years of the regime, the U.S. worked 'through a combination of export controls, demarches to foreign governments and bilateral and multilateral discussions with our MTCR partners'.[2] In 1990, it enacted laws having extra-territorial jurisdiction to strengthen the enforcement of the regime guidelines among the participating countries. The National Defence Authorisation Act of 5 November 1990 authorised the U.S. executive to impose sanctions world-wide on any U.S. or foreign person, firm or governmental entity which facilitates trade in MTCR controlled equipment and technology with person, firm or entity in the non-MTCR country. The full text of this Act is reproduced in the Appendix to this study.

An important development in the evolution of the MTCR is the broadening of the scope of the regime to include conventionally armed short-range ballistic and other categories of guided missiles. In 1991, the MTCR countries agreed to extend the focus of the regime from 'nuclear-weapons delivery systems' to vehicles capable of delivering any kind of weapon of mass destruction (i.e., nuclear, chemical and biological weapons).[3] This was formalised at the plenary meeting of the MTCR in Oslo, Norway in mid- 1992. The revised guidelines which came into force in January 1993 removed the original range and weight parameter of 300 km and 500 kilograms. They called for particular restraint and the presumption to deny transfers of *any missile* (whether or not they are included in

[2] Statement by J.E. Hinds, Deputy Secretary of Defence cited in Martin Navias, *Ballistic Missile Proliferation in the Third World*, Adelphi Paper 252 (London, 1990), p. 53.

[3] .Need to Strengthen Missile Control Regime', Announcement of the Member States of the Missile Technology Control Regime, *Wireless File*, 7 November 1991.

the annex) and of *any items in the annex* if the government judges that they are intended to be used for the delivery of weapons of mass destruction. The new guidelines are couched in tougher and less ambiguous language, and call for national export barriers against Category I transfers, "regardless of their purpose".[4] With this expansion, the regime began to target not only surface-to-surface missiles, but also other missiles such as air-to-surface and ship-to-surface missiles as these have the capability to carry biological weapons.

The revision of the earlier specification of missiles coming under the MTCR is based on the Western supplier's contention that the technology and equipment for short-range missiles can be very easily employed by a country to gain technical expertise to develop long-range missiles, as was evidenced in the Iran-Iraq war when Iraq doubled the range of its Scud missiles by reducing its payload. But the more important factor that brought the focus on conventional missiles was that the use of these missiles in Third World conflicts in the latter half of the 1980s[5] made it evident that they can have political impact far beyond their military effectiveness. During the Gulf war, faced with the combined might of the industrialised countries armed with sophisticated weapons, Iraq used its Scuds both to broaden the war by bringing Israel into the conflict and to sap support of the other regional countries for the anti-Iraqi coalition in the region. The Gulf war also strengthened the linkage between Third World missiles and chemical weapons when Iraq's chemical arsenal imposed constraints on the Allied response to the Iraqi aggression over Kuwait[6].

In the 1990s, the MTCR also began to bestow greater attention on cruise missiles and other high performance unmanned vehicles. Although the regime had always included

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[4] U.S. Arms Control and Disarmament Agency, 'Revisions to MTCR Guidelines: Missile Technology Control Regime'(Washington D.C.) Released 7 January 1993.

[5] The Scuds or their derivatives were used by Libya in an attack on the U.S. Coast Guard in 1986, by Iran and Iraq during the 'War of the Cities' in early 1988, by the poorly trained Afghan army during the siege of Jalalabad in 1989 and by Iraq during the Allied attack in 1991. In all these conflicts, these missiles were armed with conventional warheads.

[6] Although U.S. expressed concern over the spread of chemical weapons in the early 1980s following the evidence of their use by the Soviet Union in Afghanistan, by Vietnam in Laos and Kampuchea, and by Iraq against Iraq, it was only after the cease fire in Iran-Iraq war in 1988 that it pushed the subject on the international agenda. With concerns over Third World ballistic missiles already high, the two came to be linked. Many argued that a typical Third World missile with short range and low accuracy was ideal and meant for use with weapons of mass destruction payloads.

these systems as weapons of great concern, it was only after the Gulf war that the regime became concerned with the potential spread of cruise missile systems. The demonstrated effectiveness of cruise missiles during the Gulf war,[7] combined with the advent of anti-tactical ballistic missile systems(ATBMs), was seen as enhancing the attraction of cruise missiles in the Third World. Western concerns were heightened by the fact that the cruise missile technology was relatively more diffuse as compared to that of a ballistic missile[8] and these systems were difficult to intercept.[9]

In addition to the expansion of the scope of the regime, the enforcement of the regime guidelines has been progressively strengthened. In the early years of the regime, there were conflicting interpretations among the regime participants over the restrictions imposed by the regime-whether the regime restricted transfer of missile technology to countries which are not engaged in nuclear weapons programme and whether it restricted technological assistance to civilian space programmes. In 1989, France and the United States took opposing positions on the transfer of technology to civilian space programmes. Differences arose between the two when France offered to transfer Viking liquid engine technology to Brazil. France defended the technology transfer deal on the basis of the statement in the MTCR agreement that it is "not designed to impede national space programmes or international co-operation in such programmes as long as such programmes could not contribute to nuclear weapon delivery systems". The United States, on the other hand, insisted that space launch vehicles and ballistic missiles use the same technology and that any space launch programme is a potential missile programme. In its view, the regime permits co-operation in satellites and the information they handled, as

[7] During the conflict, the United States used a range of SSMs. Cruise missiles have been credited with having made a contribution to the outcome of the conflict. Seth Carus, *Cruise Missile Proliferation in the 1990s* (Westport, 1992)

[8] Western analysts contend that it is relatively easy for a Third World country to design and develop a cruise missile with an accuracy of 100 meters using the commercially available Global Positioning System (GPS) technology than a ballistic missile of the same accuracy. See Benoit F. Morel, 'Proliferation of Missile Capability', *Disarmament*, vol. XIV (3), 1991., pp.-21-43. Also see Seth Carus, n. 7.

[9] There are reasons to believe that cruise missile will remain very penetrable for some time to come. Unlike that of ballistic missiles, the launching of a cruise missile does not send very large signal easily detectable from space. Ground-based air defence radar also cannot detect cruise missiles as they fly at very low altitudes. Their detection requires airborne radars such as airborne warning and control systems (AWACS), able to distinguish a cruise missile from above, that is, from the background noise. This is very difficult and requires high processing capabilities. Morel, n. 8.

opposed to launch vehicles. It was the U.S. interpretation of the regimes restrictions that finally prevailed when France coming under pressure from other members of the regime, finally put the space technology sale on hold.[10] Such differences in the interpretation of the regime had strong commercial overtones. In order to plug the loopholes in the enforcement of the regime and reduce the possibility of MTCR members gaining competitive advantage over each other in the commercial area by adopting different interpretations of the regime guidelines, the members agreed to a 'no undercut' policy at the plenary meeting in Stockholm in October 1994. According to this policy, the MTCR partners will inform one another of cases where a license for an item contained on the MTCR Equipment and Technology Annexe has been denied. Other partners agree not to approve new licenses for the same item to the same country. Since 1989, when the U.S. interpretation over the restrictions have been adopted, the regime has been forthright in its attempts to impede civilian space programmes of emerging space competent states.

Another significant development in the evolution of the regime has been the expansion of the membership of the regime. At the London meeting of the MTCR in 1989, the participating governments decided to strengthen the regime by gaining wider adherence to the regime guidelines. Since then, some 21 countries have become members of the regime and, in addition, leaders of China, Israel, Romania, and Ukraine have agreed to 'adhere' to the MTCR guidelines but their countries have not become partners of the regime[11]. The first group of countries that joined the regime were the non-signatory countries of the European Community. In 1990, the Soviet Union/Russia, one of the principal suppliers of ballistic missiles, agreed to abide by the regime guidelines and, in January 1993, established a system of export controls on missile technology transfers on the pattern of the MTCR. Since July 1995, Russia began to participate in all aspects of the MTCR. It its efforts to transform the regime into a more inclusive group by brining most of the potential suppliers of missile and missile relevant technologies into the fold

[10] At the December 1989 meeting of the MTCR in London, the U.S. and other members of the regime pressed France to drop the offer to Brazil and preserve the integrity of the regime.

[11] The law does not clearly define the term "adherent" but the U.S. State Department has interpreted it to mean any country that has joined the MTCR (a process that requires unanimous approval of all current members) or a state that has signed a bilateral agreement with the United States government promising to abide by the regimes terms.

of the regime, the U.S. offered modest technology transfer benefits to countries that subscribed to international non-proliferation standards, enforced effective export controls and abandoned offensive ballistic missile programmes[12]. Argentina and Brazil, that had been targeted by the regimes export controls, have been admitted into the MTCR after they abandoned their ballistic missile programmes. The list of the members of the MTCR as of January 1997 is given in Table 6.1.

Membership of the MTCR		
Argentina	Germany	Portugal
Australia	GreeceIceland	Romania
Austria	Ireland	RussiaSouth
Belgium	Italy	Africa
Brazil	Japan	Spain
Canada	Luxembourg	Sweden
Denmark	Netherlands	Switzerland
Finland	New Zealands	UK
France	Norway	USA.

Except Brazil, South Africa and Iceland all the other countries are members of the Zagger Committee, the Nuclear Suppliers Group, the Australian Group and the Wassenaar Agreement of 1996. Brazil and South Africa are not members of Australian Group and the Wassenaar Arrangement. Iceland is not a member of Zagger Committee, Nuclear Suppliers Group and the Wassenaar arrangement.

Source: *SIPRI: World Armaments and Disarmament Yearbook 1997* (London, 1997), p. 346.

Although almost all potential suppliers of missile hardware and technologies are members or adherents to the MTCR guidelines, international transactions in weapons and related technologies remain largely unaffected. In the first place, the regime itself permits the transfer of technology and hardware to projects and countries which are not of proliferation concern. On this basis, the United States has actively collaborated with Israel in the development of the Arrow, a defensive anti-missile system. The U.S. also made

[12] In his address to the 48th Session of the United Nations General Assembly, the U.S. President said that: "We will seek to strengthen the Missile Technology Control Regime by transforming it from an agreement on technology transfer among just 23 nations to a set of rules that can command universal adherence". (New York, 27 September 1993).The White House Fact Sheet explained that "For the MTCR member countries, we (the United States) will not encourage new space launch programmes, which will raise questions on both non-proliferation and economic viability grounds...The United States will, however, consider exports of MTCR controlled items to MTCR member countries for peaceful space launch programmes on case-by-case basis. We will review whether additional constraints or safeguards could reduce the risk of misuse of space launch technology" Office of the Press Secretary, The White House, *"Fact Sheet: Non-proliferation and Export Control Policy"*, 27 September 1993.

arrangements to equip South Korea with Patriot missiles in spring 1994. Taiwan is also being provided with missile technology by Raytheon, the U.S. company which builds Patriot missiles.[13] Such 'legal' missile technology transfers reinforce the discriminatory character, permitting some countries the benefits of technology that could easily be converted for offensive uses.

Secondly, the MTCR, like other supplier control mechanism, has failed in preventing the 'illegal' trade in missile related exports. After the regime was activated, Israel tested and transferred the technology of the Jericho II, a missile with a range of 1500 km, to South Africa. The latter launched a missile derived from the Israeli technology in July 1990. Except for the caution by the President Bush that the transfers of ballistic missiles to South Africa would "complicate" relations between Israel and the United States, no action was initiated.[14] In 1991, it was reported that Brazil proposed developing ballistic missiles with ranges of 600 km and 1000 km for Iran.[15] Although both Brazil and Israel have suspended all missile related transfers and acceded to the MTCR, North Korea and China remained outside the regime, and have transferred missiles and missile technologies or components to a number of countries. According to Western estimates, North Korea has sold 370 Scud B and C missiles to Iraq, Syria and Iran.[16] The Haft-V or the 'Ghauri' missile which Pakistan tested in April 1998 is believed to be an enhanced version of the North Korean Rodong missile.[17]

China, however, is recognised as the major supplier of missiles, missile components and technologies and according to some reports China itself has acquired missile components and technology from Ukraine and Russia.[18] When China was asked to

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[13] *The Telegraph*, 31 March 1994, and *Asia-Pacific Defence Review* (Kuala Lampur) January/February 1994, p.97.

[14] Aaron Karp, 'Ballistic Missile Proliferation', *SIPRI Yearbook of 1990: World Armaments and Disarmament* (Oxford, 1990), p 380.

[15] Thomas G. Mahnken, 'Ballistic Missile Proliferation: Seeking Global Solutions to Regional Problems', *Disarmament*, vol. 14 (3) 1991, pp. 1-20.

[16] *Defence News*, 8-14 September 1997.

[17] According to U.S. officials and private analysts such as Gary Milhollin, Director of the Wisconsin Project on Nuclear Arms Control, liquid-fueled Ghauri missile has a range exceeding 1200 kilometers and is based on North Korean technology. *The Hindustan Times*, 12 April 1998.

[18] In early 1996, press reports suggested that China clandestinely sought to acquire the blueprints for the development of the most advanced and lethal ICBM, the SS-18. Three Chinese citizens were expelled from Ukraine over the incident. Foreign Broadcast Information Service, *Daily Report-Central Eurasia* (FBIS-SOV-96-024, 5 February 1996. Subsequently it was revealed that China was acquiring the

adhere to the regime in August 1988, Chinese officials gave three reasons for not joining the regime a) Politically, China could not afford to be viewed by the Third World countries as a member of a Western condominium designed to deprive them of technology. b) Economically, China should be allowed to make money from arms exports without interference from the U.S.. And c) China was already showing restraint in its missile exports. Thus, the Chinese transfers of missiles and related components or technologies to Saudi Arabia, Syria, Pakistan and Iran clearly fall in line with its efforts to cultivate Islamic countries in the Persian Gulf and adjacent regions. It has utilised the American decision to supply advanced military equipment to Taiwan as a lever to engage in arms transfers, including missiles. For instance, the U.S. decision to equip Saudi Arabia and Taiwan with advanced F-16 aircraft in 1992 was used by China as an excuse to walk out of the Initiative on Arms Control to the Middle East (ACME),[19] and justify its sale of the M-11 missiles to Pakistan. Finally, China has argued that the sale of CSS-II missiles to Saudi Arabia was not a violation of the MTCR, because the regime was designed specifically to "control the transfer of equipment and technology that could contribute to nuclear capable missiles" and that there is no evidence to suggest that Saudi Arabia has obtained or is trying to obtain nuclear warheads. In a similar vein, it defended the sale of M-11 missile components and technology to Pakistan on the ground that the M-11 with a range of 290 km was within the MTCR parameters.[20]

Competing political, strategic and economic interests of the regime members have precluded any success in dealing with China. In 1991, sanctions were imposed on two Chinese defence industrial firms for the transfer of components of the M series missiles

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technology and parts of the same SS-18 missile from Russia under the pretext of buying space launchers. See *The Hindu*, 23 May 1996.

[19] After the Gulf war, the United States initiated the ACME under which the five major arms suppliers-United States, Russia, China, Britain and France produced guidelines regarding the type of arms transfers to the Middle East to be avoided in the future. The five established guidelines addressing pre-notification of sales and promised to consider the state of regional stability in future arms transfer decisions. They further agreed to apply their decisions to other regions over time. Natalie J. Goldberg, 'Transfer of Advanced Technology and Sophisticated Weapons', in *Disarmament and National Security in an Interdependent World* Disarmament Topical Papers 16 (New York, 1993).

[20] However, according to *Arms Control Today* (January-February 1992), p. 46, the M-11 has a 290 kilometer range with an 800 kilogram payload; the International Institute for Strategic Studies (IISS) lists its range as 120-50 kilometers but does not account for payload. *Military Balance, 1993-1994* (London, 1993), p. 152.

to Syria and Pakistan, but these were revoked in March 1992 despite the evidence of Chinese efforts to transfer missiles to Pakistan and Iran. The waiver was made in response to Chinas public commitment to adhere to the MTCR. In August 1993, after months of reviewing the evidence on the transfer of M 11 missiles to Pakistan, the U.S. once again imposed Category II sanctions on eleven Chinese and one Pakistani arms exporting enterprises. However, the U.S. waived sanctions against China in October 1994 after the latter agreed not to export SSMs with range and payload characteristics exceeding the MTCR guidelines, including M-11 missiles.[21] While lifting the sanctions on China, the U.S. insisted that if it determines that M-11 missiles had been transferred, it would impose sanctions on China and Pakistan.[22] Since then, evidence of China having transferred additional components for the missiles and an entire plant for making M-11 missiles has come to light. There is also evidence of it having supplied missile equipment and technology for Syrian Scud-C programme.[23] However, the U.S. has chosen not to 'acknowledge' this evidence to avoid the imposition of new and more serious Category I sanctions mandated by the U.S. law. China is still not a MTCR partner and has not signed a memorandum of understanding with the United States regarding missile proliferation.[24]

2. THE MTCR AND INDIA

India's space programme and its military potential began to attract considerable attention in the West, especially the United States, in the early 1980s. Western concerns

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[21] Joint statement of the United States of America and the Peoples Republic of China on Missile Proliferation, October 4, 1994.

[22] In November 1994, it was reported that the United States has told China that if it fully disclosed its past exports of M-11 missile technology to Pakistan, Washington would waive U.S. economic sanctions that would be imposed if Washington later concluded that Beijing had exported complete M-11 missile system. Strong U.S. suspicions that China has exported complete such system, coupled with a reluctance to impose sweeping economic sanctions on China, prompted this overture. See Elanie Sciolino, 'U.S. Offers China Deal to Resolve a Missile Dispute', *New York Times*, 14 November 1994.

[23] In mid-1996, U.S. intelligence agencies reported fresh evidence of the Chinese assistance to Syrian Scud-C and anti-ship missile programmes. *The Hindu*, 25 July 1996.

[24] The United States reportedly has opposed China's affiliation with the suppliers group because of concern that China would be a force for relaxing rather than tightening controls. Nayan Chanda, 'Red Rockets Glare', *Far Eastern Economic Review*, 9 September 1996. China, on the other hand, even while expressing commitment to abide by the principles and parameters of the regime, has recently described the regime as "exclusive and discriminatory". *The Hindu* 31 April 1998.

were heightened by the fact that India had already carried out a nuclear explosion and had not accepted the Nuclear Non-Proliferation Treaty (NPT). As a result, despite the 1984 Indo-U.S. MOU on the transfer of sensitive technology, the United States remained guarded in transferring technologies that might contribute to India's nuclear or the so-called 'offensive' weapon capabilities. With concerns over the diffusion of advanced technology to the Third World gaining prominence in the domestic politics of the United States in the latter half of the decade, Indian military modernisation programme - nuclear submarine and guided missile programmes- emerged on the U.S. non-proliferation agenda. A few months prior to the formal unveiling of the MTCR in April 1987, the U.S. became convinced that India was seriously seeking to acquire ballistic missile capability.[25] It carried out an intense but quite diplomatic campaign to dissuade India from testing its ballistic missiles. With the MTCR in place by mid-1987, the other members of the MTCR joined the United States in pressing India not to go ahead with the testing of its ballistic missiles, especially the intermediate range Agni missile.[26] The testing of the Agni missile in May 1989 and the surprising Pakistani announcement in mid-1988 that it had tested two ballistic missiles, Haft-1 and Haft-2 with a range of 80 kilometers and 300 kilometers and that another one with a range of 800 km was being developed, led to heightened concerns over the emerging missile race in South Asia.

Even prior to the Agni launch, India had become a country of proliferation concern when in 1988 it acquired a nuclear submarine from the Soviet Union under a three year lease. The launching of a indigenous programme to build nuclear powered submarines and the leasing of such a submarine from the Soviet Union attracted a lot of attention and concern in the U.S. and other Western countries. The transfer of Charlie class I nuclear submarine was seen as marking a significant jump in India's naval capabilities, whose

[25] A Congressional report in 1987 concluded that the Indian efforts to establish a missile testing range on the east coast, despite local resistance to the project, are indicative of its determination to acquire ballistic missile capabilities. Arthur F. Manfredi, Robert D. Shuey et al, *Ballistic Missile Proliferation: Potential of Non-Major Military Powers, An Update*, Congressional Research Service Report (Washington D.C.: 6 August 1987).

[26] According to the then Prime Minister Rajiv Gandhi, "ambassadors of certain foreign powers" threatened to take punitive action against India if it launched the Agni. "I told them clearly that India would carry out the launch and we would not change our decision under pressure" *The Hindustan Times* 29 June 1989.

expansion programme had already become a source of concern in the West. Moreover, since these submarines required highly enriched uranium as fuel, the acquisition of these submarines by a non-nuclear state was seen as posing a threat to the non-proliferation regime.[27] The United States protested to Moscow, saying that the transfer of nuclear submarine was 'inconsistent' with the non-proliferation objectives of the London Suppliers Group, of which the Soviet Union was a founder member.[28] It was in this context of heightened concerns over the diffusion of nuclear and missile capabilities that India became a target of Western technology control regimes.

As we observed in Chapter Four, the Indian decision to acquire ballistic missile capability by harnessing indigenous resources in the early 1980s was motivated by strong security consideration arising from the spread of advanced weapons technology in the immediate neighbourhood and the deteriorating international security environment. In the six years that separated that decision and the actual testing of the missiles in 1988-89, long-range conventional weapons had emerged on the centre-stage of modern warfare. While the leading missile powers began to integrate conventionally armed long-range ballistic and cruise missiles into their armed forces, China emerged as a new supply source for missiles[29] and several countries in the Third World began acquiring these missiles. These developments combined with the possibility of these weapons finding their way into the immediate neighbourhood, accelerated missile development efforts of the IGMDP. China's burgeoning arsenal of nuclearised and conventionally armed missiles and evidence of its role in the development of Pakistani missile capabilities, and the expanding missile programmes of other Asian states (in Central Asia and Middle East) have reinforced the Indian desire to build missile deterrent capabilities despite strong opposition from the MTCR member countries.

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[27] Non-nuclear states would get access to material suitable for weapons, or a rationale for building enrichment facilities for approved 'peaceful' purposes that would otherwise not be permitted under the safeguards regime. For a detailed discussion on the Indo-U.S. differences on the issue of nuclear submarines, see Brahma Chellaney, *Nuclear Proliferation: The U.S.-Indian Conflict* (Delhi, 1993), pp. 229-43.

[28] Super Power Nuclear Gambits, *Indian Express*, 8 January 1988.

[29] China is believed to have developed the M series of ballistic missiles with foreign funding for the purpose of export. At the Asian Defence Show in Beijing, in 1986, China offered the 600 kilometer range solid fueled M-9 missile on the international market., n. 15.

The Indian Ballistic Missiles

In February 1988, the IGMDP test launched the Prithvi missile, a single stage ballistic missile with a range of 150/250 km and payload capacity of 500/1000 kilograms. A year latter it flight tested the Agni, two-stage ballistic missile capable of carrying a one tonne warhead over a distance of 2500 kilometers. Of these missiles, it is only the Prithvi that has been developed for serial production and ultimate induction into the armed forces as a battlefield support missiles. The Agni project, on the other hand, was intended to establish Indian capabilities for developing long-range missiles. The range, payload and other technical features are given in Table 6.2.

Table 6.2. Features of the Indian Ballistic Missiles

	Prithvi	**Agni**
Payload	1000 kg single warhead	1000 kg single warhead
Length	9.0 m	21.0 m
Body Diameter	1.1 m	1.3 m
Launch Weight	4000 kg	16000 kg
Warhead	Conventional /Chemical or Nuclear	Conventional /Chemical or Nuclear
Guidance	Inertial	Inertial with terminal guidance
Propulsion	Liquid	Solid first stage and liquid second stage.
Range	150-250 km [a]	2500 km
Accuracy	200 CEP	Not Known
Contractor	Bharat Dynamics, Hyderabad	Developed by the DRDL, Hyderabad.

[a] There are two version- one with 150 km range and the other with 250 km range- A third version SS-350 has been reported to be in development in 1994

(*Source: Jane's Strategic Weapons Systems*, Issue 15, May 1995.)

The Prithvi is a single stage system powered by twin liquid propellant engines and guided by strap down inertial navigation systems. For the IGMDP, the Prithvi was a de novo project. It was not based on any existing model of a missile, though it used the experience of the Defence Research Development Laboratory (DRDL) in dealing with liquid propulsion engines gained from the 'Devil' programme. The design of this missile was essentially dictated by the technology and expertise available within the country. The technological choice of using storable liquid propulsion for Prithvi was thus influenced by the familiarity of the Indian technicians and scientists with the Red Fuming Nitric Acid RFNA/ 50:50 xylidene-triethyamine fuel which was used for the SA-2 (Soviet supplied surface-to-air missile) and for the SSN-2C (Soviet supplied anti-ship missile). The Soviet Union had even set up a production facility for it in the country. The Prithvi relies on the strap-down system for guidance and control of the missile. Although the strap-down guidance is not the most advanced system[30] the choice was dictated by the familiarity of the technology. Indian engineers had in the 1970s reverse engineered the SA-2 SAM which used this guidance system. The principal innovation of the IGMDP team was the on-board computer (OBC) to control the missile. The OBC provides the missile with the ability of following a "tailored" trajectory instead of the purely ballistic one followed by the older missiles like the Scud. The Prithvi system features pre-programming capability to provide six alternative paths to a target, thereby making it much more difficult to be defeated by anti-missile systems like the Patriot.[31] Besides control and guidance, the OBC is used to detonate the warhead fuse when required.

Although the Prithvi is a nuclear capable missile, it has been essentially seen as a battlefield missile to be integrated into the artillery arm of the Army and quite similar to the U.S. Army Tactical Missile System (ATACMs). Towards this end, a range of conventional warheads, including pre-fragmented munitions, bomblets, minelets, and incendiary warheads are being considered for the missile.[32] However, it is generally believed that the missile is only as accurate as Scud or the V-2.[33] The highly volatile nature of the liquid propellant system has also called into question the ground mobility of the missile with its launcher. From the technological point of view, the Prithvi is a propulsion module with a variety of applications, ranging from SSMs, long-range SAMs, as well as an upper stage for a long-range missile. It is in this last mentioned form that the Prithvi has been involved in the Agni project.

A modified version of the Prithvi forms the second stage of the Agni, an

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[30] The limitation of this technology is that beyond the ranges of 300 km, strap downs do not provide accurate guidance. Efforts to use strap-downs in the long-range rockets may be sensible as experiments, but the results are not encouraging Aaron Karp, *'Ballistic Missile Proliferation: The Politics and Technics* (London, 1996), p. 123. Nevertheless, it should be noted that China has used similar packages for its ICBMs for nearly 20 years and in extending the range of Scuds and its derivatives, Iraq and North Korea sought to compensate the loss of accuracy to some extent by improving the electronic packages.

[31] Manoj Joshi, 'Dousing the Fire? Indian Missile Programme and the United States Non-Proliferation Policy', *Strategic Analysis*, vol. XVII (5) August 1994., pp. 557-76

[32] 'India Enters the Missile Age', Sunday 13-17 March 1989, pp. 35-37.

[33] For instance, see Karp, *Ballistic Missile Proliferation*, n. 30, p. 121.

'experimental' or 'technology demonstration' programme. In order to establish long-range missile capabilities, the IGMDP needed to test the re-entry vehicle technology, which is considered to be the single most difficult technical problem for emerging rocket powers as it involves not only advanced and costly material but also elaborate testing. Initially the plan was to use the SLV-3 as a test bed, but finally, the IGMDP opted for a combination of SLV-3 first stage and Prithvi to lift a 1000 kg payload into space to achieve the required re-entry velocity of about 3 km per second. The two stage Agni missile was thus conceived for proving technologies of long-range missiles such as re-entry vehicles, guidance and navigation and combination of liquid-solid fuel systems.[34]

Initially it was the Agni and not the Prithvi which attracted considerable attention and criticism from the MTCR. The Prithvi was below the range of what was then defined as 'destabilising' i.e. missiles with ranges and payloads more than 300 km and 500 kg respectively. However, with the broadening of the scope of the regime, particularly after the 1991 Gulf War, the Prithvi missile emerged on the non-proliferation agenda of the MTCR. In 1993, press reports indicated that the U.S., Britain, France, Germany, Japan, Canada, Italy and Australia gave separate but identical demarches to the Government of India, urging it to halt the deployment of the Prithvi missile.[35] The MTCR also adopted a new missile control policy aimed at halting the induction of the Prithivi missile into the armed forces.[36]

The Western critique of the India missiles is generic to the U.S. stated opposition to ballistic missile proliferation around the world. As we saw, since the mid-1970s, the United States had become increasingly concerned with the diffusion of military technology and its adverse impact on regional balances of power. Secondly, U.S. concern over Indian missiles emerges out of the challenge that they pose to the non-proliferation regime. The US was convinced that the deployment of even short-range missiles in South Asia would

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[34] Manoj Joshi, 'Agni: Technology Demonstrator or Missile?' *The Times of India*, 11 May 1994.
[35] In addition, they urged the Indian government to stop production of fissile material, to place all its nuclear facilities under full scope safe-guards, stop its fast breeder reactor project, stop the development of the Agni missile. *The Hindu*, 30 August 1993.
[36] At a meeting in Switzerland between 29 November and 2 December 1993, the MTCR members approved a new missile control policy which says that Third World countries should be urged not to induct missile weapons into their armed forces. The members 'decided to approach non-members to dissuade them from employing missiles capable of delivering weapons of mass destruction'

alter the strategic environment ultimately leading to the nuclearisation of the sub-continent. Such an assessment was strengthened by Pakistan's single-minded pursuit of nuclear and missile capabilities in spite of severe disapprobation by the United States. Several messages sent by the US administration to the Congress have warned that continuing tensions between India and Pakistan and their advanced programmes to obtain weapons of mass destruction, along with ballistic missile delivery systems, presage that a future Indo-Pak conflict might reach the nuclear level[37] The constructing such frightening scenarios were no doubt, part of the Administrations efforts to acquire wider support for its non-proliferation goals both at home and abroad. The publicly declared policy of the United States vis-à-vis South Asia has since the late 1993 has been to "cap, then over time, reduce, and finally eliminate the possession of weapons of mass destruction and their means of delivery systems".[38]

MTCR Controls

In spite of expressing concerns over the diversion of its technology to Indian nuclear or offensive weapons and technology leakage to the Soviet Union, the United States transferred electro-optical instrumentation for the National Testing Range at Baliapal, missile testing devices such as the CAVCTS and "shaker"[39]and computers to the IGMDP. In the wake of rising concerns over the proliferation of ballistic missiles and the test launching of the Agni, there emerged a presumption to deny advanced technologies to India. Leading members of the U.S. Congress questioned the "wisdom of providing any high technology sales to India".[40] According to a study conducted by the Centre for Policy Research, New Delhi, the U.S. government turned down 102 applications for technology export during 1989-1992 in response to rising concerns over the Agni

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[37] See for instance, USIS Official Text, *Progress Towards Regional Non-Proliferation in South Asia*, 7 May 1993., p. 2.

[38] Ibid, p. 3.

[39] The CAVCTS with a force capability of 545 kilograms and a "shaker" with a force level of 15,900 kilograms, was reportedly approved for export by the Commerce Department in 1985., Chellaney, n. 27, p. 281-283.

[40] On 22 May 1989, 22 Senators and Representatives sent a letter to President Bush questioning the 'wisdom of providing any high technology assistance to India' because 'it is developing ballistic missiles and has refused to sign' the Nuclear Non-Proliferation Treaty or open all its atomic facilities to international inspection. Cited in Chellaney, n. 27.

programme. The study found that the Department of Commerce did not license for export to India any major high-tech item for nearly three years after the first Agni test.[41] The IGMDP was unable to obtain structural components, including focal plane array, millimetre waive radar systems W band impact diodes, C band shifters and carbon performs.[42]

Even technologies which were licensed earlier were put on hold. For instance, in 1989, the United States denied the $1.2 million Combined Acceleration Vibration Climatic Test System (CAVCTS), a "shake and bake" device used to put components of re-entry vehicles to simulated tests of their ability to withstand the heat and stress of flight. The CAVCTS case is illustrative of the strengthening of U.S. policy on export of equipment and know-how in response to the MTCR. It also illustrates the complexities involved in administering the MTCR guidelines.

When the Indian government sought CAVCTS in 1984, the Wyle and MB Dynamics were granted licence to sell the system to India. The two licenses, however, expired un-utilised in May 1987. When India asked the two firms to reapply for license in August 1987 the MTCR had come into force. The decision on the fresh application was held up for two years, first because of the reorganisation of the U.S. export licensing regime in response to the MTCR and then due to the interagency differences over whether the device would contribute to an Indian nuclear missile capability. The Pentagon and the CIA argued that CAVCTS could advance India's efforts to develop nuclear capable IRBMs and therefore recommended disapproval of the long pending application. The Department of Commerce supported the proposed sale, while the State Department (which asserted its jurisdiction over the matter by declaring that the item came under its Munitions-Control List) was divided over the issue. Some officials claimed that the device designed for India was too highly sophisticated as it could save flight tests by simultaneously carrying out a number of simulated tests on a re-entry vehicle. Others cited technical assessments carried out on the CAVCTS design to say that there was "no data or intelligence to back up the argument that it could contribute to development of a

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[41] Brahma Chellaney, *The Challenge of Missile Proliferation: India and the United States* (New Delhi, 1993).
[42] Savita Pande, 'India, China and the Export Control Regime: A Study in Approaches', *Strategic Analysis*, vol. XVII (5), August 1994, pp. 543-556.

nuclear-capable missile by India".[43] The Agni launch ended the intense policy debate in the U.S. Administration over the issue. Accepting the arguments of the CIA and the Pentagon, the President barred the sale of CAVCTS to India.

The denial of CAVCTS was the beginning of a series of exports curbs on dual-use technologies on grounds of missile proliferation. When India evinced interest in acquiring cryogenic engines and related technology from Arianespace, a French-led European consortium, France came under intense U.S. pressure in 1989. The United States argued that the regime was designed as an extension of the non-proliferation regime, and that export of space launch technology should not be made to a country like India which had indicated its potential for promoting nuclear proliferation by refusing to sign the NPT. Bowing to pressure from the United States and other members of the MTCR, France suspended negotiations with India over the cryogenic engine.[44]

This prompted India to turn to Russia, a non-MTCR country. In January 1991, the ISRO concluded a deal with the Russian Space Agency, Glavkosmos, for the transfer of cryogenic engines and related technologies. A year after the contract, Russia came under relentless U.S. pressure to abrogate the technology transfer deal with India. The U.S. argued that the cryogenic engine was a Category I item of the MTCR and that the ISRO-Glavkosmos deal was a violation of the MTCR guidelines as well as the newly enacted U.S. domestic legislation giving effect to the MTCR, the National Defence Authorisation Act of 1990. In May 1992, the United States imposed sanctions on the two contracting agencies. When the Russian government did not wilt under the U.S. pressure or the sanctions against the Glavkosmos, the U.S. threatened new sanctions against Russian firms and disruption of aid to the ailing Russian economy. Russia was also offered new trade concessions, joint U.S.-Russian space collaboration and lucrative contracts to launch American satellites, for scrapping the deal with India. Russia's resistance to U.S. pressure collapsed in July 1993 when it invoked a force majeure clause of the 1991 contract, to announce the break of contractual obligations. In September, 1993, Russia and U.S. signed three main accords relating to space and missile technology, an MOU on missile related

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[43].David B. Ottaway, 'Bush Administration Debates the Sale of Missile Testing Device to India', *The Washington Post*, 28 May 1989.

[44] Kathleen C. Bailey, 'Can Missile Proliferation Be Reversed?' Orbis, Winter 1991, pp. 5-14.

exports, a U.S.-Russian commercial space launch agreement; and a joint statement on co-operation in space. In the agreement relating to missile technology, Russia committed itself to abide by the MTCR. This agreement opens up the way for U.S.-Russian co-operation in space.

In the meanwhile, the U.S. followed up the sanctions imposed on the ISRO, by placing Indian missiles, Prithvi and Agni, as well as civilian launch vehicles, the SLV-3, ASLV, PSLV and the GSLV under its Export Administration Regulation in June 1992.[45] With this, equipment, components and materials which are not part of the MTCR annex also came under export restrictions. For instance, in 1992, the U.S. administration threatened sanctions against two U.S. firms for having exported laboratory equipment to India. These tools to make rocket nozzles had nothing to do with the missile technology.[46] Similarly, the U.S. placed curbs on several items, including radiation hardened electronic components, required for the GSLV.

Barring the two-year period when sanctions were imposed on ISRO, the U.S. export restriction had focused on controlling specific set of items (Commodity Control List) to India and other countries of proliferation concern. However, efforts to strengthen export controls have gradually led to their focus being shifted on to the end-users or specific entities of proliferation concern. Beginning in early 1997, the U.S. Department of Commerce began to place export restrictions on specific end-users which have been determined to be involved in developing weapons of mass destruction or missiles used to deliver those weapons. These restrictions on specific entities of proliferation concern are traceable to the 1993 decision of the Bureau of Export Administration (BXA) to introduce a "know rule" in the Export Administration Regulations. This rule required exporters to seek a license "if they know or have reason to know" that a proposed export would be

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[45] Under the August 1991 Enhanced Proliferation Control Initiative (EPIC) of the Bush Administration, an individual validated license is required for the export of any item when the U.S. "person" knows that the export will be used for chemical and biological weapons activities anywhere. In June 1992, a new set of list and controls extending these restrictions to missiles as well was announced. These identified 21 countries and projects including those in India. For the link between EPIC and the justification of sanctions under U.S. law, see the notification of the sanctions in the *Federal Register* of 18 May 1992.
[46] The U.S. action has been seen in the Indian official circles as being directed at the Hindustan Aeronautics, that was making heat shields and nose fairing for the PSLV. R. Prasanna, 'Launcher Game', *The Week*, 3 April 1994.

used to support proliferation activities. Since exporters have no basis for a priori knowledge, an intelligence gathering system, the Wisconsin project, was instituted headed by Gary Milholin. The Wisconsin project brought out a series of reports called the Risk Reports to help exporters of high technology identify potential proliferators. They are these lists that have formed the basis for creating the 'Entity List' as a part of the Export Administration Regulations.[47] All exports to a person in the 'entity list' are subject to the Export Administration Regulations, irrespective of whether the item is a controlled one or not. In other words, any U.S. firm seeking to export to these entities now require to obtain individual validated licenses, which was hitherto limited to dual-use technologies and items. More important, these new controls are for perpetuity or till the targeted proliferation programme is abolished.

In mid-1997, the Bharat Electronics Ltd (BEL)and three agencies of the Department of Atomic Energy; the Bhabha Atomic Research Centre (BARC), the Indira Gandhi Atomic Research Centre (IGARC) and Indian Rare Earth's Limited (IREL) were placed on the Entity List. If one goes by the lists that appear in the Risk Reports, private Indian companies like Godrej & Boyce, L&T, Walchand Nagar Industries, public sector undertakings like the Hindustan Aeronautics Limited and educational institutions like the Indian Institute of Science are all likely to be targeted in the near future.

As a result of the new export regulations, there has been a widening of the range of restrictions on imports. For instance, while only 10 percent of the components being supplied to BEL used to require export licenses, now all exports to BEL require individual validated licences. Whether this requirement will cover all of the nearly 1000 components imported from the U.S. is not yet clear".[48]

Impact on Missile Programme

When the decision to go for ballistic missiles was made in the early 1980s, the planners had to contend with the high cost of imported technologies as well as the difficulties in obtaining technologies and components from abroad. The missile

[47] R. Ramachandran, 'Technology Denied is Technology Gained', *The Economic Times*, 1 August 1997.
[48] One BEL source has said "We still do not know what items they have short-listed on which curbs will be imposed". Parvathi Menon, 'On the Hit List: U.S. Imposes Export Curbs on BEL', *Frontline*, 27 June 1997., p. 106.

programme, therefore, had laid much emphasis on the indigenous development of critical missiles technologies and components. Anticipating further tightening of export controls, the IGMDP had taken a consortium approach towards critical components.[49] As a result, by the time the missiles came for testing towards the end of the 1980s, many sub-systems, components and technologies were already available within the country or were in an advanced stage of indigenisation. At the stage of development testing, the import content of Prithvi was estimated to be 20 percent by value and that of Agni six percent by value. Import content had been mainly confined to a few critical spare parts like sensitive gyros, other sensors, a few special alloys and microprocessors.[50] With the indigenisation of critical components already in an advanced stage, the import content was expected to be reduced to five percent by value by the time the Prithvi reached the production stage in the early 1990s.[51]This would make the IGMDP less vulnerable to disruption by technology controls.

Western analysts, however, believe that because of the import content, the Indian missiles are vulnerable to disruption. According to one analyst, 'if the simplicity of the Prithivi missile's design makes its indigenisation possible, other programmes will not necessarily progress as smoothly if more complex technologies are involved'.[52] Earlier in 1992, the Director of the Strategic Defence Initiative Organisation (SDIO) in a report titled "Ballistic Missile Proliferation: An Emerging Threat" had indicated that halogen based propellants, thrust vector nozzle, other exotic propellants, inertial-cryogenic gyros and precision accelerometers and terminal homing devices were elements of the technology required to develop ballistic missiles, which would be difficult for Third World countries, including India, to obtain. According to another source, the Indian missile programme would require technology transfer and other off-shore procurement of composite materials, speciality steels, and high purity graphite to sustain the present

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[49] "An industry, a lab and an academic institution were identified for a particular problem and we generated indigenous bases in various critical areas. We will activate the relevant groups. They cannot throttle us" A.P.J. Kalam in *Frontline*, July 1989

[50] Indranil Banaerjie, 'The Integrated Guided Missile Development Programme', *Indian Defence Review*, July 1990., pp. 99-108.

[51] Ibid.

[52] Eric Arnett, 'Military Technology: The Case of India', *SIPRI Yearbook 1994: World Armaments and Disarmament* (London, 1994), pp. 343-65.

progress. The Risk Report published by the Wisconsin University Project on non-proliferation has produced a detailed tabulated list indicating the items which would be required to make the IGMDP completely operational and self-reliant. The list is reproduced below.

Item Sought	Potential Use
Aluminium of alloy 2024-T3 with protective coatings	Load bearing and structural members
Ceramic chip capacitors	Electronics
FM signal generators	Development and testing of telemetry and communication system
Functions	Calibration to support advanced instrument for guidance and control.
Gas field effect transistor and bare semiconductor chip	Components for integrated circuits.
Equipment and software for the optical systems including multimeter and calibrator.	Development of advanced design imaging modules.
Oscilloscopes	Support of advanced electronics for missile guidance and other electrical systems
Torque motors	Guidance and control.
Video-imaging module.	Launch support and diagnostics intelligence collection.

Source: The Risk Report, January-February 1995, p.9.

Although it is difficult to assess the extent of dependence and thus the vulnerability of the missile programme to disruption by technology curbs and controls, the Prithivi missile has been passed on to the armed forces for user trials. A limited serial production of the missile was taken up in 1995 and the missile inducted into the Army but not deployed. Whatever delays in the production and induction of the Prithivi that have been there cannot be wholly attributed to the technology controls. The time taken to refine and develop state-of-the-art technologies, changes in the user requirements as well as the decline in defence allocations due to the general economic crisis in the early 1990s, have equally contributed to such delays. In January 1996, and then again in February 1997, the DRDO fight tested a longer variant (250 kilometer) of the Prithvi despite repeated calls by the U.S. to exercise restraint in order to avoid proliferation of missiles in the region. The Agni, that has been at the heart of the Western concern, went through the planned test launches. The third and final test launch was carried out in early 1994. Tested and proven are the basic vehicle for a long-range missile, a variety of control systems to guide the vehicle, the stage separation of the free flight of the re-entry vehicle and the terminal phase, the state-of-the-art guidance system and a re-entry vehicle with some manoeuvrability for providing greater accuracy.[53] No decision has been taken to develop and test longer range missiles which would lead to the mass production of a Agni-class missile system.

While it is not clear whether the restraints on the Agni programme are a result of external pressures[54] or a part of its strategic posture of sending strong signals of its capability without necessarily ratcheting up the arms race,[55] the IGMDP remained active in refining the missiles that had been already tested.[56] The ineffectiveness of the MTCR in preventing the illegal transactions in weapons and related technologies in general and Sino-Pak co-operation in nuclear and missile technologies in particular continued to provide a strong rationale for continuing with the missile development efforts. The IGMDP is reportedly working on a new series of missiles which, if successful, would catapult Indian into the major league. Among the more ambitious missiles being developed are: a 600 kilometer cruise missile based on the proven technology of Lakshya target drone, the Koral, an Indian version of the Russian SS-N-22 Sunburn missile; and the Sagarika, a 300 kilometer sea (submarine or ship) launched cruise missile.[57] The IGMDP is poised for a big leap during the Ninth Plan period (1997-2002) with the allocations for the IGMDP being increased from Rs 227 crores during the Eighth Plan

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[53] Joshi, n. 34. According to the head of the IGMDP, A.P.J. Kalam, Agni has proved its capabilities and "[w]e now have a carrier on which both conventional and non-conventional weapons can be delivered over a long range...we have the systems in place to make it operational within two years" *India Today*, 15 April 1994, pp. 42,43.

[54] This position is supported by those who advocate the use of technology controls for achieving non-proliferation objectives. The U.S. Congress has often emphasised the role of technology controls and other kinds of U.S. pressures in keeping the Agni on hold. For instance see: *India-Pakistan Nuclear and Missile Proliferation: Background, Status, and Issues for U.S. Policy*, Congressional Research Service Report (Washington D.C., 16 December 1996) and *Proliferation Control Regimes: Background and Status*, Congressional Research Service Report (Washington D.C., 1997).

[55] This argument is advanced by none other than Dr. Raja Ramanna, who led the 'peaceful nuclear explosion' of 1974. See, Deepa Ollapally and Raja Ramanna, 'U.S.-India Tensions: Misperceptions on Nuclear Proliferation', *Foreign Affairs*, vol. 74 (1), 1993.

[56] The Project Director of Agni, A.N. Agarwal while exhorting scientists at different research institutions to develop components controlled under the MTCR said that efforts are on to increase the range of the Agni with slight modification in the configuration of the vehicle. *Times of India*, 11 May 1994.

[57] "India's Arms Industry" Strategic Notes, International Institute for Strategic Studies (London) Reprinted in *The Hindu*, 5 March 1997.

period (1992-97) to Rs. 504 crores. The increase in the allocation for the programme is, no doubt, due to the forced indigenisation of state-of-the-art technologies.

3. THE IMPACT OF THE MTCR ON THE INDIAN SPACE PROGRAMME

As we observed in our earlier chapters, technology controls exercised by the space competent states as well as the high costs of importing whatever was available in the international market, had stimulated in self-reliant efforts in India resulting in the establishment of an advanced and diversified technology base in the country.[58] With space services becoming operational and ISRO institutionalising the technology flows from its laboratories to the Indian industry, the Indian space programme had entered into a maximum spin-off stage in the 1980s. More important, ISRO displayed design and development capabilities in all the domains related to the utilisation of outer space-satellites, launch vehicles and related ground equipment and technologies. In the area of satellite technology, ISRO began designing and developing the INSAT series of multi-purpose satellites and the IRS series of earth observation satellites. In the area of launch vehicles, having become familiar with the key elements of rocket technology, and having acquired solid and liquid engine technologies, Indian engineers began to design advanced and innovative launch vehicles. For instance, at the 38th Conference of the International Astronautical Federation (IAF) in 1988, Indian scientists presented the design of a new aerospace launch vehicle, the Hyperplane for heavy lift space cargo operations.

India's scientific capabilities generally outstrip its financial and industrial capabilities. Although ISRO had established a solid base and reputation in the design and development of space technologies, it was dependent on foreign components, equipment and materials either because the domestic industry was unable to provide space qualified products or because the material was not available within the country.[59] ISRO's satellite and space launch vehicles had considerable import content. In the early 1990s, for instance, it has

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[58] According to the Chairman of the Department of Space, Prof. U.R. Rao, as much as 60 to 70 % of the expenditure-minus the salaries-of the Department were going into the indigenous industry by the mid-1980s. *The Hindu*, 21 May 1987.

[59] For instance, in the area of optics, ISRO is seeking to acquire indigenous capabilities in camera optics required for its remote-sensing satellites. However, material from which the lenses will be ground is not available within the country. Gopal N. Raj, 'Sensing from the Sky: The IRS Success Story', *Frontline*, 14-27 September 1991.

been estimated that the foreign components in the ASLV, a vehicle derived from the SLV-3, was to the extent of 30 percent. Similarly, the indigenously designed and developed INSAT and IRS satellites incorporated a large number of imported components. Although it is difficult to establish the extent of dependence, it is safe to assume that the dependence of a emerging space power on external components, equipment and materials is relatively high than that of a established space power. It is for this reason that multilateral technology controls on dual-use items imposed in the wake of rising concerns over Indian missile programme, have had an adverse effect on ISRO's projects.

When the MTCR was unveiled in 1987, it became clear that the existing export controls on several systems required for the space programme would become more severe.[60] However, with the PSLV already in the advanced stage of development, these were not expected to impose severe limitations on ISRO's launch vehicle projects, although there was a possibility of hurdles being placed in the development of the cryogenic engine for the GSLV.[61] However, the supplier regime had wider impact on India's high technology programmes than had been estimated by the Indian space community. In the following section, we will examine how the MTCR controls began to affect the Indian space programme, its launch vehicle and satellite programmes.

Launch Vehicles Programmes

It was in the area of propulsion materials, composite materials and electronic items required for ISRO's launch vehicles that the MTCR controls have had their impact. However, the on-going indigenisation programme had ensured that export controls had a minimum effect on the area of propellant materials. By the time the U.S. stopped supply of PBAN, (the imported propellant resin used in the first two stages of the SLV-3 and the ASLV), indigenous production of the Hydroxyl Terminated Poly Butadiene (HTPB) had

[60] ISRO faced difficulties in acquiring gyros space navigational platforms, radiation hardened devices (to withstand radiation solar flares of more than 10,000 rads) Kevlar and Inconen alloys. See Prof. U.R. Rao's speech on the "Present Plans and Scenario for the Year 2000 for the DOS" at the National Institute for Science, Technology and Development Studies (NISTADS) on 19 May 1987. Reported in *The Hindu*, May 21, 1987.
[61] Ibid.

already begun for meeting the present and future requirement of ISRO launch vehicles[62]. In the area of composites, electronic items and other materials, the U.S. embargoes forced ISRO to search for alternative sources in Europe and Japan or go for the indigenous development of these items.

The sanctions imposed on ISRO in May 1992 and the Russian cancellation of the technology transfer component of the cryogenic engine deal in mid-1993 was a major set back for the ISRO. The cryogenic engine was the critical third stage of the planned GSLV, a vehicle meant for launching satellites into geo-stationary orbit. The importance of cryogenic systems for future launch vehicles was recognised in the early 1980s. Early studies on cryogenic systems established that while the country had the capabilities for the manufacture of cryogenic fuels, the LOX (liquid oxygen) and LH_2(liquid hydrogen), it had to overcome a number of technical hurdles for mastering the engine.[63] However, work on the sophisticated cryogenic systems was initiated only in 1986, when a small token amount of Rs. 16 lakhs was sanctioned to ISRO's Liquid Propulsion System Centre (LPSC) for the development of the cryogenic technology. In order to accelerate the development of the GSLV project and perhaps to avoid re-inventing the wheel, ISRO sought to secure the cryogenic engine technology from abroad. After finalising the designs for the GSLV and the cryogenic engine, ISRO considered three bids- the American (General Dynamics), French (Arianespace) and Russian (Glavkosmos)-and opted for the Russian cryo engines. The decision to go for the Russian engine was based on technical and cost considerations[64]. An additional factor was that with the MTCR in place, the G-7 countries were no longer a reliable sources of technology. The United States was already

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[62] The development of the HTPB had begun around 1984. Once the process was developed and scaled up, the technology was transferred to a private company, NOCIL, that was already involved in polymer production. 'Self-reliance in Solid Propulsion', Gopal N. Raj, *The Hindu*, 8 September 1993.

[63] These are in the areas of LH_2 cooled thrust chamber, coaxial injectors, controls components and in the handling, storing and transportation of the chemical propellants. Technology was also necessary to develop materials to withstand the LH_2. A.P.J. Kalam, *Launch Vehicle Technology: A Perspective* (Bangalore, September 1981), p.17. A more comprehensive study on cryogenic systems is the 15 volume study at the Vikaram Sarabhai Space Center (VSSC). "Cryogenic System Studies" ISRO-CRYO-SS-32(1)-83(VSSC, 1983)

[64] The General Dynamics cryogenic engine was not pursued because it offered only the engines but not the associated technology. The European consortium Arainespace quoted a high price of Rs. 710 crores for the engines and related technology. The Russian package for this supply was only Rs. 235 crores. *The Statesman* (New Delhi), 19 August 1993. citing statement made by the Indian PM in Parliament .

putting pressure on the participant countries of the regime to halt the transfer of launch vehicle technologies on missile proliferation considerations.[65] The ISRO-Glavkosmos agreement of January 1991, provided for two full cryogenic stages along with the technology for the manufacture of the cryogenic engines and stage. The first cryogenic stage was scheduled for delivery in 1995. ISRO thus planned to launch the first GSLV in 1996 or 1997.

With Russia coming under the pressure of the MTCR in early 1992, the technology transfer deal was abrogated in mid-1993. ISRO's plans to launch the GSLV in 1996-96 was pushed back by at least a decade. Based on the 8 to 10 years time taken for developing technologies by ISRO in the past and the experience of other countries such as Japan, which have taken 10 years to develop the cryogenic engine, the indigenous cryogenic engine is not expected to be available within this decade. However, the modified contract between ISRO and Glavkosmos in early 1994 provides for the transfer of cryogenic engines but not its technology, thus ensuring the launching of the GSLV in 1997-98 when the imported engines become available. Although the Indian scientific and technological base provides a fair amount of confidence to develop the engine, the indigenisation efforts are expected to cost between Rs. 400 to 500 crores.[66] The increase in the cost of the project is substantial given that the Rs. 756 crores sanctioned for the GSLV project in November 1990, had a cryogenic component which included the Rs. 235 crore Russian contract. This money may now get two development flights (provided in the project) and four stages, but definitely no technology.[67]

With the continued dependence of the country on imported components and equipment, even indigenisation efforts are susceptible to Western technology controls and this is precisely what has been happening as a result of the strengthening of export controls directed at civilian and missile programmes. For instance, the United States has been the main source for electronic items like critical integrated circuits (ICs), radiation hardened ICs and space qualified travelling wave tube amplifiers(TWTAs) that go into the GSLV. The embargoes imposed in 1992 have compelled India to go for some of these, and other

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[65] Bailey, n. 44. Also see Chellaney, *Nuclear Proliferation*, n. 27., pp. 255-57.
[66] Gopal N. Raj, 'ISRO and the Cryogenic Engine', *The Hindu*, 11 February 1994.
[67] Ibid.

items like control thrusters, wiring and space qualified adhesives, from alternative sources, Europe and Japan, but at much higher cost.[68] The recent U.S. export regulations which target specific entities such as the BEL, are also affecting the development of the GLSV. ISRO and BEL had embarked on a joint programme to produce radiation hardened electronic components which were being imported from the U.S.. By placing export restrictions on all imports by the BEL, new obstacles are being erected in the indigenistion efforts.

Impact on Satellite Programme

While the MTCR controls have been mainly targeted against launch vehicle projects, ISRO's satellite projects have not been immune to these controls. Even before India emerged as a country of non-proliferation concern, its satellite programmes were subjected to export controls. For instance, in 1988, the United States embargoed the supply of the slip ring assembly, which forms part of the solar array drives of satellites.[69] Subsequently, the U.S. laws giving effect to the MTCR, and the two year sanctions imposed on ISRO in May 1992, have reportedly led to delays in the completion of the third and fourth examples of the INSAT-II satellites.[70] The INSAT satellites incorporate a number of items imported from the United States whose procurement was affected by the restrictions placed during the two year sanctions on co-operation between ISRO and U.S. firms. The U.S. punitive action against ISRO was thus substantial and not symbolic as has been argued in some quarters.[71]

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[68] R. Ramachandran, 'Another Cold Start', *The Economic Times* (New Delhi) 12 December 1993.

[69] The slip rings transfer the power generated by the solar arrays to the satellite power lines and also carry the links to sensors on the solar arrays Fortunately, the ISRO Inertial Systems Unit (IISU) which had been set up in 1982 had managed to indigenise slip rings and solar array drives for all the INSAT-2 and IRS satellites. 'Dynamic Orientation of the Satellite', *The Hindu*, 29 December 1995.

[70] Eric Arnett, n. 52.

[71] Brahma Chellaney, for instance, argued that the sanctions were symbolic in nature as the U.S. was doing little business with the Russian and Indian space agencies. Chellaney, n. 27, p 309.

The Indian Space Programme Since 1988

Despite these adverse effects on the on going programme, ISRO had some remarkable breakthroughs in several areas. Some of the major space missions taken up by ISRO as well as those planned upto 2000 AD are listed in the Appendix-4 of this study. The most significant breakthrough is the development of the PSLV with which India has entered the operational era in launch vehicles. The PSLV was first launched in September 1993. Thereafter, two more development launches of the vehicle were carried out to operationalise the PSLV.[72] The first operational flight of the PSLV in September 1997 ended India's dependence on Russian vehicles for hoisting its remote sensing satellites. Progressively reducing the time taken to assemble the PSLV for launch, ISRO has acquired the capability to launch three to four PSLV vehicles in a year.[73] More important, with the PSLV's solid first stage and liquid second stage directly feeding into the GSLV, ISRO is on its way to acquiring access to the GSO, once the indigenous cryogenic engine that powers the upper stage of the GSLV is realised[74]. Following the cancellation of the technology transfer deal by Russia in 1993, the development of the cryo engine has been taken up. According to some reports, even after contracting for the Russian technology in 1991, ISRO had been working on a Indian cryo engine with the objective of developing engines more powerful than the Russian one.[75] Even if this be so, it was only after the U.S. slapped sanctions on ISRO that these indigenous efforts gathered momentum. Taking advantage of months of training received by the ISRO engineers as well as the design drawings and other information secured from Russia prior

[72] In the international scene, operationalisation of the vehicle meant a reliability of 98 per cent. If there were three successful launches, including exact injection of the payload into orbit, it is considered reliable.

[73] The time taken to integrate the first PSLV has steadily come down from over 90 days for the first PSLV to about 55 days for the fourth PSLV in 1996. This is expected to come down to 45 day or less in the future. Gopal N. Raj, 'Looking for Space in the Market' *The Hindu*, 17 March 1996.

[74] The 129 tonne first stage of the PSLV is also the first stage of the GSLV. The second stage of the PSLV, powered by the indigenously developed Vikas engine, functions as the second stage of the GSLV. Four such liquid engines, with augmented capability, will form the strap on motors of the GSLVs first stage.

[75] While the Russian engines are capable of a 7.5 tonne thrust with a 12 tonne propellant loading, the indigenous programme is designed to develop an engine having a 12 tonne thrust with a 14 tonne propellant loading. R. Ramachandran, 'Heavy Price For Ignoring Domestic Cryo Efforts', *The Economic Times*, 19 July 1993.

to the abrogation of the contract, the current efforts are focused on developing an engine with similar specifications as the Russian one. These are however, not based on reverse engineering[76] as ISRO's objective is to gain technological capabilities to design cryo-engines of higher capacities. The Indian industry has been associated with the development work on cryo-engines at the early stages itself to speed up the production process. By mid-1994, some 216 processes or technologies related to cryogenic engine were already perfected and transferred to private sector firms like L&T, Walchand Industries, Godrej, NOCIL and Andhra Sugars[77]. In early 1996, it was disclosed that with the designs of the engine more or less complete, the cryogenic engine had arrived at the metal cutting stage. This means that the engine will come for development testing in 1999. In the meantime, ISRO is planning to use the imported Russian cryo stages, seven of which are to be delivered by Glavkosmos according to the modified ISRO and Glavkosmos contract.

Even as work on the cryogenic engine is underway, ISRO has initiated some R&D work on air breathing engines "particularly in validating concepts, aerodynamics, fluid dynamics, structures, combined propulsion systems, advanced materials and things of that kind".[78] Given the high costs of developing aerospace vehicles using air breathing engines, an international effort is necessary. In order to participate in an endeavour of this nature, ISRO and the DRDO have sought to acquire indigenous capabilities in critical areas of technology and have carried out some studies on small size demonstrator vehicles. A sounding rocket with an air augmented ramjet was successfully launched.

ISRO's achievements in the area of satellite construction and satellite applications far outstripped those in the area of launch vehicles. By the early 1990s, both in the area of communications and remote-sensing, satellite technology reached a mature phase. Beginning in 1992, the second generation INSAT satellites, designed and developed within the country, have become operational. The first satellite in this series, the INSAT-2A was intended to be a test satellite to prove Indian capabilities, but it entered service

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[76] Gopal N. Raj, 'Challenges Ahead for New ISRO Chairman', *The Hindu*, 6 April 1994.
[77] Information given to the Standing Committee of Parliament, cited in Avinash Singh, 'Indian Needs Space to Grow', *The Hindustan Times*, 11 August 1994,
[78] K. Kasturirangan, quoted in *Frontline*, 19 April 1996.

along with its predecessor, the INSAT-1D.[79] With the INSAT-2 satellites India will be having at least 100 transponders by the end of the 1990s, making it one of the largest satcom systems in the world.[80] Imports for these satellites have been confined largely to electronic components and materials, with ISRO making efforts to achieve self-reliance in critical components. It is already developing the high speed momentum wheels and technology for making specially machined helium and propellant tanks has been acquired. Apart from the technology controls, the driving forces of these efforts are economic. According to the then head of the ISRO, Prof. U. R. Rao, by keeping the imports to the minimum, India is able to build the second generation INSAT satellites at costs well below the international prices.[81]

The steady expansion of remote sensing applications utilising aerial surveys and foreign satellite imageries and the indigenous development and manufacture of low-cost 'appropriate technologies' for the processing and interpretation of remotely sensed data have stimulated advances in remote-sensing satellite technologies. By the early 1990s, some 22 states had already set up remote sensing application centres.[82] Self-reliant operational remote sensing services began with the launching of the IRS-1A in 1988 and the IRS-1B in 1991.[83] In 1995, ISRO launched the second generation satellite in the IRS series, the IRS-1C. This satellite incorporating the state-of-the-art technologies is offering better spatial and spectral resolutions, stereo viewing, on board recording and more frequent revisits.[84] Providing imagery with resolutions of 5 metres in the panchromatic

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[79] Following the failure of the INSAT-1C, ISRO leased 12 transponders on the ARABSAT for a short time. The INSAT-2A came at an opportune time- otherwise there would have been a break in some regional TV services.

[80] A transponder is a device on the satellite which receives radio signals from the ground and then retransmits them. In the 1980s India had only 14 transponders.

[81] The 2A and the 2B probably cost Rs. 100 to 130 crores each.(the INSAT-1D cost $ 80 million some three years back). Imported ones would have cost around Rs. 360 crores or $ 120 million. Gopal N. Raj, Satellite Success, *Frontline*, 25 September 1992.

[82] Standing Committee on Science and Technology, Environment and Forests (1994-95) *Fifteenth Report* (Rajya Sabha Secretariat, February 1995), p. 2.

[83] Although these satellite incorporated a number of imported components and materials, they are basically designed and developed within the country. Indigenous systems used in these satellites are gyros for detecting the spacecraft's orientation on the three axis, the earth and star sensors which can be used to work out the spacecraft's attitude, the reaction control wheels to prevent minor changes in altitude, the thrusters and the sun sensor and the solar array drives to keep the solar panels pointed towards the sun.

[84] *The Hindu* 19 March 1995.

band and 23 metres in multi-spectral bands as well as 188 metre resolution data with wide field coverage, the IRS-1C is the most sophisticated civilian remote sensing satellite in orbit. The IRS data which is now being supplied to end users in several countries, including America and Europe, has been widely appreciated for its quality, range, reliability and cost.

Entry into the Global Market

A notable trend in the evolution of the Indian space programme during this phase has been its entry into the international market. In 1992, Antrix Corporation Limited was established as a commercial wing of ISRO/DOS, to market skills and products of the Indian space programme. A modest target of earning $ 100 million was set for the new organisation for the first five years of its operation. During these years, the main earning of the Antrix has come from providing services and data rather than selling actual products. It has done low and medium elliptical orbit studies for the International Maritime Satellite Organisation, and also made some small antennae for the same group. It has also provided training to operators of satellite systems in several countries in the Third World.

In the mid-1990s, Antrix entered the international market for satellite services and systems. In February 1995, Antrix entered into an agreement with the Earth Observation Satellite Company (or EOSAT, a joint venture between Hughes Aircraft Corp. Division of General Motors Corp. and Martin Marietta Corp.) giving the company the world-wide marketing rights of the IRS data for 10 years.[85] A host of Indian-made ground receiving systems and data processing software are augmenting several ground stations of the EOSAT to receive and process data from IRS satellites. With the largest civilian remote-sensing satellite constellation in orbit,[86] India today is a major player in the market for space based data so far dominated by American (Landsat), French (SPOT), European (ERS-I) and Russian (Resurs-F) satellites.

In the area of satellite communications, India is poised to meet the growing demand

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[85] Antrix will be receiving royalty for the data it sells on Antrix behalf. ISRO had earlier sold data to EOSAT in the past, taken from its IRS IA satellite, to partly off-set the imagery the latter had obtained earlier form the Landsat. *The Hindu*, 17 December 1995.

[86] By 1996, India had four IRS satellites in orbit, the IRS-1B, 1C, P2 and P3 satellites.

for satellites and its services. A beginning in this direction was made in early 1995, when the DOS signed a $ 100 million ten year agreement with the Intelsat organisation for leasing some of the capacity of the INSAT-2E to be launched in 1999[87]. Several others are also interested in leasing out transponders on the INSAT-2 satellites.[88] Antrix has also provided services in the form of orbit raising manoeuvres for Intelsat from ISRO's satellite tracking centre and Panamsat through the master control facility at Hassan.

Even in the area of launch vehicles, strong economic reasons are driving the commercialisation of space launch capabilities. As the head of the ISRO centre SHAR, Dr. Aravamudan says "We must ultimately commercialise our launch facilities, to justify the huge investment we have made on them...Our ultimate aim should be to become a space-faring nation that launches satellites for other countries even as we cater to our own needs".[89] The PSLV project cost Rs. 415 crores which covered, among other things, the cost of facilities for design, fabrication, production and testing of various vehicle systems, and the infrastructure built at Thiruvananthapuram, Mahendragiri and Sriharikota.[90] With each PSLV estimated to cost around Rs 45 crores, there are efforts to recover part of the costs by taking up commercial launches in the international market at 20 to 25 million dollars per launch.[91] ISRO has been eyeing the emerging market for what are termed low earth orbit (LEO) communication satellites.[92] While these satellites will be launched by Western launch firms, PSLV is seen as having bright prospects in satellite replacement market because it is cost effective. Several countries, including China, have evinced interest in sending their payloads aboard the PSLV.[93] The GSLV once it becomes

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[87] The INSAT-2E will be the first satellite to be used by the Intelsat which it does not own

[88] *The Times of India*, (Bangalore) 27 September 1995.

[89] Cited in M.D. Riti, 'Space is the Limit', *The Week*,. April, 3 1994.

[90] *The Hindu*, 16 October 1995.

[91] This is the price ISRO reportedly quoted for launching Motorola LEO satellites in 1993. Gopal N. Raj, 'The PSLV Programme', *The Hindu*, 17 October 1994.

[92] A vast majority of communication satellites, with the exception of a few Russian ones, are in the GSO. With the sudden burst of interest in cellular telephones, several Western communication companies are planning to put up a constellation of LEO satellites for cellular communications. Motorola and Inmarsat alone plan to place in orbit 66 and 40 satellites each in the LEO.

[93] The Chairman of ISRO, Dr. K. Kasturirangan said that China has made 'exploratory' enquiries for using the PSLV. *The Hindu*, 6 December 1995. However, it will be South Korean and German satellites that will be the first foreign satellites to be launched aboard the PSLV. The launching of these research-based satellites in the latter half of 1998 is to commemorate the International Year of Oceans being observed in 1998. Dr. K. Karsturirangan. Cited in *the Hindu* 13 December 1997.

operational, will no doubt be offered on the international market. In fact, with the cost escalation as a result of the technology denials and controls, the urge to commercialise the GSLV is bound to be strong. Whether a vehicle that has been designed to meet the requirement of the 1990s can cope with the increasing trend towards launching larger satellites and intensifying competition, and meet the requirements of the 21st century launcher market remains to be seen.[94]

In the recent past, ISRO has also bagged a few contracts for the supply of hardware for ground systems and space systems. These include data reception and processing hardware, satellite mechanical parts, inertial systems, propulsion elements etc. It has also supplied a Rohini sounding rocket, the RH-300 Mk-II, to the Norwegian Space Agency for conducting scientific experiments in the D and E regions (60-300 kilometers).

4. COMPETITION IN THE CIVILIAN SPACE SECTOR AND THE MTCR

From the above analysis, it is clear that the regime was targeting civilian space programmes under the cover that these would theoretically contribute to long-range missile capabilities. Although India had already acquired an ICBM capability in the form of the PSLV that was in an advanced stage of development, the U.S., the leader of the regime, forced Russia to abrogate the cryogenic technology transfer deal and thereafter erected obstacles in the development of the GSLV. The U.S. interpretation of the linkages between civilian space launchers and military missile programmes is at variance with its own earlier contention and policy. As we observed, the U.S. in an earlier era, when it had monopoly over space launch technologies, had made distinctions between civilian launchers and ballistic missiles to transfer space launch technologies. Even at the time of the imposition of sanctions on India in 1992, the U.S. did acknowledge the fact that the cryogenic engines are not suitable for military use and that the GSLV is not intended for military purposes.[95] Nevertheless it argued that the concerned technology fell within the mischief of the MTCR and that the U.S. laws mandate the imposition of the sanctions.

[94] For details see, Raj, 'ISRO and the Cryo...', n. 66.

[95] These missiles have to be fueled just prior to launch due to the extremely low temperatures of cryogenic fuels viz. minus 182 degree centigrade for liquid oxygen and minus 253 degree centigrade for liquid hydrogen. These have a corrosive effect on missile fuel tanks/engines. Such missiles are obviously not suited for short-notice launches because their fueling operations take time, which would reveal their positions and invite enemy attacks.

Why has the United States adopted a narrow and stricter interpretation of the regime guidelines and its own laws giving effect to them[96] and why was the U.S. willing to risk its relations with Russia and to a lesser extent with India over a technology of little military relevance? The answers can be found in the strategic and economic interests of the United States. In the altered geopolitical conditions of the 1990s, the United States had been trying to control and force the decline of the Russian space industry so that it would pose no future threat to U.S. economic and strategic interests. Blocking the Russian technology transfer deal was a effort in this direction. With respect to India, the U.S. had a limited objective of preventing or at least delaying the emergence of India as a space power and as a competitor in the world market for space services, especially in space launch services. In this section we will examine the economic and commercial interests that are shaping the technology transfer policies of the United States.

Economic and commercial considerations began to impinge on the U.S. space policy and programme quiet early in its evolution. When the U.S. offered to co-operate with other countries in the peaceful uses of outer space in the late 1950s, that decision was dictated by a combination of factors; the necessity of operating a programme that was inherently global in character, utilising the human and financial resources of its allies and above all political and propaganda considerations. This stimulated the interest of several countries, especially those that had a strong scientific and/or technological base. With Europe, Canada, Japan and a few developing countries organising themselves to participate in space explorations, and the U.S. became concerned over giving away technology and inviting competition in the long-run. It therefore restricted the nature and extent of co-operation. As a result, the U.S. space policy towards its allies in Western Europe, that were well placed to exploit space technologies, came to resemble that towards the Soviet Union: co-operation in space science, but decided aloofness in space engineering. This satisfied scientists in Europe but not the European aerospace firms eager to break the American monopoly in launch vehicle and satellites, or the European

[96] The U.S. decision to impose sanctions on ISRO and Glavkosmos was not a unilateral decision of the U.S. but also that of the regime. None of the other members of the regime have opposed the U.S. interpretation and the ensuing sanctions on the Indian and Russian entities. The U.S., in fact, claimed that all the (then)18 members of the MTCR supported the U.S. vote for sanctions. *The Hindu*, 29 April 1992.

parliaments looking for economic and political returns from the money they voted for space.

As civilian applications of space technology became more widespread and as the West European and Japanese made progress in space technology, the United States became increasingly concerned with the emerging competition from these countries in the area of satellites and space launch vehicles. In an effort to protect NASA and American aerospace firms, the U.S. government issued a policy directive, the NSDM-187, in 1972 prohibiting the export of launch vehicle technology.[97] Since then, the NSDM-187 has been the basis for a process of ad hoc case-by-case review of export requests.[98]

As the gap between the U.S. and the emerging space powers narrowed down in the mid-1970s, the United States supplemented its export controls with other policies to retain its leadership in space. Taking advantage of its monopoly in space transportation systems, the United States hampered the entry of these countries into the market for space services and technologies. A typical example of this policy is reflected in the conditions which NASA attached to the launch of Franco-German communication satellites Symphonie I and II. NASA agreed to launch these satellites only on the condition that France and Germany undertook not to use the satellites for commercial purposes. In the absence of an alternative launch services, the two European nations had no choice but to accept these conditions. Similarly, the United States sought to keep Japan out of the space transportation business. An agreement between the Japanese and U.S. governments signed in 1969 and updated in 1976 and later in 1979 permitted the U.S. industry to transfer certain space hardware and related technology to Japan under restricted conditions. The terms of the 1976 revisions to the agreement prohibited Japan from using launchers developed with U.S. technology, to launch payloads for any third country without the consent of the U.S. government. Japan was thus prevented from offering on the world market, the N and M rocket series which incorporated U.S. technology.[99] Such policies

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[97] The public version of the NSDM-187 is 'Launch Assistance for Space Satellite Projects', *Weekly Compilation of Presidential Documents*, vol. 8 (42) 16 October 1972.
[98] Karp, Aaron 'Ballistic Missiles in the Third World', International Security, vol. 9 (3) 1984/85., pp. 166-95.
[99] Stephan F. von Welck, 'The Export of Space Technology: Prospects and Dangers', *Space Policy*, vol. 3 (3), August 1987, pp. 221-231.

helped the U.S. to maintain its dominance in space technology for a long time, but they also accelerated the efforts of Western Europe and Japan in developing their own space systems.[100] The U.S. monopoly in space transportation services ended in 1979 when the European Space Agency launched its Ariane rocket.

Beginning in the early 1980s, commercialisation of space gathered momentum and competition between and within the space faring nations got intensified. By the mid-1980s, governments and private firms were offering a range of products and services on commercial basis. The following chart identifies some of the key areas of commercialisation. Several governments began to establish companies for commercialising and exporting space technologies and services. French firms, Arianespace and Spot-Images began to market space launch services and satellite data. China established the Great Wall Industrial Corporation to offer space launch services. In early 1985, the Soviet Union set up the Glavkosmos for promoting Soviet space equipment and launch services on the world market. Japan began developing the H series of rockets for offer on the international market in the 1990s. Thus, governments which had produced launch vehicles primarily for their own uses, began to produce launch vehicles for direct economic and commercial reasons.

CHART 6.1

AREAS OF SPACE COMMERCIALISATION

Industrial participation in the development of space technology and in building space and ground support	Communication and navigation.	Evaluation exploitation of existing space research results for industrial applications (spin-off effects)
Earth observation / remote sensing	Using space environment (micro-gravity) for R&D and production-processing techniques-material sciences, life science.	Specific services to space activities-launching services-financing-insuring-consulting.

Source: Ralf-Peter Thurbach, 'Overview of the Commercial Space Market', *Space Commerce*, Proceedings of the Second International Conference on Commercial and Industrial Use of Outer Space, Montreux, Switzerland, 21-25 February 1988 (New York, 1988), pp. 21-36.

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100 ibid.

Another important feature of commercialisation of space technologies was the growing participation of the private sector in space industry and business. Private firms in market-dominated economies of U.S., Western Europe and Japan, entered space business, including in the area of space launch vehicles. Otrag, a private German firm, that sought to develop rockets for orbiting satellites on commercial terms heralded the entry of private industry into space launch services. We have noted in an earlier section that in the late 1970s several private firms in the U.S. evinced interest in developing new rockets to meet the growing domestic and international demand for launch services. In addition, there was a growing trend towards the privatisation of launch vehicles which were hitherto operated by NASA or the U.S. Air Force. The U.S. government actively promoted the privatisation of space launchers and in October 1984, the U.S. Congress passed the Commercial Space Launch Act to encourage and support private U.S. companies offering space launch services on a commercial basis.[101]

While the private firms in the U.S. began to develop new rockets or modifying the existing ones for their use in the 1990s, there were only two main contenders in the early 1980s, for taking satellites into geo-stationary orbit- the American Space Shuttle and the Ariane, a launcher developed by the European Space Agency and sold by French company called Arianespace. While the Shuttle was a reusable vehicle capable of carrying people, the Ariane was a expendable launch vehicle (ELV), a standard three stage rocket. The competition between the two has focused attention on the respective costs of spaceflight. The fact that many of the shuttles components can be re-flown time and again should, in theory, make the vehicle cheaper. But the costs of the vehicle were pushed in the opposite direction because it was a versatile piece of machinery trying to be several different entities at once; putting communication satellites in geo-stationary orbit, placing military

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[101] Commercial Space Launch Act of 1984 was designed, among other things, to "encourage the United States's private sector to provide launch vehicles and associated services by simplifying...the issuance...of commercial launch licenses and by facilitating...the utilisation of Government-developed space technology...", Public Law 98-575. Reprinted in Office of Technology Assessment, *International Cooperation and Competition in Civil Space Activities* (Washington DC: 1985), p. 446.

spacecraft into low orbits and carrying people for certain missions.[102] In 1983, a single shuttle mission of a week to ten days cost some $250 million (operational cost) but the eighth shuttle flight in August that year recouped for NASA a fee of a mere $8 million, (or just over three per cent of the total bill for the trip into space)- the fee paid by the Indian government in return for the shuttle taking an Indian communication satellite into orbit.

Competition between the U.S. and Europe came into open in 1984 when NASA offered to launch one tonne payloads at $16 million giving the Shuttle a distinct price advantage over Ariane which cost $24 million. This agitated Ariane's backers who pointed to the huge government subsidies which financed Shuttle flights. When Ariane itself reduced the prices for launching American satellites, the fledgling ELV firms in the U.S. charged the Arianespace with unfair trade practices and called for action under U.S. Trade Act of 1974.[103] The U.S. Administration however found that "ESA practices are not sufficiently different from those of the U.S. to be actionable under Section 301".[104]

While the U.S. Shuttle faced competition from abroad (that is, Ariane), the ELV industry at home was not happy either. Although the U.S. government committed itself to the promotion of domestic private space launchers, the privatisation of ELV rockets such as the Delta, Atlas-Centaur and Titan and others that were under development was handicapped by the price competitiveness of the Shuttle. This situation prevailed until the

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[102] The costs escalated because among other things, the Shuttle could climb no higher than about 700 kilometer from earth...Satellites required to enter higher orbits must be boosted into their trajectory by an upper-stage rocket inside the shuttles cargo bay. In addition, the Shuttle carried oxygen systems, waste disposal facilities and other mechanical paraphernalia needed to keep people alive which added to the costs of what is, after all, the fairly simple job of placing satellites into space. Peter Marsh, *The Space Business: A Manual on the Commercial Uses of Space* (London, 1985), pp. 194-5.

[103] Transpace Carriers, the U.S. space transportation company offering Delta launcher, charged the Arianespace with unfair trade practices. In its June 1984 petition filed with the U.S. Trade Representative's Office, Transpace Carriers charged the European Space Agency (ESA) member states (particularly France) with subsidising Arianespace in its provision of expendable launch services. Its complaint, among other things, objected to Arianspace's two-tiered pricing structure (lower for non-European buyers) and the subsidised provisions of launch and range facilities, services, and personnel. The complaint asked the U.S. President to negotiate for an end to such practices, in the meantime to bar Arianespace from marketing its services in the U.S., and to impose economic penalties against ESA-country imports under Sec. 301 of the Trade Act of 1974.

[104] Presidential Documents, Memorandum of 17 July 1985, *Federal Register*, vol. 50 (140).

mid-1980s when a series of disasters encountered by the Shuttle fleet[105] forced the U.S. government to abandon its policy of sole reliance on the Space Shuttle and adopt a range of measures to promote and protect the domestic ELV industry. The first step in this direction was to prohibit the Shuttle from carrying commercial payloads that can be launched on the unmanned ELVs. The U.S. government created a domestic market for the ELV manufactures by restricting the government payload launches to U.S. vehicles. The domestic ELV industry was further strengthened through defence contracts. The Defence Departments shift from its reliance on the Shuttle to ELVs such as the Titan- IV for its future launch requirements and the various weapons development programmes of the 1980s, such as the SDI and ATBM programmes, were aimed at strengthening the domestic ELV industry.[106] Through such large military orders, it was hoped that "the major vehicle manufactures will realise economies of scale, reducing operating costs while improving methods of production, develop advanced vehicles through internal R&D efforts, and adapt the vehicles developed for the Defence Department for commercial purposes".[107]

The Shuttle disaster boosted the ELV industry abroad as well. After the Challenger disaster of 1986, many Shuttle customers looked around desperately for launchers. With the ELV firms yet to take off, many customers including the American companies signed up with the Ariane (Arianespace had chalked up outstanding orders to launch 43 satellites through to 1991) while at the same time attention was focused on new possibilities, Japan, China and Soviet Union. When the Ariane V-I8 failed in May 1986, the market became wide open. While China and the Soviet Union entered the fray with renewed vigour, and people looked even further afield, with reports that Japan was in the market and that India

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[105] The Challenger mission in February 1984 ended in a failure, launching the satellites owned by Western Union and Indonesian governments into wrong orbits. The launch of Discovery, the third member of the Shuttle fleet, got postponed after two aborted attempts to get it off the ground in June 1984. Another Challenger mission in January 1986 ended in disaster with the Shuttle blowing up.

[106] A study in 1982, which laid the foundation of the SDI made it clear that one of the objectives of the 'high frontier' was to "provide...incentives for realizing the enormous industrial and commercial potential of space" Lt. General Daniel O. Graham, *High Frontier: A New National Strategy* (Washington, D.C., 1982), p.3.

[107] Henry R. Hertzfeld, 'Economic Issues Facing the United States in International Space Activities, in V. Lopez and D. Vadas, eds., *The U.S. Aerospace Industry, A Global Perspective for the 1990s* (Washington D.C., September 1991).

and even Brazil soon would be.[108] With new players making a bid to enter the space launcher business, the U.S. sought to establish and regulate the space launcher business favourable to the domestic ELV industry. With export restrictions already in place against the Soviet Union, the U.S. raised the issue of 'technology transfer' to prevent Glavkosmos from entering the launcher market.[109]. In the late 1980s, when a Soviet firm, Technopribor and a Texas based firm in the U.S., Space Commerce Corporation (SSC) initiated the START project to launch American satellites aboard the modified SS-20 missile that had been scrapped under the INF Treaty, the U.S. officials expressed concerns over security issues arising from the project, while the private ELV firms accused the SSC of helping a centrally planned economy to 'dump' low-cost launch services on Western markets.[110]

The argument that launch services provided by centrally planned economies constituted unfair trade practices was also advanced against China. In the latter half of the 1980s, with the access to outer space limited by the Challenger disaster and failure of the three workhorse ELVs, the U.S. relaxed export restrictions vis-à-vis China, permitting its Long March vehicle to carry American satellites. In the interest 'national security and fair trade,' the U.S. struck a deal with China in the late 1980s by which it agreed to license several satellites built by the Hughes Aircraft Company, an American enterprise, for launch on Long March vehicles on the condition that the Chinese alter their pricing policy after a few discount-price launches and adopt launch-preparation practices that reduce the chances of their surreptitiously gaining technical knowledge from Western payloads.[111] In 1990, when China outbid the Western launchers companies in the Asian satellite market

[108] As one observer noted " the objection of the U.S. is more to ensure that its fledgling ELV companies do not lose business -and face- to the Soviets". Tim Furniss, 'World Launcher Market', Paper presented at the Second International Conference on Commercial and Industrial Use of Outer Space, Montreux, Switzerland, 21-25 February, 1988. Proceedings published as *Space Commerce* (New York, 1988), p. 247.
[109] ibid.
[110] In 1989, the Soviet space agency had arrived at an understanding with U.S. space launch services firm, Space Commerce Corporation (SSC) based in Houston, to develop and market 'START' a new commercial launch vehicle based on the SS-20 missile. The START proposal was intended to be the first step in the practical implementation of a long-term conversion process as outlined by the Soviet leader Mikhail Gorbachev to facilitate the nations military-industrial complex to make a transition into commercial activities. Michael Potter, 'Swords into Ploughshares: Missiles as Commercial Launchers', *Space Policy*, vol. 7 (2) May 1991., pp. 146-150.
[111] John M. Logsdon and Ray A. Williamson, 'U.S. Access to Space', *Scientific American*, vol. 260 (3) March 1989., pp. 18-24.

for launching the Asiasat, at half the fee charged by the West, the U.S. raised objections. It ordered the American companies not to supply any space related technology to China. Using trade and other pressures, the U.S. finally succeeded in disallowing China to outbid the U.S. firms out of the launcher market by signing an MOU with China in early 1995. According to the MOU, "the PRC will take steps to ensure that its providers do not materially impair the smooth and effective functioning of the international market for commercial launch services. Among these steps, the PRC will ensure that any support to its providers is in line with the practices of market economies". China will now have to maintain insurance charges at par with the Western companies, a step which is likely to erode its competitive edge.[112]

With the U.S. government taking active interest in the promotion of the domestic ELV industry, the first flight of a private ELV took place in 1989. But by then, competition in the launcher market had got intensified and new players such as India emerged on the horizon. The U.S. launchers had by the early 1990s, lost a huge chunk of the market to Europe's Arianespace and future prospects were disturbing. For instance, in 1992-93, as many as 22 of the 43 civilian satellites placed in the orbit were by Ariane; the rest were shared by the American, Chinese and Russian launchers. Besides, once the huge backlog with them is cleared by 1996-97, global communication systems are expected to get saturated.[113] With the Europeans looking towards Europe to launch their own satellites, the U.S. launcher firms turned to the Asia-Pacific countries, where the demand for satellites was expected to grow.[114] It is here that the emerging new players-China, Japan and even India -posed a challenge. With their low costs, these new entrants could undercut the established players and corner the market as China was already doing. The U.S. actions under the MTCR, such as the technological hurdles erected in the development of the GSLV, are thus strongly motivated by commercial and industrial considerations.

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[112] *The Hindu*, 16 October 1995.
[113] Pransanna, 'Launcher Game', n. 46.
[114] India alone, for instance, is planning to launch about 15 application satellites in the 1990s.

5. CONCLUSION

India became a target of the Missile Technology Control Regime in 1989, when it first test launched the Agni, an experimental IRBM Since then India was not only subjected to export controls of the regime but intense political and economic pressures to halt the deployment of the Prithvi missile and freeze the Agni project. As we saw, the development of the GSLV in the civilian space sector has been pushed back by nearly a decade resulting in continued dependence on foreign launchers. Apart from the high costs that India has to bear for orbiting its INSAT -II satellites on foreign launchers, the obstacles placed in the development of the GSLV have resulted in the soaring of the costs of the programme. In the military sector, technology denials and controls did not have comparable adverse effects given that both the Prithvi and Agni were well beyond the development stage when the regime came to target India. Nevertheless, because the missiles incorporated some imported components as well as because of the political pressure brought on India by the regime to cap and roll back its missile programme, the pace of missile development efforts came to be affected.

As we saw, strong industrial and commercial interests are shaping the technology transfer policies of the industrial nations. The US attempts to erect hurdles in the development of the GSLV are clearly aimed at preventing or at least delaying the entry of Antrix into the already competitive launcher business. Industrial interests are also playing an important role in demonising Third World ballistic missiles and calling for appropriate military responses to this development. For instance, General Dynamics Corporation, the U.S. firm engaged in the manufacture of a variety of rockets, such as the Tomahawk missiles and Atlas-Centaure launchers projected a astonishing scenario for South Asia in the post-cold war period. In the National Journal of 6 April 1991, it argued that India would be making nuclear strikes against Pakistan by 2000 AD and the U.S. should, therefore, stop India from resorting to such strikes by firing 190 cruise missiles from submarines, ships and B-52 bombers at a wide range of Indian targets while holding more missiles in reserve. General Dynamics later apologised to that Indian Ambassador to the US saying that it never meant to imply that India was a 'aggressive nation' or a possible target for the US military planning[115], but the incident is indicative of the role played by private rocket firms in shaping American policy in high technology areas.

[115] G.V. Gopalakrishnan, 'Hi-Tech is Neutral' *The Hindu*, 28 June 1997.

CHAPTER SEVEN

CONCLUSIONS

In sharp contrast to the models existing elsewhere, that had military or political objective at the forefront, the Indian space programme and policy laid emphasis on realising the benefits of space technology and applications for the economic development of the country. The formal launching of the Indian space programme in 1961 was in many ways an extension of the studies begun long ago, on understanding the scientific phenomena encountered in outer space. It however, represented a departure in that the programme was not exclusively confined to scientific research but aimed at tapping the potential of space technology for national development. As the space powers made rapid progress in satellite technologies bringing out the economic potential of these technologies, Indian planners became convinced of the relevance of space technologies for a developing country of the size and diversity of India. Recognising the potential of the space technologies for accelerating national development and pitchforking the country into a higher level of economic activity and social development, the Indian leadership made a firm commitment to outer space activities in the mid-1960s. With the Thumba sounding rocket launching station that became operational in 1963 serving as the core, space activities multiplied and spread, offering a variety of services and stimulating industrialisation. Space technology and its applications have enabled the country to strengthen its economy, reduce external dependence, develop more autonomy in international relations, and acquire greater control over its economy and capacity for autonomous development.

Equally important, they are providing a number of technology related strategic choices to deal with the national security challenges facing the country. Despite its civilian thrust, the space programme had to contend with a significant military push. The diffusion of nuclear and advanced conventional weaponry in country's immediate neighbourhood, particularly Pakistan and China with which India has had adversarial relations contributed to these pushes and pulls. The first major push came in the mid-1960s itself, when in response to the nuclear explosion conducted by China in October 1964, the Indian government revised its nuclear policy and reserved the option to go nuclear. It is in this context that the military potential of the nascent space programme attracted attention. Since then, the space programme came to be seen as a civilian-oriented but defence-related programme. Thereafter, continuing testing by China and advances made by it in rocketry kept alive the debate on India's nuclear option and strengthened the advocates of the military use of space technologies. Another push came in the later half of the 1970s as a result of the military-technological revolution in the form of precision guided munitions. With the PGMs bringing about qualitative changes in the battlefield environment, various types of rockets, including long-range missiles, acquired importance from the conventional defence point of view.

In the early 1980s, taking advantage of the growing technological capabilities within the country, the Government of India decided to establish design and production capabilities for guided missiles within the country to meet the perceived immediate and future needs of the armed forces for the defence of the country. That decision was strengthened by the belief that achieving self-reliance in critical technologies and weapon systems in a selective manner would not only meet the military security requirement but also reinforce and strengthen the country's capabilities in dual-use technologies and therefore its development of high-technology. The IGMDP, set up under the aegis of the DRDO, the primary source of all R&D within the country, was charged with the task of developing a variety of missiles. Utilising the missile R&D base that was already present in the DRDO and deriving sustenance and strength from industrial and technological infrastructure established by the civilian space programme, the IGMDP achieved quick results. Within a short span of seven years, the IGMDP developed a variety of guided missiles and established the country's capability for indigenous production of long-range ballistic missiles.

It was the development of the Agni, an experimental intermediate-range missile, that brought India in direct confrontation with the MTCR, an ad hoc and discriminatory technology control mechanism set up by the G-7 countries. India rejected the arms control approach adopted by these countries to deal with the problem of ballistic missile proliferation as inadequate and discriminatory and went ahead with the testing of the Agni in 1989. With this, India became a country of proliferation concern for the regime. The MTCR member countries restricted technology transfers to India and brought pressure on other non-member states to do the same. They supplemented these technology transfer restrictions with intense political and economic pressures to achieve three closely related objectives with regard to India: limiting India's technological capabilities, capping of India's missile programme with the eventual objective of rolling it back, and gaining India's adherence to the regime's norms and guidelines.

In this study, we have focused on the impact of the regime's technology restrictions on India's security and development programmes. A significant finding of this study is that the impact of technology controls has been more on the civilian projects than on the country's missile development efforts. This is primarily because the Indian missiles, Prithvi and Agni, over which the MTCR members expressed concern, had already passed the development stage when export restriction came into effect. On the other hand, ISRO's project, the GSLV launch vehicle that was at an early stage of development, was most vulnerable to the regime's technology transfer restrictions. Although the cryogenic engine technology used in the upper stages of the GSLV is of little military significance, the United States as the leader of the regime, brought intense pressure on Russia in the early 1990s, forcing the latter to cancel the ISRO-Glavkosmos cryogenic technology transfer deal. The result was that India's plans to operationalise the GSLV in the latter half of the 1990s were pushed back by at least a decade. The two-year sanctions imposed on ISRO had a wider impact on several on-going space projects. Thereafter, the US strengthened its technology control mechanism by erecting hurdles in the indigenous development of the cryogenic engine. The recently enforced controls against specific entities or end-users (research laboratories, industrial units, academic centers) which supplement the earlier export controls on specific items of proliferation concern, are clearly aimed at achieving this objective. Apart from delaying the project, technology restrictions have led to an increase in the total cost of the programmes by provoking a search for autonomous alternatives, such as the development and production of indigenous components and equipment. Beyond these areas, restrictions have also affected the flow of services and the development of co-operative ventures.

The MTCR has emerged as a gnawing impediment to India's realisation of its two major goals: the development of an independent launch capability that is necessary for deriving the benefits of space applications on a reliable and low-cost basis; and building of a missile deterrent capability against China and Pakistan and against extra-regional power that can strike its territory. The selective and ad hoc nature of the regime as well as the its efforts to obstruct the country's civilian space programme have strengthened the support base for high-technology programmes. Technology controls have compelled the Indian planners to locally develop the technologies, components and equipment denied to them. Efforts to mitigate the financial burden imposed by forced indigenisation efforts are resulting in the strengthening of linkages between the government, industry, and research and academic institutions. Symbiotic linkages between civilian and military programmes, that are characteristic of high-technology programmes in the advanced countries of the North, are gradually emerging in the country, the nascent phase of which is visible in the efforts to develop air breathing engines for the reusable aerospace plane, a high cost futuristic project that is at the conceptual stage.

While the impact of technology restrictions on the country's missile programme was relatively less as compared to the civilian programmes, the missile programme was also vulnerable to technology restrictions, though it is difficult to assess the extent of this vulnerability. More important, the political instability and economic crisis that the country has witnessed since the late 1980s, made the country vulnerable to external pressures, resulting in postponement of crucial decisions and making concessions inconsistent with the country's security interests. The industrialised countries of the North exercised their leverages on the human rights issue in Kashmir, India's adherence to the NPT, the CTBT and the norms established by the dual-use technology regimes to cap India's missile programme and nearly succeeded. Despite the evidence of the Sino-Pak missile co-operation, governments surviving with wafer thin majorities or with support from parties outside the government, were paralysed by the warnings issued by the United States and other members of the MTCR on missile development and deployment. They could not utter the word 'deployment' in relation to the Prithvi; instead they talked about 'induction'. The Agni 'technology demonstrator' project which took five long years was put on hold after the completion of the fourth and final test conducted in 1994. Even in the area of civilian space programme, crucial decisions were delayed. The indigenous development of the cryogenic engine technology did not receive adequate support until Russia backed out of the cryogenic technology transfer deal in mid-1993.

In the absence of purposeful action on strategic programmes, the country could not derive security or political benefits from its growing technology prowess. This caused the missile R&D to lag behind schedule, but more important the country's security options got restricted, as proliferation of nuclear and missile capabilities went on unabated and as pressures mounted on India to adhere to the non-proliferation norms established by the big powers. It is in this context that the present government carried out a series of five nuclear tests on May 11 and 13 to establish the country's capability for producing a variety of nuclear weapon devices and carrying out sub-critical non-explosive tests. The government has also granted clearance for the development of 'extended range' version of the Agni missile.

New technology embargoes imposed by the industrialised nations, particularly the United States, in the wake of nuclear tests are unlikely to have any significant effect on the country missile development efforts. The warnings given to India not to go ahead with the testing of long-range missiles are unlikely to deter India in building such a force. India can take advantage of defensive missile programmes against which the MTCR members are less concerned to develop and test longer range missiles. Moreover, it also has the option to take advantage of its civilian space launch programme to develop and test such missiles. External efforts to limit India's missile capabilities through technology controls will impose restrictions on the country's efforts to integrate with the global economy; but by provoking autonomous development efforts, technology controls will only serve to further strengthen the linkages between the civilian and military programmes in the country.

While targeting India's civilian space projects, the members of the MTCR also began to express concern over the emergence of India as a potential second-tier supplier of missile hardware and technologies. The United States, as part of its broader strategy to build greater legitimacy for the technology control regimes has openly sought India's compliance with the guidelines of the MTCR and other technology control cartels. India 's publicly stated position is that even while it is committed to preventing proliferation, it opposes discriminatory and ad hoc regimes which implicitly (and in the case of the NPT, explicitly) allow some nations to have a certain class of weapon systems that others are forbidden to have. It is significant to note that India's opposition to the MTCR, and even NPT, is mainly due to their discriminatory character and not because of the provision of technology controls. India has supported 'non-discriminatory' regimes, such as the biological weapons convention and chemical weapon convention which involve weapon system prohibition for all states. Given this position as well as given that India remains the target of the MTCR, India can neither join the MTCR nor enact national laws that incorporate multilateral export-control standards, procedures and lists commonly used by Western suppliers. Consistent with its policy, India would rather go in for a formal universal treaty of the kind for prohibiting the use of Chemical and Biological weapons, which governs missile production, stockpiling, use or transfers.

However, given the rapid expansion of Indian space industry in the last decade or so and the commercialisation of space technologies that has gathered momentum, there is a strong need for India to establish its own export control machinery. This is necessary not only to strengthen the image of the country as a responsible exporter, but also to address the security concerns that it has expressed over the proliferation of missiles. A selective transfer of technology in this area can also enable India to derive maximum value from the technologies developed so painstakingly by it over a period of time, as well as foreign policy benefits.

The limitations of the selective and ad hoc technology controls regime in dealing with the problem of dual-use technologies and the spread of ballistic missiles became obvious in the early years of the MTCR. Several concrete proposals to manage the use and transfer of dual-use technologies have emerged both within the member countries of the regime as well as outside. These fall under two broad categories; those that seek to eliminate ballistic missiles on a universal and non-discriminatory basis and those that seek to evolve other forms of control regime or mechanism governing the production, stockpiling, transfer and use of ballistic missiles, thus ensuring co-operation in civilian space launchers. However, neither of these approaches has gained wide support among the member countries of the regime. This is not surprising given the strong military, industrial and commercial considerations that have come to dominate policy making in high-technology areas. As we saw, the promotion of fledgling private launch vehicle industry in the West has acted as an important constraint in establishing a global system for technology sharing. In the last ten years or so, the private launch vehicle industry in the West has matured. Beginning in 1989, the ELV industry in the U.S. has totalled over 70 commercial launches[1]. The United States is also poised to attain a launch-on-demand capability in the next decade or so[2]. Given this, as the leader of the regime, the U.S. should seize the opportunity to transform the MTCR into a formal, legally binding regime governing the production, stockpiling, use and transfer of ballistic missile technologies. Without this, the MTCR, instead of serving the purpose of its adherence to stop the nuclear and ballistic missile proliferation may result in creating further tension and introducing greater instability in international relations.

[1] NASA, *Aeronautics and Space Report of the President, Fiscal Year 1996 Activities* (Washington D.C.: 1996), p. 34.
[2] *Jane's Defence Weekly*, 26 November 1997.

APPENDIX-1

MTCR Documents

STATEMENT BY THE ASSISTANT TO THE PRESIDENT FOR PRESS RELATIONS, THE WHITEHOUSE, 16 APRIL 1987

The President is pleased to announce a new policy to limit the proliferation of missiles capable of delivering nuclear weapons. The US Government is adopting this policy today in common with the governments of Canada, France, the Federal Republic of Germany, Italy, Japan, and the United Kingdom. These nations have long been deeply concerned over the dangers of nuclear proliferation. Acting on this concern, these seven governments have formulated Guidelines to control the transfer of equipment and technology that could contribute to nuclear-capable missiles. This initiative was completed only recently, following several years of diplomatic discussions among these governments. The fact that all seven governments have agreed to common guidelines and to a common annex of items to be controlled serves to prevent commercial advantage or disadvantage for any of the countries. Both the Guidelines and the Annex will be made available to the public.

The President wishes to stress that it is the continuing aim of the United States Government to encourage international cooperation in the peaceful uses of modern technology, including in the field of space. The Guidelines are not intended to impede this objective. However, such encouragement must be given in ways that are fully consistent with the non-proliferation policies of the US Government.

The Untied States, and its partners in this important initiative, would welcome adherence of all states to these guidelines in the interest of international peace and security.

MISSILE TECHNOLOGY CONTROL REGIME: FACT SHEET TO ACCOMPANY PUBLIC ANNOUNCEMENT

The United States Government has, after careful consideration and subject to its international treaty obligations, decided that, when considering the transfer of equipment and technology related to missiles whose performance in terms of payload and range exceeds stated parameters, it will act in accordance with the attached Guidelines beginning on April 16, 1987.

GUIDELINES FOR SENSITIVE MISSILE-RELEVANT TRANSFERS

1. The purpose of these Guidelines is to limit the risks of nuclear proliferation by controlling transfers that could make a contribution to nuclear weapons delivery systems other than manned aircraft. The Guidelines are not designed to impede national space programmes or international cooperation in such programmes as long as such programmes could not contribute to nuclear weapons delivery systems. These Guidelines, including the attached annex, form the basis for controlling transfers to any destination beyond the Government's jurisdiction or control of equipment and technology relevant to missiles whose performance in terms of payload and range exceeds stated parameters. Restraint will be exercised within the annex and all such transfers will be considered on a case-by-case basis. The Government will implement the guidelines in accordance with national legislation.

2. The Annex consists of two categories of items, which term includes equipment and technology. Category I items, all of which are in annex items 1 and 2, are those items of greatest sensitivity. If a Category I item is included in a system, that system will also be considered as a Category I, except when the incorporated item cannot be separated, removed or duplicated. Particular restraint will be exercised in the consideration of Category I transfers. And there will be a strong presumption to deny such transfers. Until further notice, the transfer of Category I production facilities will not be authorized. The transfer of other Category I items will be authorized only on rare occasions, and

where the Government (a) obtains binding government-to-government undertakings embodying the assurances from the recipient government called for in paragraph 5 of these Guidelines; and (b) assumes responsibility for all steps necessary to ensure that the item is put only to its stated end-use. It is understood that the decision to transfer remains the sole and sovereign judgment of the supplying government.

3. In the evaluation of export applications for Annex items, the following factors will be taken into account:

A. Nuclear proliferation concerns

B. The capabilities and objectives of the missile and space programmes of the recipient state;

C. The significance of the transfer in terms of the potential development of nuclear weapons delivery systems other than manned aircraft;

D. The assessment of the end-use of the transfers, including the relevant assurance of the recipient states referred to in subparagraphs 5.A and 5.B below.

E. The applicability of relevant multilateral agreements.

4. The transfer of design and production technology' directly associated with any items in the Annex will be subject to as great a degree of scrutiny and control as will be equipment itself, to the extent permitted by national legislation.

5. Where the transfer could contribute to nuclear weapons delivery systems, the Government will authorise transfers of items in the annex only on receipt of appropriate assurances from the Government of the recipient state that

A. The items will be used only for the purpose stated and that such use will not be modified nor replicated without the prior consent of the Government;

B. Neither the items nor replicas nor derivatives thereof will be retransferred without the consent of the Government.

6. In furtherance of the effective operation of the Guidelines, the Government will, as necessary and appropriate, exchange relevant information with other Governments applying the same guidelines.

7. The adherence of all States to these Guidelines in the interest of international peace and security would be welcome.

SUMMARY OF THE EQUIPMENT AND TECHNOLOGY ANNEX

(Only the full text of the Annex is authoritative, and it should be consulted for precise details)

Category I

Complete rocket systems (including ballistic missile systems, space launch vehicles, and sounding rockets) and unmanned air vehicle systems (including cruise missile systems, target drones, and reconnaissance drones) capable of delivering at least a 500 kg payload to a range of at least 300 km as well as the specially designed production facilities for these systems.

Complete subsystems usalbe in the systems in item I , as follows, as well as the specially designed production facilities and production equipment therefor :

- Individual rocket stages
- Re-entry vehicles;
- Solid or Liquid fuel rocket engines;
- Guidance sets; Thrust vector controls;
- Warhead safing, arming, fuzing, and firing mechanisms.

Category II

- Propulsion components.
- Propellant and constituents.
- Propellant production, technology and equipment.
- Missile structural composites: production technology and equipment.
- Pyrolytic deposition/densification technology and equipment.
- Structural materials.
- Flight instruments, inertial navigation equipment, software, and production equipment.
- Flight control systems.
- Avionics equipment.
- Launch/ground support equipment and facilities.
- Missile computers.
- Analogue-to-digital converters.
- Test facilities and equipment.

- Software and related analogue or hybrid computers.
- Reduced observable technology, materials, and devices.
- Nuclear effects protection.

EQUIPMENT AND TECHNOLOGY ANNEX

1. Introduction

(a) This annex consists of two categories of items, which term includes equipment and technology. Category I items, all of which are in Annex Items 1 and 2, are those items of greatest sensitivity. If a Category I item is included in a system, that system will also be considered as Category I, except when the incorporated item cannot be separated, removed or duplicated. Category II items are those items in the Annex not designated Category I.

(b) The transfer of design and production technology directly associated with any items in the Annex will be subject to as great a degree of scrutiny and control as will the equipment itself, to the extent permitted by national legislation.

2. Definitions

For the purpose of this Annex, the following definitions shall apply:

(a) The term technology means specific information which is required for the development, production or use of a product. The information may take the form of technical data or technical assistance.

(b)(I) *Development* is related to all stages prior to serial production such as
- design
- design research
- design analysis
- design concepts
- assembly and testing of prototypes
- pilot production schemes
- design data
- process of transforming design data into a product
- configuration design
- integration design
- layouts

2) *Production* means all production stages such as
- production engineering
- manufacture
- integration
- assembly (mounting)
- inspection
- testing
- quality assurance

3) *Use* means
- operation
- installation (including on-site installation)
- maintenance (checking)
- repair
- overhaul and refurbishing

(c)(1) *Technical data* may take forms such as blueprints, plans, diagrams, models, formulae, engineering designs and specifications, manuals and instructions written or recorded on other media or devices such as disk, tape, read-only memories.

(2) *Technical Assistance* may take forms such as
- instruction
- skills
- training
- working knowledge
- consulting services

(d) Note: This definition of technology does not include *technology in the public domain* nor *basic scientific research.*

(1) *In the public domain* as it applies to this Annex means technology which has been made available

without restrictions upon its further dissemination. (Copyright restrictions do not remove technology from being in the public domain).
(2) *Basic scientific research* means experimental or theoretical work undertaken principally to acquire new knowledge of the fundamental principles of phenomena and observable facts, not primarily directed towards specific practical aim or objective.
(e) The term *production facilities* means equipment and specially designed software therefor integrated into facilities for prototype development or for one or more stages of Serial production.
(f) The term *production equipment* means tooling, templates, jigs, mandrels, moulds, dies, fixtures, alignment mechanisms, test equipment, other machinery and components thereof, limited to those specially designed or modified for prototype development or for one or more stages of serial production.

ITEM 1- CATEGORY I

Complete rocket systems (including ballistic missile systems, space launch vehicles, and sounding rockets) and unmanned air vehicle systems (including cruise missile systems, target drones, and reconnaissance drones) capable of delivering at least a 500 kg payload to a range of at least 300 km as well as the specially designed production facilities for these systems.

ITEM 2 - CATEGORY I

Complete subsystems usable in the systems in Item 1, as follows, as well as the specially designed production facilities and production equipment therefor:

(a) Individual rocket stages;
(b) Reentry vehicles, and specially designed equipment therefor, as follows, except as provided in note (1) below for those designated for non-weapons payloads:
(1) Heat shields and components thereof fabricated of ceramic or ablative materials;
(2) Heat sinks and components thereof fabricated of light-weight, high capacity materials:
(3) Electronic equipment specially designed or modified for reentry vehicles;
(c) Solid or liquid fuel rocket engines, having a total impulse capacity of 2.5 x 10^5 lb-sec or greater, except as provided in note (1) below for those specially designed or modified for orbital correction of satellite;
(d) Guidance sets capable of achieving system accuracy (CEP) of 10 km or less at a range of 300 km, except as provided in note (2) below for those designed for missiles with range under 300 km or manned aircraft;
(e) Thrust vector controls, except as provided in note (2) below for those designed for rocket systems with range under 300 km;
(f) Warhead safing, arming, fuzing, and firing mechanisms, except as provided in note (1) below for those designed for systems other than those in Item 1.

Notes to Item 2:
(1) The exceptions in (b), (c), (d), (e) and (f) above may be treated as Category 11 if the subsystem is exported subject to end use statements and reentry limits appropriate for the excepted end use stated above.
(2) CEP (circular error probability) is a measure of accuracy of the radius of the circle centered at the target, at a specific range, in which 50 per cent of the payloads impact.

ITEM 3- CATEGORY II

Propulsion components and equipment usable in the systems in Item I, as follows, as well as the specially designed production facilities therefor:

(a) Lightweight turbojet and turbofan engines (including turbocompound engines) that are small and fuel efficient;
(b) Ramjet/Scramjet engines, including devices to regulate combustion, and specially designed production equipment therefor;
(c)Rocket motor cases and specially designed production equipment therefor;
(d) Staging mechanisms and specially designed production equipment therefor;
(e) Liquid fuel control systems and components therefor, specially designed to operate in vibrating environments of more than 12g rms between 20Hz and 2000Hz including:
(1) Servo valves designed for flow rates of 24 liters per minute or greater at a pressure of 250 bars, and having flow contact surfaces made of 90 percent or more tantalum, itanium or zirconium, either separately or combined, except when such surfaces are made of materials containing more than 97 percent and less than 99.7 percent titanium;
(2)Pumps (except vacuum pumps) having all flow contact surfaces made of 90 percent or more

tantalum, titanium or zirconium, either separately or combined, except when such surfaces are made of materials containing more than 97 percent and less than 99.7 percent titanium.

Notes on Item 3:

(1) Item 3(a) engines may be exported as part of a manned aircraft or in quantities appropriate for replacement parts for manned aireraft.

(2) Item 3(c) systems and components may be exported as part of a satellite.

ITEM 4- CATEGORY II

Propellants and constituent chemicals for propellants *as* follows:

(a)Propulsive substances:

(1) Hydrazine with a concentration of more than 70 percent;

(2) Unsymmetric dimethyihydrazine (UDMH);

(3) Spherical ammonium perchlorate with particles of uniform diameter less than 500 microns;

(4) Spherical aluminum powder with particles of uniform diameter of less than 500 microns and an aluminum content of 97 percent or greater;

(5)Metal fuels in particle sizes less than 500 microns. whether spherical, atomized, spheroidal, flaked or ground, consisting of 97 percent or more of any of the following: zirconium, titanium, uranium, tungsten, boron. zinc, and alloys of these; magnesium; Misch metal;

(6)Nitro-amines (cyclotetramcthvlene-tetranitramine (UNIX), cyclotetramethylenetrinitramine (RDX) when specially' formulated as propulsive substances

(b)Polvmeric substances:

(1) Carboxy-terminated polybutadiene (CTPB);

(2)Hydroxy-terminated polybutadiene (HTPB);

(c) Composite propellants including molded glue propellants and propellants with nitrated bonding and aluminum content in excess of 5 percent.

(d) Other high energy density fuels such as Boron Slurry, having an energy density of 40 x 106 joules/kg or greater.

ITEM 5- CATEGORY II

Production technology or production equipment specially designed or modified for production, handling, mixing, curing, casting, pressing, machining and acceptance testing of the liquid or solid propellants and propellant constitutes as described in Item 4.

ITEM 6- CATEGORY II

Equipment, technical data and procedures for the production of structural composites usable in the systems in Item 1 as follows, and specially designed components and accessories and specially designed software therefor:

(a) Filament winding machines of which the motions for positioning, wrapping and winding fibres are coordinated and programmed in three or more axes, specially designed to fabricate composite structures or laminates from fibrous and filamentary materials; and coordinating and programming controls;

(b) Tape-laying machines of which the motions for positioning and laying tape and sheets are coordinated and programmed in two or more axes, specially designed for the manufacture of complete airframes and missile structures;

(c) Interlacing machines, including adapters and modification kits for weaving, interlacing or braiding fibres to fabricate composite structures, except textile machinery which has not been modified for the above end-uses;

(d)Specially designed or adapted equipment for the production of fibrous and filamentary materials as follows:

(1) Equipment for converting polymeric fibres (such as polyacrylonitrile, rayon, or polycarbosilane) including special provision to strain the fibre during heating;

(2) Equipment for the vapor deposition of elements or compounds on heated filamentary substrates; and

(3) Equipment for the wet-spinning of refractory ceramics such as aluminum oxide);

(e).Specially designed or adapted equipment for special fibre surface treatment or for producing prepregs and preforms. Note: Equipment covered by this sub-item includes but is not limited to rollers, tension stretchers, coating equipment, cutting equipment and clicker dies.

(f) Technical data (including processing conditions) and procedures for the regulation of temperature, pressures or atmosphere in autoclaves when used for the production of composites or partially processed composites.

Note to Item 6: Specially designed or adapted components and accessories for the machines covered by this entry include, but are not limited to, moulds, mandrels, dies, fixtures and tooling for the preform pressing, curing. casting, sintering or bonding of composite structures, laminates and manufacture thereof.

ITEM 7 - CATEGORY II

Pyrolytic deposition and densification equipment and technology as follows:

(a)Technology for producing pyrolytically derived materials formed on a mold, mandrel or other substrate from precursor gases which decompose in the 1300 CC to 2900 CC temperature range at pressures of 1 mm Hg to ~50 mm Hg (including technology for the composition of precursor gases, flow-rates, and process control schedules and parameters);

(b) Specially designed nozzles for the above processes;

(c) Equipment and process controls, and specially designed software therefor, specially designed for densification and pyrolysis of structural composite rocket nozzles and reentry vehicle nose tips.

ITEM 8 - CATEGORY II

Structural materials usable in the systems in Item 1, as follows:

(a)Composite structures, laminates, and manufacturing thereof, including resin impregnated fibre prepegs and metal coated fibre preforms therefor, specially designed for use in the systems in Item 1 and the subsystems in Item 2 made either with an organic matrix or metal matrix utilizing fibrous or filiamentary reinforcements having a specific tensile strength greater than 7.62 x 10 m (3 x 106 inches) and a specific modulus greater than 3.18 x 106 m (1.25 x 108 inches);

(b) Resaturated pyrolized (i.e., carbon-carbon) materials specially designed for rocket systems;

(c) Fine grain artificial graphites for rocket nozzles and reentry vehicle nosetips having all of the following characteristics:

(1) Bulk density of 1.79 or greater (measured at 293K);

(2) Tensile strain to failure of 0.7 percent or greater (measured at 293K);

(3) Coefficient of thermal expansion of 2.75 X 106 or less per degree K (in the range of 293K to 1,255K);

d) Ceramic composite materials specially designed for use in missile radomes.

ITEM 9- CATEGORY II

Compasses, gyroscopes, accelerometers and inertial equipment and specially designed software therefor, as follows; and specially designed components there for usable in the systems in Item 1:

(a) Integrated flight instrument systems which include gyrostabilizers or automatic pilots and integration software there for, specially designed or modified for use in the systems in Item 1;

(b) Gyro-astro compasses and other devices which derive position on orientation by means of automatically tracking celestial bodies;

(c) Accelerometers with a threshold of 0.005 g or less, or a linearity error within 0.25 percent of full scale output or both, which are designed for use in inertial navigation Systems or in guidance systems of all types;

(d) Gyros with a rated free directional drift rate (rated free precession) of less than 0.5 degree (1 Sigma or rms) per hour in a ~ g environment;

(e) Continuous output accelerometers which utilize servo or force sequence techniques and gyros; both specified to function at acceleration levels greater than 100 g;

(f) Inertial or other equipment using accelerometers described by subitems (c) and (e) above or gyros described by subitems (d) or (e) above, and systems incorporating such equipment, and specially designed integration software the refor;

(g)Specially designed test, calibration, and alignment equipment for the above;

(h) Specially designed production equipment for the above, including the following:

(1) For ring laser gyro equipment, the following equipment used to characterize mirrors, having the threshold accuracy shown or better:

(i) Rectilinear Scatterometer (10 ppm);

(ii) Polar Scatterometer (10 ppm):

(iii) Reflectometer (50 ppm);

(iv) Profilimeter (5 Angstroms);

(2) For other inertial equipment:

(i) Inertial Measurement Unit (INIU Module) Tester;

(ii)IMU Platform Tester;
(iii) IMU Stable Element Handling Fixture;
(iv) IMU Platform Balance Fixture;
(v) Gyro Tuning Test Station;
(vi) Gyro Dynamic Balance Station:
(vii) Gyro Run-In/Motor Test Station;
(viii) Gyro Evacuation and Fill Station;
(ix) Centrifuge Fixture for Gyro Bearings;
(x) Accelerometer Axis Align Station;
(xi) Accelerometer Test Station.

Note to Item 9: Items (a) through (f) may be exported as part of a manned aircraft or satellite or in quantities appropriate for replacement parts for manned aircraft.

ITEM 10-CATEGORY II

Flight control systems usable in the systems in Item 1 as follows, as well as the specially designed test, calibration, and alignment equipment therefor:

(a) Hydraulic, mechanical, electro-optical. or electro- mechanical flight control systems (including fly-by- wire Systems) specially designed or modified for the systems in Item I;

(b) Attitude control equipment specially designed or modified for the systems in Item 1;

(c) Design technology for integration of air vehicle fuselage, propulsion system and lifting and control surfaces to optimize aerodynamic performance throughout the flight regime of an unmanned air vehicle;

(d) Design technology for integration of flight control, guidance, and propulsion data into a flight management system for optimization of rocket system trajectory.

Note to Item 10: Items (a) and (b) may be exported as part of a manned aircraft or satellite or in quantities appropriate for replacement parts for manned aircraft.

ITEM 11 - CATEGORY II

Avionics equipment specially designed or modified for use in unmanned air vehicles or rocket systems and specially designed software and components therefor usable in the systems in Item 1, including but not limited to:

(a) Radar and laser radar systems, including altimeters;

(b) Passive sensors for determining bearing to specific electromagnetic sources (direction finding equipment) or terrain characteristics;

(c) Equipment specially designed for real-time integration, processing, and use of navigation information derived from an external source

(d)Electronic assemblies and components specially designed for military use incorporating any of the following:

(1) Specially designed, integral structural supports;
(2) Techniques for conductive heat removal'
(3) Radiation hardening;
(4) Design for reliable short term operation at temperatures in excess of 125 0C'

(e) Design technology for protection of avionic and electrical subsystems against electromagnetic pulse (ENIP) and electromagnetic interference (EMI) hazards from external sources, as follows:

(1) Technology for design of shielding systems;
(2) Technology for the configuration design of hardened electrical circuits and subsystems;
(3) Determination of hardening criteria for the above.

Notes to Item 11:

(1) Item 11 equipment may be exported as part of a manned aircraft or satellite or in quantities appropriate for replacement parts for manned aircraft.

(2) Examples of equipment included in this item:

*Terrain contour mapping equipment;
*Scene mapping and correlation (both digital and analog) equipment;
*Doppler navigation radar equipment;
*Passive interferometer equipment;
*Imaging sensor equipment (both active and passive).

ITEM 12 - CATEGORY II

Launch and ground support equipment and facilities usable for the systems in item 1, as follows:

(a) Apparatus and devices specially designed or modified for the handling, control, activation and launching of the systems in Item 1;
(b) Military vehicles specially designed or modified for the handling, control, activation and launching of the systems in Item 1;
(c) Gravity meters (gravimeters), gravity gradiometers, and specially designed components therefor, designed or modified for airborne or marine use, and having a static or operational accuracy of one or better, with a time to steady-state registration of two minutes or less;
(d) Telemetering and telecontrol equipment suitable for use with unmanned air vehicles or rocket systems;
(e) Precision tracking systems:
(1) Tracking systems which use a translator installed on the rocket system or unmanned air vehicle in conjunction with either surface or airborne references or navigation satellite systems to provide real-time measurements of inflight position and velocity;
(2) Software systems which process recorded data for post mission precision tracking enabling determination of vehicle position.

ITEM 13 -CATEGORY II

Analog computers, digital computers, or digital differential analyzers specially designed or modified for use in air vehicles or rocket systems and usable in the systems in Item 1, having any of the following characteristics:
(a) Rated for continuous operation at temperatures from below -45 0C to above 55 0C;
(b) Designed as ruggedized or radiation hardened equipment and capable of meeting military specifications for ruggedized or radiation hardened equipment; or
(c) Modified for military use.
Note to Item 13: Item 13 equipment may be exported as part of a manned aircraft or satellite or in quantities appropriate for replacement parts for manned aircraft.

ITEM 14- CATEGORY II

Analog-to-digital converters, other than digital voltmeters or counters, usable in the systems in Item 1 and having any of the following characteristics: rated for continuous operation at temperatures from below -450 Celsius to above 550C; designed to meet military specifications for ruggedized equipment, or modified for military use; or designed for radiation resistance as follows:
(a) Electrical input type analog-to-digital converters having any of the following characteristics:
(I) A conversion rate of more than 200,000 complete conversions per second at rated accuracy;
(2) An accuracy in excess of I part in more than 10,000 of full scale over the specified operating temperatures range;
(3) A figure of merit of 1 x 10 or more (derived from the number of complete conversions per second divided by the accuracy);
(b) Analog-to-digital converter microcircuits having both of the following characteristics; (I) A maximum conversion time to maximum resolution of less than 20 microseconds;
(2) A rated non-linearity of better than 0.025 percent of full scale over the specified operating temperature range.

ITEM 15 - CATEGORY II

Test facilities and equipment usable for the systems in Item 1, as follows:
(a) Vibration test equipment using digital control techniques and specially designed ancillary equipment and software therefor capable of imparting forces of 100 kN (22,500 lbs) or greater;
(b) Supersonic (Mach 1.4 to Mach 5), hypersonic (Mach 5 to Mach 15), and hypervelocity (above Mach 15) wind tunnels, except those specially designed for educational purposes and having a test section size (measured internally) of less than 25 cm (10 inches);
(c) Test benches with the capacity to handle solid or liquid fuel rockets of more than 20,000 lbs of thrust and capable of measuring the three thrust components.
Note to Item 15(a): The term 'digital control' refers to equipment, the functions of which are partly or entirely, automatically controlled by stored and digitally coded electrical signals..

ITEM 16-CATEGORY II

Specially designed software, or specially designed software and related specially designed analog or hybrid (combined analog/digital) computers, for modelling, simulation, or design integration of rocket systems and unmanned air vehicle systems, usable for the systems in Item 1.

ITEM 17- CATEGORY II

Technology, materials, and devices for reduced observables such as radar reflectivity, optical/infrared signatures and acoustic signatures (i.e., stealth technology), for military application in rocket systems and unmanned air vehicles, and usable for the systems in Item I, for example.

(a) Structural materials and coatings specially designed for reduced radar reflectivity;

(b)Optical coatings, including paints, specially designed or formulated for reduced optical reflection or emissivity, except when specially used for thermal control of satellites.

ITEM 18- CATEGORY II

Technology and devices specially designed for use in protecting rocket systems and unmanned air vehicles against nuclear effects (e.g., Electromagnetic Pulse (EMP), X-rays, combined blast and thermal effects), and usable for the systems in Item 1, for example:

(a) Hardened microcircuits and detectors specilly designed to withstand radiation as follows:

(1) Neutron dosage of 1×10^{12} neutrons/cm^2 accompanied by a peak overpressure of greater than 7 pounds per square inch.

Note to Item 18 (a): A microcircuit is defined as a device in which a number of passive and active circuit elements are considered as indivisibly associated on or within a continuous structure to perform the function of a circuit.

APPENDIX-2

US National Defence Authorisation Act for Fiscal Year 1991

Public Law: 101-510, November 5, 1990

Title XVII-Missile Technology Controls
Sec. 1701, Policy.
Sec. 1702, Amendment to the Export Administration Act of 1979.
Sec. 1703, Amendment to Arms Export Control Act of 1979.
Sec. 1704, Report on missile proliferation.

Sec. 1701, Policy.

It should be the policy of the United States to take all appropriate measures-
(1) to discourage the proliferation, development, and production of weapons, material, and technology necessary to produce or acquire missiles that can deliver weapons of mass destruction;
(2) to discourage countries and private persons in other countries form aiding and abetting any states from acquiring such weapons, material, and technology'
(3) to strengthen United States and existing multilateral export controls to prohibit the flow of materials equipment, and technology that would assist countries in acquiring the ability to produce or acquire missiles that can deliver weapons of mass destruction , including missiles, warheads and weaponisation technology, targeting technology, test and evaluation technology, and range and weapons effect measurement technology; and
(4) with respect to the Missile Technology Control Regime (MTCR) and its participating governments-
(A) to improve enforcement and seek a common and stricter interpretation among MTCR members of MTCR principles,
(B) to increase the number of countries that adhere to the MTCR; and
(C) to increase information sharing among United states agencies and among government on missile technology transfer, including export licensing and enforcement activities.

Sec. 1702. Amendment to the Export Administration Act of 1979

(a) Missile Technology Controls-Section of the Export Administration Act of 1979 (50 USC App. 2405) is amended-
(1)by redesignating subsections (k) through (p) as subsections (m) through (r) respectively; and
(2)by inserting after subsection (j) the following :

(k) Negotiations with other countries-

(1) *Countries participating in certain agreements*-The Secretary of State, in consultation with the Secretary, the Secretary of Defence, and the heads of other appropriate departments and agencies shall be responsible for conducting negotiations with those countries participating in the groups known as the Co-ordinating Committee, the Missile Technology Control Regime, the Australian Group, and the Nuclear Suppliers Group, regarding the co-operation in restricting the export of goods and technology in order to carry out-
(A) the policy set forth in section 8 (2) (B) of this Act, and

(B) United States policy opposing the proliferation of chemical, biological, nuclear and other weapons and their delivery systems, and effectively restricting the export of dual use components of such weapons and their delivery systems, in accordance with this subsection and subsections (a) and (1).

Such negotiations shall cover, among other issues, which goods and technology should be subject to multilaterally agreed export restrictions, and the implementation of the restrictions consistent with the principles identified in section 5 (b) (2) (C) of this Act.

(2) *Other Countries*-The Secretary of State in consultation with the Secretary, the Secretary of Defence and the heads of other appropriate departments and agencies shall be responsible for conducting negotiations with countries and groups of countries not referred to in paragraph (1) regarding their operation in restricting the export of goods and technology consistent with purposes set forth in paragraph (1). In case where such negotiations produce agreements on export restrictions that the Secretary, in consultation with the Secretary of State and the Secretary of Defence, determines to be consistent with the principles identified in section 5 (b) (2) (C) of this Act, the Secretary may treat exports, whether by individual or multiple licenses, to countries party to such agreements in the same manner as exports are treated to countries that are MTCR adherents.

(3) *Review of Determinations*-The Secretary shall annually review any determination under paragraph (2) with respect to a country. For each such country which the Secretary determines is not meeting the requirements of an effective export control system in accordance with section 5 (b) (2) (C) that Secretary shall restrict or eliminate any preferential licensing treatment for exports to that country provided under this subsection.

(1) Missile Technology-

(1) *Determination of controlled items*- The Secretary in consultation with the Secretary of State, the Secretary of Defence, and the heads of other appropriate departments and agencies-

(A) shall establish and maintain, as part of the control list established under this section, a list of all dual use goods and technology on the MTCR Annex; and

(B) may include, as part of the control list established under this section, goods and technology that would provide a direct and immediate impact on the development of missile delivery systems and are not included in the MTCR Annex but which the United States is proposing to the other MTCR adherents to have included in the MTCR Annex.

(2) *Requirement of Individual Validated Licences*-The Secretary shall require an individual validated license for -

(A) any export of goods or technology on the list established under paragraph (1) to any country; and

(B) any export of goods or technology that the exporter knows is destined for a project or facility for the design, development or manufacture of missile in a country that is mot an MTCR adherent.

(3) *Policy of Denial or Licenses*- (A) Licenses under paragraph (2) should in general be denied if the ultimate consignee of the goods or technology is a facility in a country that is not an adherent to the Missile Technology Control Regime and the facility is designed to develop or build missiles.

(B) Licenses under paragraph (2) shall be denied if the ultimate consignee of the goods or technology is a facility in a country the government of which has been determined under subsection (j) to have repeatedly provided support for acts of international terrorism.

(4) *Consultation with other Departments-* (A) A determination of the Secretary to approve an export licence under paragraph (2) for the export of goods or technology to a country of concern regarding missile proliferation may be made only after consultation with the Secretary of State for a period of 20 days. The countries of concern referred to in the preceding sentence shall be maintained on a classified list by the Secretary of State , in consultation with the Secretary and the Secretary of Defence.
(B) Should the Secretary of Defence disagree with the determination of the secretary to approve an export license to which subparagraph (A) applies , the secretary of Defence shall so notify the Secretary within 20 days provided for consultation on the determination. The Secretary of Defence shall at the same time submit the master to the President for resolution of the dispute. The secretary shall also submit the Secretary's recommendation to the President on the license application.
(C) The President shall approve or disapprove the export license application within 20 days after receiving the submission of the Secretary of Defence under subparagraph (B).
(D) Should the Secretary of Defence fail to notify the Secretary within the time period prescribed in subparagraph (B) the Secretary may approve the license application without awaiting the notification by the Secretary of Defence. Should the President fail to notify the Secretary of his decision on the export license application within the time period prescribed in subparagraph (C), the Secretary may approve the license application without awaiting the President's decision on the license application.
(E) Within 10 days after an export license is issued under this subsection , the Secretary shall provide to the Secretary of defence and the Secretary of State the license application and accompanying "documents issued to the applicant, to the extent that the relevant Secretary indicates the need to receive such application and documents.
(5). *Information sharing -* The secretary shall establish a procedure for information sharing with appropriate officials of the intelligence community , as determined by the director of Central Intelligence, and other appropriate Government agencies, that will ensure effective monitoring of transfers of MTCR equipment or technology and other missile technology."
(b) *Sanctions for Missile Technology Proliferation -* The export Administration Act of 1979 is amended by inserting after section 11A (50 U.S.C. App. 2410a) the following :
(a) Missile Proliferation Control Violations
Sec. 11 B. (a) Violations by United States Persons-
(1) **Sanctions** - (A) If the President determines that a United States person knowingly -
(i) exports, transfers, or otherwise engages in the trade of any item on the MTCR Annex, in violation of the provisions of sections 38 (22 U.S.C. 2778) or chapter 7 of the Arms Export Control Act, section 5 or 6 of this Act or any regulations or orders issued under any such provisions.
(ii) conspires to or attempts to engage in such export, transfer, or trade, or
(iii) facilitates such export, transfer, or trade by any other person, then the President shall impose the applicable sanctions described in subparagraph (B).
(E) The sanctions which apply to a United States person under subparagraph (A) are the following :
(i) If the item on the MTCR Annex involved in the export, transfer, or trade is missile equipment or technology within category II of the MTCR Annex, then the president shall

deny to such United Stated person, for a period of 2 years, licenses for the transfer of missile equipment or technology controlled under this Act.
(ii) If the item on the MTCR Annex involved in the export, transfer , or trade in missile equipment or technology within category I of the MTCR annex, then the President shall deny such United States person , for a period of not less than 2 years all licenses for items the export of which is controlled under this Act.
(k) **Discretionary Sanctions** - In the case of any determination referred to in paragraph (1) , the Secretary may pursue any other appropriate penalties under section 11 of this Act.
(l) *Waiver* - The President may waive the imposition of sanctions under paragraph (1) on a person with respect to a product or service if the President certifies to the Congress that -
(A) the product or service is essential to the national security of the United States; and
(B) such person is a sole source supplier of the product or service, and the need of the product or service is not available from any alternative reliable supplier, and the need for the product or service cannot be met in timely manner by improved manufacturing processes or technological developments.
(b) Transfers of Missile Equipment of Technology By Foreign Persons -
(1) Sanctions - (A) Subject to paragraph (3) through (7) if the President determines that a foreign person, after the date of enactment of this section, knowingly.
(i) exports, transfers or otherwise engages in the trade of any MTCR equipment or technology that contributes to the design, development, or production of missiles in a country that is not an MTCR adherent and would be if it were United States origin equipment or technology , subject to the jurisdiction of the United States under this Act.
(ii) conspires to or attempts to engage in such export, transfer or trade or
(iii) facilitates such export , transfer or trade by any other person, or if the President has made a determination with any foreign person under section 78 (a) of the Arms Export Control Act, then the President shall impose on that foreign person applicable sanctions under subparagraph (B).
(B) The sanctions which apply to a foreign person under subparagraph (A) are the following :
(i) If the item involved in the export , transfer, or trade is within category II of the MTCR Annex , then the President shall deny, for a period of not less than 2 years, licenses for the transfer to such foreign person of missile equipment or technology the export of which is controlled under this Act.
(ii) If the item involved in the export, transfer or trade is within category I of the MTCR Annex, then the President shall deny, for a period of not less then 2 years , licenses for the transfer to such foreign person of items the export of which is controlled under this Act.
(iii) If, in addition to actions taken under clauses (I) and (ii), the President determines that the export transfer, or trade has substantially contributed to the design, development, or production of missiles in a country that is not a MTCR adherent then the President shall prohibit, for a period of not less that 2 years the importation into the United States of products produced by that foreign person.
(2) *Inapplicability with respect to MTCR adherents* - Paragraph (1) does not apply with respect to -

(A) any export, transfer activity that is authorised by the laws of an MTCR adherent if such authorisation is not obtained by misrepresentation or fraud ; or

(B) any export , transfer of an item to an end user in a country that is an MTCR adherent.
(3) *Effect of enforcement actions by MTCR adherents* - Sanctions set forth in paragraph (1) may not be imposed under this subsection on a person with respect to acts described in such paragraph or , if such sanctions are in effect against a person on account of such acts, such sanctions shall be terminated , if an MTCR adherent is taking judicial or other enforcement action against that person has been found by the government of an MTCR adherent to be innocent of wrongdoing with respect to such acts.
(4) *Advisory opinions* - The Secretary, in consultation with the Secretary of States and the Secretary of Defence, may, upon the request of any person , comes an advisory opinion to that person as to whether a proposed activity by that person would subject that person to sanctions under this subsection. Any person who relies on good faith on such an advisory opinion which states that the proposed activity would not subject a person to such a sanctions, and any person who thereafter engages in such activity may not be made subject to such sanctions on account of such activity.
(5)*Waiver and Report to Congress*-(A) In any case other than one in which an advisory opinion has been issued under paragraph (4) stating that a proposed activity would not subject a person to sanctions under this subsection, the President may waive the application of paragraph (1) to a foreign person if the president determines that such a waiver is essential to the national security of the United States
(B) In the event that the President decides to apply the waiver described in subparagraph (A), the President shall notify the Congress not less than 20 working days before issuing the waiver. Such notification shall include a report fully articulating the rationale and circumstances which led to the President to apply the waiver.
(6) Additional Waiver-
The President may waive the imposition of sanctions under paragraph (1) on a person with respect to a product or service if the President certifies to the Congress that-
(A)the product or service is essential to the national security of the United States; and
9B)such person is a sole source supplier of the product or service, the product or services is not available from any alternative reliable supplier, and the need for the product or service cannot be met in a timely manner by improved manufacturing processes or technological developments.
(7)*Exceptions*-The President shall not apply the sanction under this subsection prohibiting the importation of the products on a foreign person-
(A)in the case of procurement of defence articles or defence services-
(i) under existing contracts or subcontracts, including the exercise of options for production quantities to satisfy requirements essential to the national security of the United States;
(ii)if the President determines that the person to which the sanctions would be applied is a sole source supplier of the defence articles and services, that the defence articles or services are essential to the national security' of the United States, and/that alternative sources are not readily or reasonably available; or
(iii) if the President determines that such articles or services are essential to the national security of the United States under defence co-production agreements or NATO Programme of Cooperation;
(B)to products or services provided under contracts entered into before the date on which the President publishes his intention to impose the sanctions; or

(C)to
(i)spare parts,
(ii)component parts, but not finished products, essential not United States products or production.
(iii) routine services and maintenance of products to the extent that alternative sources are not readily or reasonably available, or
(iv) information and technology essential to United States products or production.
(c)Definitions-For purposes of this section and subsections (k) and (l) of section 6-
(l) the term 'missile' means a category I system as defined in the MTCR Annex, and
any other unmanned delivery system of similar capability, as well as the specially designed production facilities for these systems;
(2)the term 'Missile Technology Control Regime' or 'MTCR' means the policy statement, between the United States, the United Kingdom, the Federal Republic of Germany, France, Italy, Canada, and Japan, announced on April 16, 1987, to restrict sensitive missile-relevant transfers based on the MTCR Annex, and any amendments thereto;
(3) the term 'MTCR adherent' means a country that participates in the MTCR or that, pursuant to an international understanding to which the United States is a party, controls MTCR equipment or technology in accordance with the criteria and standards set forth in the MTCR;
(4) the term 'MTCR Annex' means the Guidelines and Equipment and Technology Annex of the MTCR, and any amendments thereto;
(5) The terms missile equipment or technology and 'MTCR equipment or technology' mean those items listed in category I or category II of the MTCR Annex;
(6) the term 'foreign person' means any other person other than a United States person;
(7)(A) the term 'person' means a natural person as well as a corporation, business association, partnership, society; trust, any other non-governmental entity, organisation, or group, and any governmental entity operating as a business enterprise, and any successor of any such entity; and
(B) in the case of countries where it may be impossible to identify a specific governmental entity referred to in subparagraph (A), the term 'person' means
(i) all activities of that government relating to the development of production of any missile equipment or technology; and
(ii) all activities of that government affecting the development or production of aircraft, electronics and space systems or equipment; and
(8) the term 'otherwise' engaged in the trade of means with respect to a particular export or transfer, to be freight forwarder or designated exporting agent, or a consignee or end user of the item to be exported or transferred.
Sec. 1703. Amendment to the Arms Export Control Act
The Arms Export Control Act is amended by inserting after chapter 6 (22 USC 2795b et seq) the following new chapter:
Chapter 7-Control of Missiles and Missile Equipment or Technology
Sec. 71. Licensing
(a) Establishment of List of Controlled Items-The Secretary of State, in consultation with the Secretary of Defence and the heads of other appropriate departments and agencies, shall establish and maintain, as part of the United States Munitions List, a list of all items on the

MTCR Annex the export of which is not controlled under section 6(1) of the Export Administration Act of 1979.

(b) *Referral of License Applications 1)* A determination of the Secretary of State to approve a license for the export of an item on the list established under subsection (a) may be made only after the license application is referred to the Secretary of Defence.

(2) Within 10 days after a license is issued for the export of an item on the list established under subsection (a), the Secretary' of State shall provide to the Secretary of Defence and the Secretary of Commerce the license application and accompanying documents issued to the applicant to the extent that the relevant Secretary indicates the need to receive such application and documents.

(c) **Information Sharing**-The Secretary of State shall establish a procedure for sharing information with appropriate officials of the intelligence community, as determined by the Director of Central Intelligence, and with other appropriate Government agencies, that will ensure effective monitoring of transfers of MTCR equipment or technology and other missile technology.

Sec. 72. Denial of the Transfer of Missile Equipment or Technology by United States Persons

(a) *Sanctions-(1)* If the President determines that a United States person knowingly-

(A)exports, transfers, or otherwise engages in the trade of an item on the MTCR Annex, in violation of the provision of section 38 of this Act, section 5 or 6 of the Export Administration Act of 1979 (50 USC App 2404, 2405), or any regulations or orders issued under any such provisions,

(B) conspires to or attempts to engage in such export, transfer, or trade, or

(C) facilitates such export, transfer, or trade by any other person, then the president shall impose the applicable sanctions described in paragraph (2).

(2) The sanctions which apply to a United States person under paragraph (1) are the following:

(A) If the item on the MTCR Annex involved in the export, transfer, or trade is missile equipment or technology within category II of the MTCR Annex, then the President shall deny to such United States person for a period of 2 years-

(i) United States Government contracts relating to missile equipment or technology; and

(ii) licenses for the transfer of missile equipment or technology controlled under this Act.

(B) If the item on the MTCR Annex involved in the export, transfer, or trade is missile equipment or technology within category I of the MTCR, then the President shall deny to such United States person for a period of not less than 2 years

(i) all United States Government contracts, and

(ii) all export licenses and agreements for items on the United States Munitions List.

(b) *Discretionary Sanctions*-In the case of any determination made pursuant to subsection (a) the President may pursue any penalty provided in section 38(c) of this Act.

(c) *Waiver*-The President may waive the imposition of sanctions under subsection (a) with respect to a product or service if the President certifies to the Congress that-

(1) the product or service is essential to the national security of the United States; and

(2) such person is a sole source supplier of the product or service, the product or service is not available from any alternative reliable supplier, and the need for the product or service cannot be met by improved manufacturing processes or technological developments.

Sec. 78. Transfers of Missile Equipment or Technology by Foreign Persons

(a) *Sanctions-* (1) Subject to Subsections (c) through (g), if the president determines that a foreign person, after the date of the enactment of this chapter, knowingly-

(A) exports, transfers or otherwise engages in the trade of any MTCR equipment or technology that contributes to the design, development or production of missiles in a country that is not an MTCR adherent and would be, if it were Untied States origin equipment or technology, subject to the jurisdiction of the United States under this act.

(B) conspires to or attempts to engage in such export, transfer or trade, or

(C) facilitates such export, transfer, or trade by any other person,

or if the president has made a determination with respect to a foreign person under section 11B(b)(I) of the Export Administration Act of 1979, then the president shall impose on that foreign person the applicable sanctions under paragraph (2)

(2) The sanctions which apply to a foreign person under paragraph (1) are the following:

(A) If the item involved in the export, transfer or trade is within category II of the MTCR Annex, then the President shall deny, for a period of two years-

(i) United States Government contracts relating to Missile equipment or technology controlled under this Act.

(B) If the item involved in the export, transfer, or trade is within category I of the MTCR Annex, then the President shall deny, for a period of not less than two years-

(i) all Untied States Government contracts with such foreign person; and

(ii)Licenses for the transfer to such foreign person of all items on the United States Munitions List.

C) If, in addition to actions taken under subparagraphs (A) and (B), the President determines that the export, transfer or trade had has substantially contributed to the design, development, or production of missiles in a country that is not an MTCR adherent, then the President shall prohibit, for a period of not less than 2 years, the importation into the United States of products produced by that foreign person.

(b) *Inapplicability with Respect to MTCR Adherents-* Subsection (a) does not apply with respect to-

(1) any export, transfer, or trading activity that is authorized by the laws of an MTCR adherent, if such authorization is not obtained by misrepresentation or fraud; or

(2) any export, transfer, or trade of an item to an end user in a country that is an MTCR adherent

(c) *Effect of Enforcement Actions by MTCR Adherents-*Sanctions set forth in subsection (a) may not be imposed under this section on a person with respect to acts described in such subsection or, if such sanctions are in effect against a person on account of such acts, such sanctions shall be terminated, if an MTCR adherent is taking judicial or other enforcement action against that person with respect to such acts, or that person has been found by the government of an MTCR adherent to be innocent of wrongdoing with respect to such acts.

(d) *Advisory Opinions-*The Secretary of State in consultation with the Secretary of Defence and the Secretary of Commerce, may, upon the request of any person issue an advisory opinion to that person as to whether a proposed activity by that person would subject that person to Sanctions under this section. Any person who relies in good faith on such an advisory opinion which states that the proposed activity would not subject a person to such sanctions, and any person who thereafter engages in such activity, may not be made subject to such sanctions on account of such activity.

(e) *Waiver and Report to Congress-(l)* In any case other than one in which an advisory opinion has been issued under subsection (d) stating that a proposed activity would not subject a person to sanctions under this section the President may waive the application of subsection (a) to a foreign person if the President determines that such waiver is essential to the national security of the United States.
(2) In the event that the President decides to apply the waiver described in paragraph (1), the President shall so notify the Congress not less than 20 working days before issuing the waiver. Such notification shall include a report fully articulating the rationale and circumstances which led the President to apply the waiver.
(f) *Additional Waiver:* The President may waive the imposition of sanctions under paragraph (1) on a person with respect to a product or service if the President certifies to the Congress that-
(1) the product or service is essential to the national security of the United States; and
(2) such person is a sole source supplier of the product or service the product or service is not available from any alternative reliable supplier, and the need for the product or service cannot be met in a timely manner by improved manufacturing processes or technological developments.
(g) *Exceptions*-The President shall not apply the sanction under this section prohibiting the importation of the products of a foreign person
(1) in the case of procurement of defence articles or defence services-
(A) under existing contracts or subcontracts, including the exercise of options for production quantities to satisfy requirements essential to the national security of the United States;
(B) if the President determines that the person to which the sanctions would be applied is a sole source supplier of the defence articles and services, that the defence articles or service are essential to the national security of the United States, and that alternative sources are not readily or reasonably available; or
(C) if the President determines that such articles or services are essential to the national security of the United States under defence coproduction agreements or NATO Programmes of Cooperation;
(I) to products or services provided under contracts entered into before the date on which the President publishes his intention to impose the sanctions; or
(3) to
(A) spare parts,
(B) component parts, but not finished products, essential to United States products or production,
(C) routine services and maintenance of products, to the extent that alternative sources are not readily or reasonably available, or
(D) information and technology essential to United States products or production.
Sec. 74. Definitions
For purposes of this chapter-
(1) the term 'missile' means a category I system as defined in the MTCR Annex, and any other unmanned delivery system of similar capability, as well as the specially designed production facilities for these systems.
(2) the term 'Missile Technology Control Regime' or 'MTCR' means the policy statement, between the United States, the United Kingdom, the Federal Republic of Germany, France,

Italy, Canada, and Japan, announced on April 16, 1987, to missile-relevant transfers based on the MTCR Annex, and any amendments thereto,

(3) the term 'MTCR adherent' means a country that participates in the MTCR or that, pursuant to an international understanding to which the United States is a party, controls MTCR equipment or technology in accordance with the criteria and standards set forth in the MTCR

(4) the term 'MTCR Annex' means the Guidelines and Equipment and Technology Annex of the MTCR, and any amendments thereto;

(5) the terms 'missile equipment or technology' and 'MTCR equipment or technology' mean those items listed in category I or category II of the MTCR Annex;

(6) the term 'United States person' has the meaning given that term in section 16(2) of the Export Administration Act of 1979 (50 USC App 2415(2));

(7) the term 'foreign person' means any person other than a United States person;

(8)(A) the term 'person' means a natural person as well as a corporation business association, partnership, society, trust, any other nongovernmental entity, organisation, or group, and any governmental entity operating as a business enterprise, and any successor of any such entity; and

(B) in the case of countries where it may he impossible to identify a specific governmental entity referred to in subparagraph (A), the term 'person' means-

(i) all activities of that government relating to the development or production of any missile equipment or technology; and

(ii) all activities of that government affecting the development or production of aircraft, electronics, and space systems or equipment; and

(9) the term 'otherwise engaged in the trade of means with respect to a particular export or transfer, to he a freight forwarder or designated exporting agent or a consignee or end user of the item to he exported or transferred'.

Sec. 1704. Report on Missile Proliferation

(1) *Contents of Report*-Not later than 90 days after the date of the enactment of this Act, and every 180 days thereafter, the President shall submit to the Congress a report on international transfers of aircraft which the Secretary has reason to believe may be intended to be used for the delivery of nuclear, biological, or chemical weapons (hereinafter in this section referred to as "NBC capable aircraft" and international transfers of MTCR equipment or technology to any country that is not an MTCR adherent and is seeking to acquire such equipment or technology, other than those countries excluded in subsection (b). Each such report shall include-

(1) the status of missile and aircraft development programmes in any such country including efforts by such country to acquire MTCR equipment or technology and NBC capability aircraft and an assessment of the present and future capability of such country to produce and utilise such weapons.

(2) a description of assistance provided after the date of the enactment of this Act, to any such country in the development of missile systems, as defined in the MTCR, and NBC capable aircraft by persons and other countries, specifying those persons and other countries which continue to provide MTCR equipment or technology to such country as of the date of the report.

(3) a description of diplomatic measures that the United States has taken or that other MTCR

adherents have made to the United States with respect to activities of private persons and countries suspected of violating the MTCR;

(4) an analysis of the effectiveness of the regulatory and enforcement regimes of the United States and other MTCR adherents to control the export of MTCR equipment or technology.

(5) determination of whether transfers of MTCR equipment or technology by any country pose a significant threat to the national Security of the United States;

(6) a summary of advisory opinions issued under section 1IB(b)(4) of the Export Administration Act of 1979 and under section 73(d) of the Arms Export Control Act; and

(7) an explanation of United States policy regarding the transfer of MTCR equipment or technology to foreign missile programmes, including space launch vehicle programmes.

(b) *Exclusions*-The countries excluded under subsection (a) are Australia, Belgium, Canada, Denmark, the Federal Republic of Germany, France, Greece, Iceland, Israel, Italy, Japan, Luxembourg, Netherlands, Norway, Portugal, Spain, Turkey, and the United Kingdom.

(c) *Classification*-The President shall make every effort to submit all of the information required by subsection (a) in unclassified form whenever the President submits any such information in classified form, he shall submit such classified information in an addendum and shall also submit simultaneously a detailed summary in classified form of such classified information.

(d) *Definitions*-For purposes of this section, the terms "missile", "MTCR", "MTCR equipment or technology", and "MTCR adherent" have the meanings given those terms in section 74 of the Arms Export Control Act. [Public Notice 1626J

APPENDIX-3

CRYOGENIC DEAL WITH RUSSIA: PRIME MINISTER'S STATEMENT IN THE RAJYA SABHA ON AUGUST 18, 1993.

I am aware of the great concern felt by Hon'ble members on the reports about the difficulty that has arisen in implementing the commitment of the Government of Russian Federation regarding the transfer of technology and production equipment under the Agreement on cryogenic stages and technology transfer signed in January 1991. I would like to take the House into confidence on this most important issue.

The primary goal of the India space programme from its very inception has been to use the immense potential of the space science and technology for national development, particularly in the vital areas of communication, meteorology and remote sensing of natural resources. The utilisation of India remote sensing satellites (IRS-1A and 1B) and INSAT system of satellites stand testimony to this.

In order to achieve full potential of our space programme it was necessary that along with application projects and satellite segments, we acquire the capability to have our own operational launch vehicles. Self-reliance in launch vehicles is most essential in providing continuity in operational space services.

While the solid and liquid propulsion technologies developed by ISRO have enabled our space scientists to proceed with the launch vehicles programme, the need for launching 2.5 ton class of satellites into geo-synchronous transfer orbits by Geosyschronous Satellite Launch Vehicle requires the more efficient cryogenic propulsion system. The cryogenic technology is highly sophisticated and has taken over 10 years for development even in advanced nations. Glavkosmos of the then USSR offered the technology transfer and cryogenic stages at most competitive rates. Other countries under consideration as a source of this technology were France and the US. Government decided to accept the Glavkosmos offer. An agreement was signed in January 1991 with the Glavkosmos at a cost of Rs. 235 crores for technology transfer along with supply of two units of cryogenic stages in a period of about six years. This contract has been making normal progress.

In May 1992, USA imposed embargo on ISRO and Glavkosmos for two years citing that the Agreement violates MTCR. Both the sides have consistently pointed out that this Agreement does not come under the purview of MTCR since the intended use of this cryogenic upper stage as a part of the GSLV is not only for launching geo-synchronous satellites for peaceful uses towards national development. There is also provision in the contract against transfer of the technology to any third country.

As a part of routine periodical consultations between M/S Glavkosmos and Indian Space Research Organisation, Secretary, Department of Space and a team of officers visited Moscow I the early part of July, 1993.

The Indian side during the course of their discussions reiterated:

- the long standing relation between the two countries in space
- MTCR concern is not relevant to cryogenic technology
- The technology transfer is the heart of the Agreement

the provision in the Agreement on the non-transfer of technology to a third country.

Subsequently, the Chief of the Directorate of International Scientific and Technical Cooperation of the Russian Ministry of Foreign Affairs handed over one paper to the India Ambassador in Moscow on the 16th July in which it has been stated that in the context of unforeseen circumstances, Glavkosmos finds itself in a situation of not being able to fulfill further its obligations regarding the transfer of technology and production equipment under the Agreement of January 1991. The paper given to the Indian Ambassador invokes the force majeure clause of the January 1991 Agreement as the basis of Glavkosmos resiling from its contractual obligations. No other communication regarding the agreement has been received. The Russian side, however, has expressed its readiness to hold further consultations with India in this matter.

The Government firmly believes in self-reliance in our launch vehicle programme and development of cryogenic technology is an essential part of it. Our space engineers have been simultaneously working to develop technologies for our own design of cryogenic engine. If the Agreement cannot be implemented , we are quite confident of our space scientists and engineers who would be able to develop our own technology.

We have had fruitful cooperation in peaceful application of space technology with several countries including the erstwhile Soviet Union, France and United States and now Russia. We would like to continue such cooperation for mutual benefit where feasible. In any event, I want to assure this House that we are committed to achieving self-reliance in high technology particularly in areas like space which have a major bearing on our economic and social development.

Major Indian Space Missions 1988-2000

Year	Satellite Programmes	Launch Vehicle Programmes
1988 March	IRS-IA, the first operational remote-sensing satellite launched by a Russian Vostok rocket.	
1988 July	INSAT-IC launched by Ariane. Abandoned after 15 months following a power anomaly.	ASLV-D2, the second developmental flight fails.
1990 June	INSAT-ID launched by U.S. Delta rocket	
1991 August	IRS-1B launched by a Russian rocket	
1992 July	INSAT-2A, first of the second generation satellites, launched by Ariane.	
1993 July	INSAT-2B launched by Ariane.	
1993 September	IRS-1C launched aboard PSLV.	First development flight of PSLV fails
1994 May		ASLV-D3 successful.
1994 October	IRS-P2 launched by PSLV-D2	PSLV-D2 launches 804 kg IRS satellite into 820 km orbit.
1995 December	INSAT-2C launched by Ariane-IV- IRS IC launched by Russian Molniya rocket.	
1996 March	IRS-P3 launched INSAT-2D abandoned after three months in September	PSLV-D3 orbits 922 kg IRS satellite.
1997 September	IRS-1D launched. Its a virtual clone of the IRS-1C.	PSLV-C1 launches 1200 kg operational satellite IRS-1D into 820 km orbit.
1999	IRS-P4 (Oceansat-1) for ocean applications to be launched to coincide with the International Ocean Year. INSAT-2E to be launched on an Ariane rocket IRS-P5 (Cartosat) for cartographic applications	PSLV-C2 to launch South Korean and German scientific satellites along with IRS-P4..
2000	IRS-P6 for agricultural applications	

SELECT BIBLIOGRAPHY

Primary Sources

Government of India, *Science Policy Resolution*, 4 March 1958.

India, *Atomic Energy and Space Research: A Profile for the Decade 1970- 1980* (Bombay: Atomic Energy Commission, July 1970)

India, Department of Atomic Energy, *Annual Reports*, 1958-1972.

India, Department of Space, *Annual Reports*, 1973-1997.

India, Lok Sabha, Standing Committee on Defence (1995-96), *Defence Research and Development-Major Projects* (New Delhi: Lok Sabha Secretariat, March 1996).

India, Lok Sabha, Standing Committee on Defence (1995-95), *Defence Policy, Planning and Management*, Sixth Report (New Delhi: Lok Sabha Secretariat March 1996).

India, Ministry of Defense, *Annual Reports*, 1960-1997.

India, Ministry of External Affairs, *Annual Reports*, 1958-1964 and 1987-1993.

India, 'The National Paper of India for the Second United Nations Conference on Exploration and Peaceful Uses of Outer Space (UNISPACE-82)'(New Delhi: 1981)

India, Indian National Statement presented by Prof. Satish Dhawan, leader of the Indian Delegation to the UNISPACE-82 Conference on 10 August 1982 in Vienna, Austria.

India, Rajya Sabha, Standing Committee on Science and Technology, Environment and Forests (1994-95), *Fifteenth Report on the Annual Report of the Department of Space for the Year 1993-94* (New Delhi, Rajya Sabha Secretariat, February 1995).

Indian Space Research Organisation, *A Glimpse of Space Science Research at ISRO AND PRL* (Bangalore: ISRO-SN-060-78, May 1978).

_____, *Pricing of Spin-off Technologies* (Bangalore: ISRO-TTG-CR-01-79, December, 1979).

_____, *20 Years of Rocketry in Thumba, 1963-8* (Vikram Sarabhai Space Centre, ISRO, Undated).

_____, INDUSPACE 1992/93, *Indian Space Programme's Partnership With Industry* (Bangalore, Directorate of Technology Transfer & Industry Co-operation, ISRO, December. 1993).

India, *Technology Policy Statement*, January 1983.

United States (U.S.), Congress, Office of Technology Assessment, *Report on Export Controls and Non-proliferation Policy* (Washington, D.C., 1995).

_______, House Committee on S & T, SubCommittee on Space Science and Applications, *World Wide Space Activities*, (Congressional Research Service Report, 95th Congress, September, 1977).

______, Office of Technology Assessment, *Civilian Space Policy and Applications*, OTA (Washington D.C.: US Governmental Printing Office (USGPO), 1981).

______,Office of Technology Assessment, *Proliferation of Weapons of Mass Destruction: Assessing the Risks*, OTA,-ISC-559, (Washington D.C.: USGPO, August 1993).

______,Office of Technology Assessment, *Technologies Underlying the Weapons of Mass Destruction*, OTA-BP-ISC-115 (Washington D.C.: USGPO, December 1993)

______,Office of Technology Assessment, *Export Controls and Non-proliferation Policy*, OTA-ISS-596 (Washington D.C.: USGPO, May 1994).

______,House of Representatives, Subcommittee on Space Science and Applications of the Committee on Science and Technology, *Space Activities of the US, Soviet Union and Other Launching Countries, Organisations: 1957-82* (Washington D.C.: USGPO, 1983).

_____, *International Co-operation and Competition in Civilian Space Activities* (Washington D.C.: USGPO, 1985.

______,Committee on Science, Engineering and Public Policy, *Balancing the National Interest: US National Security Export Controls and Global Economic Competition* (Washington D.C.: National Academy Press, 1987).

______,*Holding the Edge: Maintaining the Defence Technology Base*, OTA, ISC-420, April, 1989.

______,*Export Controls, Some Controls Over Missile Related Technology Exports to China are Weak*, Report to the Chairman, Committee on International Relations (Washington D.C.: US General Accounting Office, GAO/NSAID-95-82, April 1995).

______,Government Accounting Office, *Military Exports: A Comparison of Government Support in the United States and Three Major Competitors* (Washington D.C.: GAO, May 1995).

_____, Departments of Commerce, Defence, Energy, and State, *The Federal Government's Export Licensing Processes for Munitions and Dual-Use Commodities, Final Report*, September 1993.

______, Strategic Defence Initiative Organisation, *The 1990 Report to the Congress on the SDI* (Washington D.C.: SDIO, May 1990).

______, Commission on Integrated Long-Term Strategy, *Discriminate Deterrence* (Washington D.C., USGPO, 1988).

______, *India-Pakistan Nuclear and Missile Proliferation: Background, Status, and Issues for US Policy*, Report for Congress, CRS, December 1996.

______,*Proliferation Control Regimes: Background and Status*, Report for Congress, CRS, 1997.

U.S., Department of State, Missile Technology Control Regime, *Fact Sheet*, Along with the Equipment and Technology Annex, (Washington, DC., 16 April 1987).

U.S., Information Service, *Progress Towards Regional Non-Proliferation in South Asia* (Washington D.C., 7 May 1993).

U.S, Office of the Press Secretary, The White House, *Fact Sheet: Non Proliferation and Export Control Policy* (Washington D.C., September 1993).

United Nations Documents

"International Cooperation in the Peaceful Uses of Outer Space", *Official Records of the General Assembly*, 1472 (XIV) 856th, 12 December 1959.

"International Cooperation in the Peaceful Uses of Outer Space", *Official Records of the General Assembly*, A/RES/ 1721 (XVI), 20 December 1961.

"Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies", *Official Records of the General Assembly*, A/RES/ 2222 (XXI), Annex, 19 December 1966.

United Nations, *The Application of Space Technology for Development*, A Report Prepared for the 12th Session of the Advisory Committee on Application of Space Technology to Development (New York: United Nations, 1973).

The United Nations yearly series entitled *The United Nations Yearbook* (New York: United Nations).

Secondary Sources

Books and Reports

Agarwal, K. Rajesh, *Defence Production and Development* (New Delhi: Birla Institute of Scientific Research, Economic Research Division, Arnold-Heinemann, 1978).

Anderson, S. Robert, *Building Scientific Institutions in India : Saha and Bhabha* (Montreal: MaGill University Press, 1975).

Anthony, Ian, ed., *Arms Export Regulations* (London: Oxford University Press (OUP), Stockholm International Peace Research Institute (SIPRI), 1991).

_____, *The Arms Trade and Medium Powers: Case Studies of India and Pakistan 1947-1990* (Hertfordshire: Harvester Wheatsheaf, 1992).

Arnett, Eric, ed., *New Technology for Security and Arms Control: Threats and Promises* (Washington D.C.: American Association for the Advancement of Science (AAAS), 1989).

______and Thomas W. Wander, eds., *The Proliferation of Advanced Weaponry: Technology, Motivations and Responses* (Washington D.C.: AAAS, 1992).

_____, Elisabeth J. Kirk and Thomas Wander, eds., *Science and Security :Technology Advances and the Arms Control Agenda* (Washington D.C.: AAAS, 1990).

_____. ed., *Military Capacity and the Risk of War: China, India, Pakistan and Iran* (New York: OUP, SIPRI, 1997).

Babbage, Ross, and Sandy Gardon, eds., *India's Strategic Future: Regional State or Global Power?* (New York: St. Martin Press, 1992).

Babu, Shyam, *Nuclear Non-Proliferation: Towards a Universal NPT Regime* (Delhi: Konarak Publishers, 1992).

Bailey, C. Kathleen, *Doomsday Weapons in the Hands of Many: Arms Control Challenge of the 1990s* (Urbana: University of Illinois Press, 1991).

______,ed., *Weapons of Mass Destruction: Costs versus Benefits* (New Delhi: Manohar, 1994).

Bajpai, U.S., ed., *India's Security: The Politico-Strategic Environment*, Proceedings of a Seminar held by School of International Studies(JNU) and Institute for Defence Studies and Analysis, New Delhi, March 29-31,1982, (New Delhi: Lancers Publishers, 1983).

Baker, David, *The Rocket: The History of Development of Rocket and Missile Technology* (London: New Cavendish Books, 1978).

Banerji, Arun Kumar, ed., *Non-Proliferation in a Changing World: India's Policy and Options* (Calcutta: Allied Publishers Ltd., Jadavpur University, 1997).

Barker, John, Elleman Michael Harvey and Uzi Rubin, *Assessing Ballistic Missile Proliferation and its Control* (Stanford: Centre for International Security and Arms Control, 1991).

Balaschak, Mark, Jack Ruina, Gerald Steinberg and Anslem Yaron, *Assessing the Capability of Dual-Use Technologies for Ballistic Missile Development* (Mass.: MIT Press,Centre for International Studies, 1981).

Bauch, Hans Gunter, ed., *Controlling the Development and Spread of Military Technology* (Amsterdam: VU University Press, 1992).

______, ed., *Military Technology, Armament Dynamics and Disarmament* (London: Macmillan Press, 1989).

Becklake, John, ed., *History of Rocketry and Astronauts*(New York: American Astronautical Society (AAS) Publication, History Series, vol. 17,1995).

Bertsch, K. Gary, Richard T Cupitt and Steven J Elliot-Gower, eds., *International Co-operation on Non-Proliferation Controls: Prospects for the 1990s and Beyond* (Georgia: Centre for East-West Trade Policy and Dept. of Political Science, 1992).

Bertsch, K. Gary and Steven Elliot-Gower, eds., *Export Controls in Transition*, (Durham, N.C: Duke University Press, 1992).

Betts, K. Richard, *Cruise Missiles: Technology, Strategy, Politics* (Washington, D.C.: Woodrow Wilson Centre Press, 1992).

Bhaneja, Balwant, *Science and Government-The Nehru Era: Accountability of Science in India* (New Delhi: National Publishing House, 1992).

Bhatt, S., *Legal Controls of Outer Space: Law, Freedom and Responsibility* (New Delhi: S. Chand and Co., 1973)

______, *International Aviation and Outer Space Law and Relations : Reflections on Future Trends* (New Delhi: Asian Institute of Transport Development, 1996).

Bilder, H. Carl, 'The Prospects and Implications of Non-Nuclear Means for Strategic Conflict', *Adelphi* Paper 200 (London: International Institute for Strategic Studies (IISS), Summer, 1985).

Birtles, Philip and Paul Beaver, *Missile Systems* (London: Ian Allen Ltd., 1985).

Bloomfield, P. Lincoln, ed., *Outer Space: Prospects for Man and Society* (New York: Columbia University, Praeger: Revised Edition, 1968).

Bristow, Damon, *India's New Armament Strategy: A Return to Self-Sufficiency?* (London: Royal United Services Institute for Defence Studies (RUSI), 1995).

British-American Security Information Council, *A European Code of Conduct on the Arms Trade* (Washington, D.C.: May 1995).

Burrows E. William & Robert Windrem, *Critical Mass* (New York: Simon and Schuster Ltd, 1994).

Buzan, Barry, *An Introduction to Strategic Studies: Military Technology and International Relations* (New York: St. Martin's Press, 1987).

______ and Gowher Rizvi, *South Asian Insecurity and the Great Powers* (London: Macmillan Press, 1986).

Cahn, Anne Hessing, Joseph J Kruzel, and others, *Controlling Future Arms Trade* (New York: McGraw Hill Book Company, 1977).

Carnegie Task Force on Non-Proliferation and South Asian Security, *Nuclear Weapons and South Asian Security* (Washington D.C.: Carnegie Endowment for International Peace, 1986).

Carus, W. Seth, *Ballistic Missiles in Modern Conflict* (New York: Praeger, 1991).

_____, *Cruise Missile Proliferation in the 1990s* (Westport: Praeger, 1992).

Chari P.R., *Indo-Pak Nuclear Stand-off: The Role of the United States* (New Delhi: Manohar, 1995).

Chellaney, Brahma, *Nuclear Proliferation: The US-Indian Conflict* (New Delhi: Orient Longman, 1993).

Christian, Schmidt, ed., *The Economics of Military Expenditures* (London: Macmillian, 1986).

Chowdhry, Kamal, ed., *Science Policy and National Development: Vikram Sarabhai* (Delhi: Macmillan, 1974).

Clark, A. Asa IV and John F. Lilley, eds., *Defence Technology* (New York: Praeger, 1989).

Clark, Norman, *The Political Economy of Science and Technology* (Oxford: Basil Blackwell, 1985).

Cohen, Linda and Roger G. Noll, *The Technology Pork Barrel* (Washington D.C.: The Brookings Institution, 1991).

Cohen, P. Stephen, ed., *The Security of South Asia: Asian and American Perspectives* (Urbana: University of Illinois Press, 1987).

_____, *Nuclear Proliferation in South Asia: The Prospects for Arms Control* (New Delhi: Lancer International, 1991).

Cordesman, H. Anthony, *US Strategic Interests in the India-Pakistan Military Balance* (New Delhi: The English Book Store, 1988).

Crunden, Robert, Manoj Joshi and R.V.R. Chandrasekhara Rao, eds., *New Perspectives on America and South Asia* (New Delhi: Chanakya Publishers, 1984).

Crawford, Beverly, *Economic Vulnerability in International Relations* (New York: Columbia University Press, 1993).

Davis S. Zachary, Steven R Bowman, Robert Shuey and Theodore W Galdi, *Proliferation Control Regimes: Background and Status* (Washington D.C.: Library of Congress, Congressional Research Service (CRS), 27 April 1995.

Deltac Limited and Safer World, *Proliferation and Export Controls: An Analysis of Sensitive Technologies and Countries of Concern* (UK: Doveton Press, 1995).

Dhawan, Satish, *The Indian Space Programme: Chanakya Defence Annual 1979* (Allahabad: Chanakya Publishing House, 1979).

Doyel, E. Stephen, *Civil Space Systems: Implications for International Security* (UK; Dartmouth, UNIDIR, 1994).
Dunn, Lewis and others, *U.S. Defence Planning for a More Proliferated World* (Philadelphia: Hudson Institute, 1979).
Dunnigan F. James, *Digital Soldiers: The Evolution of High-Tech Weaponry and Tomorrow's Brave New Battlefield* (New York: St. Martin Press, 1996).
Egbert, F. Leslie Jr. and James O. Frankosky, *Technology List for Observing Possible Indigenous Development/Production of a Surface-to-Surface Missile System by a Less Developed Country* (Arlington Va: Science Applications, Inc., August 1997)
Ezrahi, Yaron, Everett Mendelsohn and Howard Segal, *Technology, Pessimism and Post-Modernism, Sociology of the Sciences Yearbook 1993* (Dordrecht: Kluwer Academic Publishers, 1994).
Feld BT, Greenwood, Rathjens and Weinberg, eds. *Impact of New technologies on Arms Race* A Pugwash Monograph, Proceedings of 10th Pugwash Symposium held at Wingspread, Wisconsin June 26-9, 1970 (Mass.,: MIT Press, 1971).
Ferrari, L. Paul Knopf and Madrid, *US Arms Exports: Policies and Contractors* (Washington D.C.,: Investor Responsibility Research Center Inc., 1987).
Finch, R. Edward Jr. and Amanda Lee Moore, *Astrobusiness: A Guide to Commerce and Law of Outer Space* (New York: Praeger, 1985).
Findlay, Trevor, ed., *Chemical Weapons and Missile Proliferation: With Implications for Asia/Pacific Region* (Boulder: Lynne Rienner, 1991).
Frankle, Francine, ed., *Bridging the Non-Proliferation Divide: The United States and India* (New Delhi: Konarak Publishers Private Ltd., 1995).
Frelk J. James and Glen E Tait, eds., *Defending Against Ballistic Missile Attacks: The Concept of Defensive Deterrence* (Washington D.C.: George L. Marshall Institution, 1990).
Frutkin, W. Arnold, *International Co-operation in Space*, (Delhi: S. Chand & Co., 1966).
Garden, Timothy, *The Technology Trap: Science and the Military* (London: Brassey's Defence Publishers, 1989).
Garfinkle M. Adam, ed., *Global Perspectives on Arms Control* (New York, Praeger: Foreign Policy Research Institute Series, 1984).
Gasparini A. Pericles, *Prevention of an Arms Race in Outer Space: A Guide To the Discussion in the Conference on Disarmament* (New York: UNIDIR, 1991).
_, *Access To Outer Space Technologies: Implications for International Security* (New York: UNIDIR, 1992).
Goldberg, M, *Technology Transfer: How it Happens* (New York: US Naval Institute Proceedings, 1988).
Goldman, C. Nathan, *Space Commerce: Free Enterprise on the High Frontier* (Cambridge, Mass,: Ballinger, 1985).
Greenberg, S. Joel and Henry R. Hertzfeld, eds., *Space Economics*, Progress in Astronautics & Aeronautics, vol. 144, 1992.
Gormley, Dennis M. and Scott K. McMohan, *Controlling the Spread of Land-Attack Cruise Missiles* AISC Paper 7 (California: Marina del Rey, American Institute for Strategic Co-operation, January, 1995).
Gubarev, Valdimir, *Aryabhata- The Space Temple* (New Delhi: Deep & Deep Publication, 1976).
Gupta, Bhabani Sen, *Nuclear Weapons? Policy Options for India* (New Delhi: Sage Publishers, 1983).
Haas, B. Ernest, Mary Pat Williams and Don Babai, *Scientists and World Order: The Use of Technical Knowledge in International Organisations* (Berkley, L.A.: University of California Press, 1977).
Headrick, R. Daniel, *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940*, (New York: OUP, 1988).

Handa, Rohit, *Policy for India's Defence* (New Delhi: Chetana Publications, 1976).
Harrison, J. Glennon, *Export Controls: Background and Issues* (Washington D.C.: Library of Congress, CRS Report no. 94-30E, 12 January 1994).
Harrison, S. Selig and Geoffrey Kemp, *India and America After the Cold War* (Washington D.C.: Carnegie Endowment for International Peace, 1993).
Harshberger, E. R., *Long Range Conventional Missiles: Issues for Near-Term Development* (Santa Monica: Rand, Report no. N-3328-RGSD, 1991).
Hartcup, Guy, *The Silent Revolution: Development of Conventional Weapons*, (London: Brassey's, 1993).
Harvey, John, et al., *A Common-Sense Approach to High-Technology Export Controls* (Stanford, California: Centre for International Security and Arms Controls, March 1995).
Hudon E. Heather, *Communication Satellites: Their Development and Impact* (New York: The Free Press, 1990).
Indian National Science Academy, *Science in India: Fifty Years of the Academy* (New Delhi: INSA, 1985).
Jain J.P., *Nuclear India*, vol. 1 & 2(New Delhi: Radiant Publishers, 1975).
Jasani, Bhupendra, ed., *Peaceful and Non-Peaceful Uses of Space: Problems of Definition for the Prevention of an Arms Race* (New York: UNIDIR, Taylor and Francis, 1991).
Jasentuliyana, N. and Ralph Chipman, eds., *International Space Programmes and Policies* (Amsterdam: Elxevier Science Publishers, 1984).
Jetly, Col. Ranjitlal, *Rockets, Guided Missiles and Satellites* (Bombay: Allied Publishers Private, 1964).
Jones, W. Rodney, ed., *Small Nuclear Forces and US Security Policy: Threats and Potential Conflicts in the Middle East and South Asia* (Mass, Toronto: Lexington Books, 1984).
______and Steven A. Hildreth, *Modern Weapons and Third World Powers* (Georgetown: Westview Press, 1984).
Joshi, P.K., *Vikram Sarabhai: The Man and the Vision* (Ahmadabad: Mapin Publishing Pvt. Ltd., 1992).
Kalam, A.P.J. Abdul, *Launch Vehicle Technology: A Perspective* (Bangalore, ISRO: ISRO-TN-21-81, September, 1981).
______, *Large Boosters for Space Missions* (Bangalore, ISRO: ISRO-HQ- TN-26-82, May, 1982).
Kapur, Ashok, *India's Nuclear Option: Atomic Diplomacy and Decision Making* (New York: Preager Publishers, 1976).
Kapur, D.D., *Building a Defence Technology Base* (New Delhi: Lancer International, 1990).
Karnad, Bharat, ed., *Future Imperilled: India's Security in the 1990's and Beyond* (New Delhi: Viking, 1994).
Karp, Aaron, *Ballistic Missile Proliferation: The Politics and Technics* (London: OUP, SIPRI, 1996).
Karthikeyan T.V. and A.K. Kapoor, *Guided Missiles* (Delhi: Defence Science Documentation Centre, 1991).
Kaul, Ravi, *India's Nuclear Spin-Off* (Allahabad: Chanakya Publishers, 1975).
Katz, James Everett, ed., *Arms Production in Developing Countries: An Analysis of Decision Making* (Mass.: Lexington Books, 1984).
Keatly, G. Anne, ed., *Technological Frontiers and Foreign Relations* (Washington, D.C.: National Academy Press, 1985).
Kemme, M. David, ed., *Technology Markets and Export Controls in the 1990s* (New York: University Press, 1991).
Kemp, Geoffrey, R. Pfaltzgraff and U. Ra'anan, eds., *The Other Arms Race* (Mass; Lexington Books, 1975).
Kemp, Geoffrey with Shelly Stahl, *The Control of the Middle East Arms Race*, (Washington D.C.: Carnegie Endowment for International Peace, 1991).

Khastgir, S.R, *A Decade of Science in India* (Indian Science Congress Association, 1973).
Khera, S.S., *India's Defence Problem* (New Delhi: Orient Longmans, 1968)
King, John Kerry, ed., *International Political Effects of the Spread of Nuclear Weapons* (Washington D.C.: US Government Printing Office (USGPO), 1979).
Kirk, J. Elizabeth, Thomas W. Wander and Brain D. Smith, eds., *Trends and Implications for Arms Controls, Proliferation and International Security in the Changing Global Environment* (Washington, D.C.: AAAS, 1993).
Kolodzie, A. Edward, *Making and Marketing Arms: The French Experience and its Implications for the International System* (New Jersey: Princeton University Press, 1987).
Krepon, Michael, Peter D. Zimmerman, L Spector and others, eds., *Communication, Observation Satellites and International Security* (New York: Macmillan 1992).
Krushchev S. Nikita, *Krushchev Remembers: The Last Testament*, Strobe Talbott, trans (Boston, 1974).
Lall, Sanjaya, *Learning to Industrialise- The Acquisition of Technological Capability by India* (London: Macmillan, 1987).
Lawrence M. Robert, *Strategic Defence Initiative: Bibliography and Research Guide* (Colorado: Westview Press, University of Colorado, 1987).
Lewis H. William and Stuart E. Johnson, eds., *Weapons of Mass Destruction: New Perspectives on Counterproliferation* (Washington D.C.: National Defence University Press, 1995).
Limaye, P. Satu, *US-Indian Relations : The Pursuit of Accommodation* (Colorado: Westview Press, 1993).
Long A. Frankling, Donald Hafner and Jeffrey Boutwell, eds., *Weapons in Space* (New York: American Academy of Arts and Sciences, W.W. Norton and Company, 1986).
Long J. William, *United States Export Control Policy: Executive Autonomy Vs Congressional Reform* (New York: Columbia University Press, 1989).
Macdonald, Stuart, *Technology and the Tyranny of Export Controls: Whisper Who Dares* (London: Macmillan, 1990).
Mackenzie, Donald, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (Mass.: The MIT Press, 1990).
Mandelbaum, Michael, *The Fate of Nations: The Search for National Security in the Nineteenth & Twentieth Centuries* (Mass.: Cambridge University Press, 1988).
Mani, V.S., S Bhatt and VB Reddy, eds., *Recent Trends in International Space Law and Policy* (New Delhi: Lancers Books, 1997)
Marsh, Peter, *The Space Business: A Manual on the Commercial Uses of Space* (London: Penguin Books, 1985).
Mathews, Ron, *Defence Production in India* (New Delhi: ABC Publishing House, 1989).
McDougall, A. Walter, *...the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985).
McIntyre, R John and Daniel S Papp, *The Political Economy of International Technology Transfer* (New York: Quorum Books, 1988)
McNeill, H. William, *The Pursuit of Power: Technology, Armed Forces and Society Since 1000 AD* (Chicago: Chicago University Press, 1980).
Marwah, Onkar and Jonathan D. Pollack, *Military Power and Policy in Asian States: China, India, Japan* (Boulder: Westview Press, 1980).
Manfredi, F. Arthur and others, *Ballistic Missile Proliferation: Potential in the Third World* (Washington D.C.: Library of Congress, CRS Report, No 86-29 SPR, 1986).
McNamara, S. Robert, *The Changing Nature of Global Security and its Impact on South Asia* (New Delhi: India International Center (IIC), Monograph Series no 18, 1992).
Mellor W. John, ed., *India: A Rising Middle Power* (New Delhi: Select Book Services, 1981).
Mendelsohn, Everett, Merritt Roe Smith and Peter Weingart, eds., *Sociology of the Sciences, Yearbook 1988*, vol. 1 (Dordrecht: Kluwer, 1988).

Menon, P.K., *The United Nations Efforts to Outlaw the Arms Race in Outer Space* (New York: Edwin Mellen Press, 1988).
Mirchandani, G.G., *India's Nuclear Dilemma* (New Delhi: Popular Book Services, 1968).
______ and P.K.S. Namboodiri, *Nuclear India: A Technological Assessment* (New Delhi: Vision Books, 1981).
Morehouse, Ward, *Assessment of US-Indian S&T Relations: An Analytical Study of Past Performance and Future Prospects* (UA, Springfield: National Technology Foundation, 1980).
Myres, S. McDougal, Lasswell and Valsic, *Law and Public Order in Space* (New Haven: Yale University Press, 1963).
National Academy of Science, Committee on Science, Engineering, and Public Policy, *Finding Common Ground: US Export Controls in a Changed Global Environment* (Washington, D.C.: National Academy Press, 1991).
Navias Martin, 'Ballistic Missile Proliferation in the Third World', *Adelphi Paper 252* (London, IISS, Summer, 1990).
______, *Going Ballistic: The Build Up of Missiles in the Middle East* (London: Brasseys, 1993).
Nayer, Baldev Raj, *India's Quest for Technological Independence*, vols. I & II (New Delhi: Lancers Publishers, 1983).
Neuman, G. Stephanie and Robert E Harkavy, eds., *Arms Transfer in the Modern* World (New York: Praeger, 1979).
Neuneck, Gotz and Otfriend Ischebeck, eds., *Missile Technologies, Proliferation, and Concepts for Arms Control* (Beaden- Baden: Nomos Verlag, 1993).
Nolan, E. Janne, *Trappings of Power: Ballistic Missiles in the Third World* (Washington, D.C.: Brookings, 1991).
_____and Michael Brzoska, eds., *Arms Production in the Third World* (London: Taylor & Francis, 1986).
Ollapally, Deepa and S. Rajagopal, eds., *Nuclear Co-operation: Challenges and Prospects* (Bangalore: National Institute for Advanced Studies, 1997).
Panandiker, VA Pai, ed., *India's Policy Problems: Defence, Security and Social Development* (Delhi: Centre for Policy Research, Konarak Publishers, 1996).
Payne, B. Keith, *Missile Defence in the 21st Century: Protection Against Limited Threats* (Boulder; Westview, 1991).
Pearson, Frederick, *The Global Spread of Arms :Political Economy of International Security* (Boulder, Westview, 1994).
Pearton, Maurice, *The Knowledgeable State: Diplomacy, War and Technology since 1830* (London, 1982).
Pierre J. Andrew, *The Global Politics of Arms Sales* (New Jersey: Princeton, A Council on Foreign Relations Book, 1982).
Potter, C. William and Harlam W. Jencks, eds., *The International Arms Bazaar: The New Suppliers Network* (Boulder: Westview, 1994).
Poulose, T.T., ed., *Perspectives of India's Nuclear Policy*, (New Delhi: Young Asia Publications, 1978).
Prakasam, K.P., *Space Horizons* (New Delhi: Sterling Publisher, 1981).
Putnam D. Robert and Nicholas Bayne, *Hanging Together: The Seven Power Summits* (London: Heinemann, 1984).
Ra'anan, Uri, Pfaltzgraff and G. Kemp, eds., *Arms Transfer to the Third World : The Military Build Up in Less Industialised Countries* (Boulder: Westview Press, 1978).
Rajan, S. Mohan, *Indian Space Flights* (New Delhi: Publications Division, Ministry of Information and Broadcasting, 1985).
______, *India in Orbit* (New Delhi: Publications Division, Ministry of Information and Broadcasting, May 1997).

Rana A.P., ed., *Four Decades of Indo-US Relations-A Commemorative Retrospective* (New Delhi: Har Anand, 1994).
Rao, P.V.R, *Defence Without Drift* (Bombay: Popular Prakasham, 1970)
Rao, U.R., *Space Technology for Sustainable Development* (New Delhi: Tata McGraw Hill, 1996).
Reyonolds, Glenn and Robert P. Merges, *Outer Space: Problems of Law and Policy* (Boulder: Westview Press, Second ed. 1997).
Renner, Michael, *Swords into Plowshares : Converting to a Peace Economy*, Worldwatch Paper 96, (Washington, D.C.: Worldwatch Institute, June 1990).
Rioux, Jean-Fancois, ed., *Limiting the Proliferation of Weapons: The Role of Supply Side Strategies* (Ottawa: Carleton University Press, 1992).
Sandholtz, Wayne, M Borrus, J Zysman, and others, eds., *The Highest Stakes: The Economic Foundations of the Next Security System*, A Berkeley Roundtable on the International Economy (BRIE)Project on Economy and Security (New York: OUP, 1992).
Sarabhai, A. Vikram, Bhaskar, P.D., Chitnis and others, *The Applications of Space Technology to Development* (New York: United Nations, 1973).
Sarin, H.C., *Defence and Development*, United Services Institute's National Security Lecture (New Delhi, USI, 1979).
Schaefr, Carlo, Brian Holden and David Carlton, *New Technologies and the Arms Race* (London: Macmillan, 1989).
Schauer, H. William, *The Politics of Space: A Comparison of the Soviet and American Space Programs* (New York, London: Holmes & Meier Publishers, 1976).
Schmidt, Christian, ed., *The Economics of Military Expenditure: Military Expenditures, Economic Growth and Fluctuations* (London: Macmillan, 1987).
Segal Aaron, ed., *Learning By Doing: Science and Technology in the Developing World* (Boulder: Westview Press, 1984).
Sengupta, Bhabani, *Nuclear Weapons? Policy Options for India* (New Delhi: Sage Publishers, 1983).
Sharma, Dhirendra, *India's Nuclear Estate* (New Delhi: Lancer Publishers, 1983).
Sharma I.D., *Outer Space: A Problem in Politics* (Agra: L.N. Aggarwal Publishers, 1964).
Shelton, L. Williams, *The US, India and the Bomb* (Baltimore: The John Hopkins Press, 1969).
Shuey, D Robert, and others, *Missile Proliferation: Survey of Emerging Missile Forces* (Washington D.C.: Library of Congress, CRS Report No.88-642F, October, 1988.
Singh, Jasjit, ed., *Indo-US Relations in a Changing World*, Proceedings of the Second Indo-US Strategic Symposium December 1990, (New Delhi: Lancer Publishers, 1992).
_____, ed., *The Road Ahead: Indo-US Strategic Dialogue*, Proceedings of the Fourth Indo-US Strategic Dialogue in September 1993, (New Delhi: Lancer International, 1994).
Sinha, P.B. and R.R. Subramanian, *Nuclear Pakistan: Atomic Threat to South Asia* (New Delhi: Vision Books, 1980).
Skolnikoff, B. Eugene, *The Elusive Transformation :Science Technology and the Evolution of International Politics* (New Jersey: Princeton University Press, 1993).
Smith, Chris, *India's Ad Hoc Arsenal: Direction or Drift in Defence Policy?* (London: SIPRI, OUP, 1993).
Solinger, Edward and others, eds., *Scientists and the State: Domestic Structures and the International Context* (Ann Arbor: University of Michigan, 1994).
Space Commerce, Proceedings of the Second International Conference on Commercial and Industrial Use of Outer Space, Montreux, Switzerland, 21-25 February 1988 (New York: Gordon and Breach, 1988).
Spector, S. Leonard, *The Undeclared Bomb* (Cambridge, Mass: Ballinger, 1988).
______ with Jacqueline R. Smith, *Nuclear Ambitions: The Spread of Nuclear Weapons, 1989-1990* (Boulder: Westview Press, 1990).

Subramanian R.R, *India, Pakistan, China: Defence and Nuclear Triangle in South Asia* (New Delhi: ABC Publishing House, 1989).

Subrahmanyam, K., ed., *The Second Cold War* (New Delhi: ABC Publishing House, 1983).

______, *Nuclear Proliferation and International Security* (New Delhi: Institute for Defence Studies and Analysis, 1985).

Sudhakar, V., *Sounding Rockets of ISRO*, (Bangalore: Indian Space Research Organisation (ISRO) Technical note, ISRO-VSSC-TN-02-20, December 1976).

Taylor, Trevor and Ryu Kichi Imai, eds., *The Defence Trade: Demand Supply and Control* (London: The Royal Institute of International Affairs & Institute for International Policy Studies, 1994).

Thakur, Kailash, *Outer Space and Military Supremacy : Jurisdiction in International Law* (New Delhi: Deep & Deep Publications, 1985).

Thakur, Ramesh, *The Politics and Economics of India's Foreign Policy* (Delhi: Oxford University, 1994).

The Challenge of Nuclear Weapons to India's Foreign Policy-Selected Readings (New Delhi: School of International Studies, 1966).

The Diffusion of Aircraft, Missiles and Their Supporting Technologies, A Report prepared by Browne and Shaw Research Corporation for the Office of the Assistant Secretary of Defence (International Security Affairs) October, 1966.

Thee, Marek, *Military Technology, Military Strategy and the Arms Race* (London: Croom Helm, 1986).

Thomas, G.C. Raju, *The Defence of India: A Budgetary Perspective of Strategy and Politics* (Delhi: Macmillan, 1978).

_____, *Indian Security Policy*, (New Jersey: Princeton University Press, 1986).

United Services Institute Seminar, *Nuclear Shadow Over the Subcontinent* Proceedings of a seminar on 9 April 1981(New Delhi, Seminar No 9, USII, 1981).

Varma R.K. and others, eds., *Space: In Pursuit of New Horizons* (Allahabad: National Academy of Sciences, 1992).

Venkatraman, G, *Bhabah and His Magnificent Obsession* (New Delhi: Oxford University Press, 1994).

Verma, K.R., ed., *Advances in Space Research in India: A Three Decade Profile* (New Delhi: Indian National Science Academy, 1994).

Von Ham, Peter, *Managing Non-Proliferation Regimes in the 1990's: Power, Politics and Policies*, The Royal Institute for International Affairs (London: Pinter, 1993).

Vayrynen, Raimo, *Military Industrialisation and Economic Development: Theory and Historical Case Studies* (Cambridge: Dartmouth, UNIDIR, 1992).

Victor I. Cecil, *India :The Security Dilemma* (New Delhi: Patriot Publishers, 1990).

Walersteim M and Granger Morgan, *Controlling the High-Tech Militarisation of the Developing World* (Washington, D.C.: American Association for the Advancement of the Sciences, 1992).

Waltz, N. Kenneth, *The Spread of Nuclear Weapons: More May Be Better, Adelphi Paper 171* (London, IISS, Autumn, 1981).

Yash Pal, *Space and Development* (UK: Pergamon, COSPAR, 1980).

York, F. Herbert, *Making Weapons Talking Peace: A Physicists Odyssey from Hiroshima to Geneva* (New York: Basic Books Inc., Publishers, 1987).

Zegveld, Waler and Christien Enzing, *SDI and Industrial Technology Policy: Threat or Opportunity* (London: Francis Pinter Publishers, 1987).

Zukerman, Lord, *Star Wars in the Nuclear World* (London: William Kimber, 1986).

Articles in Books and Journals

Abraham, Itty, 'India's "Strategic Enclave": Civilian Scientists and Military Technologies', *Armed Forces and Security*, vol. 18, Winter 1992.

Aftergood, Steven, Hafemeister and others, 'Nuclear Power in Space', *Scientific America*, vol. 264, June, 1991.

Adler, Emanuel, 'Arms Control, Disarmament and National Security: A Thirty Year Retrospective', *Daedalus*, Winter 1991.

Ahmed, Acqueil, 'Politics of Science Policy Making in India', *Science and Public Policy*, October 1985.

Alam, Shahid, 'Some Implications of the Aborted Sale of Russian Cryogenic Engines to India', *Comparative Strategy*, vol. 13 July-September, 1994.

Albight, David and Tom Zamora, 'India, Pakistan's Nuclear Weapon; All the Pieces in Place', *The Bulletin of the Atomic Scientists*, June 1989.

______and Mark Hibbs, 'India's Silent Bomb', *The Bulletin of the Atomic Scientists*, September 1992.

Anderson, S. Robert, 'Cultivating Science as Cultural Policy: A Contrast of Agriculture and Nuclear Science in India', *Pacific Affairs*, vol. 56, 1983.

Anson, Peter and Cummings, 'First Space War: The Contribution of Satellite to the Gulf War', *RUSI Journal*, vol. 36, Winter, 1992.

Appadorrai, A, 'Technology and International Relations', *Nehru Memorial Lecture*, 1965, Viswabarathi, Calcutta, 1966.

Arguilla, John, 'Bound to Fail: Regional Deterrence After the Cold War', *Comparative Strategy*, June 1995.

Baley C Kathleen, 'Can Missile Proliferation be Reversed?' *Orbis*, Winter 1991.

Banerjie, Indranil, 'The Integrated Guided Missile Development Programme', *Indian Defence Review*, July 1990.

Banks, M. Peter and Sally K. Ride, 'Soviets in Space', *Scientific American*, vol. 260, February 1989.

Beaudan, Eric Yann, 'Space Age Pioneers: The Commercial Use of Space', *Defense and Diplomacy*, vol. 7 (6) June 1989 and (7/8) July/August 1989.

Berg Per and Guinalla Herolf, '"Deep Strike": New Technologies for Conventional Interdiction', *SIPRI Yearbook 1984: World Armaments and Disarmament* (London: Oxford, 1984).

Beri, Ruchita, 'Ballistic Missile Proliferation, *Asian Strategic Review*', 1991-92, IDSA, New Delhi, 1992.

Berman, J. Harold and John R. Garson, 'United States Export Controls-Past, Present and Future', *Columbia Law Review*, vol. 67, May 1967.

Besch, Edwin, 'How the Technology Explosion is Changing World Power Relationships', *Defence and Foreign Affairs*, March 1991.

Bhatia, Anita, 'India's Space Program: Cause for Concern?', *Asian Survey*, vol. XXV, October 1985.

Bilveer, S., 'Agni: India Fires into the Missile Age', *Asian Defence Journal*, September 1989.

Blackaby, Frank, 'Space Weapons and Security', *SIPRI Yearbook of World Armaments and Disarmament 1986* (London: OUP, 1986).

Bose, D. M., 'India's Recent Achievements in Atomic and Space Research, *Science and Culture*, vol. 34 (6), June 1968.

Brecher, Michael, 'Elite Images and Foreign Policy Choices: Krishna Menon's View of the World', *Pacific Affairs*, vol. XL, 1967.

Brey, T.J. Frank and Michael Moodie, 'Nuclear-Politics in India', *Survival*, vol. 20, (3), May-June, 1977.

Bhatt S, 'International Problems Concerning Use of Space: Survey of Source Material', *International Studies*, December 1972.

Bailey, C. Kathleen, 'Can Missile Proliferation Be Reversed?' *Orbis*, Winter, 1991.

Bitzinger, Richard, 'The Globalisation of the Arms Industry: The Next Proliferation Challenge', *International Security*, vol. 19 (2), Fall 1994.

Bloomfield, P. Lincoln, 'The Politics of Outer Space', *The Bulletin of the Atomic Scientists*, May, 1963.

Burt, Richard, 'Nuclear Proliferation and the Spread of New Conventional Weapons Technology', *International Security*, vol. 1, (3), Winter, 1977.

Buzan, Barry and Gautham Sen, 'The Impact of Military Research and Development Priorities on the Evolution of the Civil Economy in Capitalist States', *Review of International Studies*, vol. 16, 1990.

Chandrasekhar S, 'Export Controls and Proliferation: An Indian Perspective', ISRO, Bangalore Undated.

_____, 'Missile Technology Control and the Third World: Are there Alternatives?', *Space Policy*, Vol. 6, November 1990.

_____,'Peaceful and Non Peaceful Uses of Space: A View From an Emerging Space Power', in Bhupendra Jasani, ed., *Peaceful and Non-Peaceful Uses of Space: Problems of Definition for the Prevention of an Arms Race* (New York and Geneva: UNIDIR, 1993)

Chari, P R, 'An Indian Reaction to US Non Proliferation Policy', *International Security*, vol. 3, Fall, 1978.

_____, 'How to Prevent a Nuclear Arms Race Between India and Pakistan' in Bhabhani Sen Gupta, ed., *Regional Co-operation in South Asia*, vol. 1 (New Delhi: South Asia Publishers, 1986).

Chellaney, Brahma, 'South Asia's Passage to Nuclear Power', *International Security*, vol. 16, 1991.

_____, 'An Indian Critique of US Export Controls', *Orbis*, vol. 38, Summer, 1994.

Cheema, Zafar Iqbal, 'Nuclear Diplomacy in South Asia during the 1980s', *Regional Studies*, vol. 1, Summer, 1992.

Cheung, Tai Ming, 'China and its Role in Response Towards Nuclear and Missile Proliferation in South Asia After the Cold War', Paper presented at workshop on nuclear proliferation in South Asia at The Centre for International and Security Studies at Maryland, School of Public Affairs, University of Maryland, 12-13 November, 1993.

Clarke, C. Arthur, 'Star Wars and Star Peace', *19th Nehru Memorial Lecture, NMML* Occasional Paper (New Delhi: 13 November 1986).

_____,'What Is To Be Done?', *The Bulletin of the Atomic Scientists*, May, 1992.

Cohen, P. Stephen, 'India's Role in the New Global Order: A US Perspective', *Indian Journal of Asian Affairs*, vol. 6, 1993.

Cohen, Richard and Peter A. Wilson, 'Superpowers in Decline? Economic Performance and National Security', *Comparative Strategy*, vol. 7 (2), 1988.

Crawford, Beverly, 'The New Security Dilemma's under International Economic Interdependence', *Millennium, Journal of International Studies*, vol. 23, 1994.

Cypher, M. James, 'Military Spending ,Technical Change and Economic Growth: A Disguised Form of Industrial Policy?', *Journal of Economic Issues*, vol. 21 (1), 1987.

Cremins, E. Thomas, 'Security in the Space Age', *Space Policy*, February 1990.

Danyes, Edmond, 'Missiles in Gulf Buoy India's Defence Drive', *Defence News*, 2 February, 1991.

Davis S Zachary, 'America's Non-Proliferation Policy: A Congressional Perspective', in Shai Feldman and Ariel Levita, ed., *Arms control and the New Middle East Security Environment* (Boulder and Tel Aviv: Westview Press, 1994).

_____, 'China's Non-Proliferation and Export Control Policies', *Asian Survey*, vol. XXXV, June 1995.

Deger, Saadet and S Sen, 'Defence Industrialisation, Technology Transfer and Choice of Techniques in LDCs', in Silvio Borner and Alwyn Taylor, eds., *Structural Change, Economic Interdependence and World Development* (London: Macmillan, 1987).

Dhawan, B.D, 'Satellite TV Revisited' *Economic and Political Weekly*, 20 April 1974.

______, 'INSAT TV Plan: Questionable Features and Parameters', *Economic and Political Weekly*, October 1975.

Dhawan, Satish, 'Manned Flight', *Seminar*, November 1960.

______,'The Indian Space Programme', *Chanakya Defence Annual 1979*(Lucknow, 1979).

______,'Space Launchers for India', *Sir M Visvesvarayya Memorial Lecture* Inst. of Engineers, Hyderabad, 8 February 1981, (Bangalore: ISRO) March 1982.

_____, 'Applications of Space Technology in India', *Aryabhata Lecture*, Indian National Science Academy, 2 August 1985, (Bangalore: ISRO).

_____, 'Star Wars: The Arms Race in Space', *Lecture to Peace Conference*, 5 July, 1986, (Bangalore: ISRO).

_____, 'Space and Foreign Policy', *Man and Development*, March 1989.

_____, 'The Only Alternative of the Elimination of Nuclear Weapons', *Disarmament*, vol. XVII (20), 1994.

Doleman J. Anthony, 'Disarmament, Development, Dual-Purpose Technologies and the Like Minded Countries' *Co-operation and Conflict*, XIX 1984.

Dubey, Muchkund, 'SDI From the Viewpoint of the Non-aligned Nations', in Bhupendra Jasani, ed., *Space Weapons and International Security* (Oxford: SIPRI, 1987).

Dula, M Arthur, 'Export Controls Affecting Space Operations', *Journal of Air Law and Commerce*, vol. 51, Summer 1986.

Dunn, A. Lewis, 'Half Past India's Bang', *Foreign Policy*, Fall, 1979.

_____, 'Rethinking the Nuclear Equation: The US and the New Nuclear Powers', *The Washington Quarterly*, Winter 1994.

Eisenstein, Maurice, 'Third World Missiles and Nuclear Proliferation', *The Washington Quarterly*, vol. 15, Summer, 1982.

Elkin, F. Jarrold and Brian Fredricks, 'Military Applications of India's Space Programme', *Air University Review*, (34), May/June 1983.

Ferguson, Charles, 'America's High-Tech Decline', *Foreign Policy*, vol. 74, Spring, 1989.

Fetter, Steven, 'Ballistic Missiles and Weapons of Mass Destruction: What is the Threat? What Should be Done', *International Security*, Summer, 1991.

Flamm, Don, 'US Conventional Arms Transfers: Rhetoric and Reality', *Asian Defence Journal*, May 1994, pp. 33-39. *Flight International*, India Aims for Self-Sufficiency in Space, 14 June, 1986.

Frey, Alton, 'Zero Ballistic Missiles?' *Foreign Policy*, vol. 88, Fall, 1992.

Friedberg, Aaron, 'The Changing Relationship Between Economic and National Security', *Political Science Quarterly*, Summer, 1991.

Forsberg, Randall, 'Abolishing Ballistic Missiles', *International Security*, vol. 12, Summer, 1987.

Ghosh, S.K, 'India's Space Programme and its Military Implications', *Asian Defence Journal* , September, 1981.

Gilpin, Robert, 'Has Modern Technology Changed International Politics?', in James N Rosenau, Vincent Davis and Maurice A East, eds., *The Analysis of International Politics* (New York: The Free Press, 1972).

Gill, Stephen and David Law, 'Reflections of Military-Industrial Rivalry in the Global Political Economy', *Millennium*, vol. 16, 1987.

Glenn, John, 'Omnibus Nuclear Proliferation Control Act of 1993: A Section-by Section Description', *Congressional Record*, 27 May, 1993.

Gottlieb, Anthony, 'Selling Space Exploration: Luxury or Necessity?' *Space Policy*, November, 1988.

Graybeal, Sidney and Patricia McFate, 'GAPALS and Foreign Space Launch Vehicle Capabilities', *Science Applications International Corporation*, Prepared under SDIO Contract no. 84-91-C-0012.

Gupta, Amit, 'The Indian Arms Industry: A Lumbering Giant ?', *Asian Survey*, September, 1990.

_____, 'Fire in the Sky', *Defence and Diplomacy*, 1990.

Hagerty, D, 'India's Regional Security Doctrine', *Asian Survey*, vol. 13, 1991.

Hamish, McDonald, 'Price of Self-Reliance', *Far Eastern Economic Review*, vol. 155, 10 December 1992.

Haritesh, Nirmal, 'Links between the Political System and the Scientific and Technology system in India', *Journal of Scientific and Industrial Research*, vol. 39, 1980.

Hartman J. Lisa, 'Controlling the Proliferation of Missiles', in Shai Feldman and Ariel Levita, *Arms Control and the New Middle East Security Environment* (Boulder: Westview Press, Jaffee Center for Strategic Studies, Tel Aviv University, 1994)

Herolf, Gunilla, 'Emerging Technologies', in *SIPRI Yearbook 1986. World Armaments and Disarmament* (London, OUP, 1986).

Hertzfeld R. Henry 'Economic Issues Facing the United States in International Space Activities' in V Lopez & D. Vadas, eds., *The US Aerospace Industry: A Global Perspective for the 1990s* (Washington D.C.: Aerospace Industries Association of America, 1991).

Hoag D.G, 'Inertial Guidance of Ballistic Missiles', in G Rathjens, B.J. Feld and others, eds., *Impact of New Technologies on Arms Race*, A Pughwash Monograph MIT Press, Cambridge, 1971.

Hoag, W. Paul, 'Hi-Tech Armaments, Space Militarisation and the Third World', in Colin Creighton and Martin Shaw, eds., *The Sociology of War and Peace* (London: Macmillan, 1987).

Hoagland J.H and J.B. Teeple, 'Regional Stability and Weapons Transfer: The Middle Eastern Case', *Orbis*, vol. IX (3), 1966.

Hudson, C.I. Jr., 'The Impact of PGMs on Arms Transfers and International Stability', in Stephanie G Neuman and Robert E Harkavy, eds., *Arms Transfer in the Third World* (New York: Praeger, 1979).

Hull, Andrew, 'Motivations for Producing Ballistic Missiles and SLVs', *Jane's Intelligence Review*, February, 1993.

Huntington, P. Samuel, 'Trade, Technology and Leverage: Economic Diplomacy', *Foreign Policy*, vol. 32, Fall, 1978.

Inman, B.R and Daniel F. Burtonn Jr., 'Technology and Competitiveness: The New Policy Frontier', *Foreign Affairs*, vol. 69, 1990.

Iqbal, J. Mohammad, 'Missile Proliferation in South Asia', *Regional Studies*, Spring, 1990.

______, 'India's Space Programme', *Regional Studies* (Islamabad), vol. 2, Winter, 1983.

Jervis, Robert, 'Security Regimes', *International Organisation*, Spring, 1982.

Johnson, Joel, 'Conventional Arms Transfer Policy: An Industry Perspective', *Military Technology*, vol. 18, (2) October 1991.

Joshi, Manoj, 'The Missile Edge', *Frontline*, 2-15 April, 1988.

______, 'Agni: Importance, Implications', *Frontline*, 10-23 June, 1989.

______, 'Right on Target', *Frontline* , 15-23 September, 1990

______, 'The Indigenous Effort', *Frontline*, April 13-26, 1991.

______, 'Vehicles of War: The Prithvi, the MBT, the ALH'', *Frontline*, September 25, 1992.

______, 'Dousing the Fire? Indian Missile Programme and the US Non-proliferation Policy', *Strategic Review*, August, 1994.

Kapur, K.D., 'Missile Technology Control Regime: An Extension of Nuclear Non-Proliferation Regime' *Foreign Affairs Reports* (New Delhi: Indian Council of World Affairs), vol. XLII (11 & 12) November/December 1993.

Karp, Aaron, 'Space Technology in the Third World', *Space Policy*, May, 1986.

______, 'Ballistic Missiles in the Third World', *International Security*, Winter, 1984-85.
______, 'Ballistic Missile Proliferation', *SIPRI Yearbook 1990: World Armaments and Disarmament* (London: OUP, 1990).
______, 'Controlling Ballistic Missile Proliferation', *Survival*, Nov-December, 1991.
Kaye, Lincoln, 'Step by Step Towards Self-Reliance', *Far Eastern Economic Review*, vol. 137 August 27 1987.
Kato, Masahide, 'Nuclear Globalism: Traversing Rockets, Satellites, and Nuclear War via the Strategic Gaze', *Alternatives*, vol. 18, 1993.
Kingwell, Jeff, 'The Militarisation of Space: A Policy Out of Step with World Events?', *Space Policy*, May 1990.
Klare, T. Michael, 'The Unnoticed Arms Trade: Export of Conventional Arms Making Technology', *International Security*, vol. 8, Fall, 1983.
Kothari D.S. and A.S. Nagarajan, 'Exploration Prospects', *Seminar*, November 1960.
Krepon, Michael, 'Spying from Space', *Foreign Affairs*, vol. 75. Summer 1989.
Lall, Sanjaya, 'Developing Countries and the Emerging International Order', *Journal of International Affairs*, 1979.
Leitenberg, Milton, 'Satellite Launchers and Potential Ballistic Missiles in the Commercial Market', *Current Research on Peace and Violence*, (2), 1981.
Leonard, F. James and Adam M. Scheinman, 'Denuclearising South Asia: Global Approaches to a Regional Problem', *Arms Control Today*, June, 1993.
Levy, M. Deborah, 'Export Controls: Benefit or Bust for US Business?', *USA Today* (Society for the Advancement of Education), vol. 117, July, 1988.
Lewis, Wilson John and Hua Di, 'China's Ballistic Missiles Programmes', *International Security*, vol. 17 (2), Fall, 1992;
Logsdon, M. John, 'Space Commercialisation: How Soon the Payoffs?', *Futures: The Jr of Forecasting and Planning*, vol. 16, (1), February, 1984.
______, and Ray A. Williamson, 'US Access to Space', *Scientific American*, vol. 260, March 1989.
Lumpe, Lora, 'Zero Ballistic Missiles and the Third World', *Arms Control*, April 1993.
______, Lisbeth Gronlund and David C. Wright, 'Third World Missiles Fall Short', *The Bulletin of the Atomic Scientists*, vol. 48 (2), March 1992.
Mahnken, G. Thomas, 'Ballistic Missile Proliferation: Seeking Global Solutions to Regional Problems', *Disarmament* (United Nations), vol. XIV (3), 1990.
______and Timothy D. Hoyt, 'Missile Proliferation and American Interests', *SAIS Review*, vol. 10, Winter/Spring 1990.
Majeed, Akthar, 'Indian Security Perspectives in the 1990s', *Asian Survey*, November 1990.
______, 'Agni From Prithvi to Akash: The Rationale and Performance of India's Missile Development', *Strategic Studies Journal*, vol. VIII, 1995.(Aligarh: Centre for Strategic Studies).
Maocheng, Zhuang, 'Proliferation of Ballistic Missiles and Regional Security', *Disarmament*, vol. XIV (3), 1991.
Mama, Hormuz, 'Progress on India's Tactical Missiles', *International Defence Review*, July 1989.
Malik, J. Mohan, 'India's Response to the Gulf War Crisis: Implications for Indian Foreign Policy', *Asian Survey*, September 1991.
Mani. V.S, 'Transfer of Technology, MTCR, National Security, and Space Oligopoly: A Study of Recent Indo-Russian Experience' in V.S. Mani, S. Bhatt and V.B. Reddy, eds., *Recent Trends in International Space Law and Policy* (New Delhi: Lancers Books, 1997).
Marwah, Onkar, 'India's Nuclear and Space Programs: Intent and Policy', *International Security*, Fall, 1977.
______, 'India and Pakistan: Nuclear rivals in South Asia', *International Organisation*, vol. 35, Winter, 1981.

Mastanduno, Michael, 'Trade as a Strategic Weapon : American and Allied Export Control Policy in the Early Post-war Period', *International Organisation*, Winter 1988.

______, 'The United States Defiant : Export Controls in the Post-war Era', in Raymond Vernon and Ethan B. Kapstein, eds., *Defence and Dependence in a Global Economy* (Washington D.C.: Congressional Quarterly Inc., 1992).

Matthews R.G., 'The Development of India's Defence-Industrial Base', *Journal of Strategic Studies*, vol. 12, December 1989.

Menon, M.G.K, 'Some Aspects of Cosmic Ray Research' *Journal of Scientific and Industrial Research*, vol. 24, March 1965.

Menon, Raja, 'The Economy and National Security Strategy', *Strategic Analysis*, vol. XVII, February 1995.

Milhollin, Gary, 'India's Missiles: With a Little Help from Our Friends', *The Bulletin of the Atomic Scientists*, vol. 45, November 1989.

Mishra P, 'Technology and Development in the Third World : Some Critical Notes on North-South Technology Transfer Debate', *Indian Journal of Political Science*, vol. 53 (1) January 1992.

Mohan, C. Raja and K. Subrahmanyam, 'High Technology Weapons in the Developing World' in Eric Arnett, ed,, *New Technologies for Security and Arms Control: Threats and Promise*, AAAS, Washington, 1989.

Moodie, Michael, 'Beyond Proliferation: The Challenge of Technology Diffusion', *The Washington Quarterly*, vol. 18 (2),1995.

Moran H. Theodore and David C. Mowery, 'Aerospace and National Security in an Era of Globalisation' in David C. Mowery, ed., *Science and Technology Policy in Interdependent Economies* (Boston: Kluwer Academic Publishers, 1994)

Morehouse, Ward, 'Frontier Technologies and their Role in International Economic and Political System: A Decade of Rapid Change', *Philosophy and Social Action*, Vol.(X) Jan-June, 1984.

______, 'Dominance, Equity and Technology: Ambivalence and Conflict in US Policy Towards the Third World', *Journal of International Affairs*, 1979.

Morel, F. Benoit, 'Proliferation of Missile Capability', *Disarmament*, vol. XIV, (3), 1991.

Mountain J Maurice, 'Technology Exports and National Security', *Foreign Policy*, vol. 32, 1978.

Mukherjee, Sadanand, 'India has ICBM Capability', *Jane's Defence Weekly*, 3 February 1990.

Mullins, E. Robert, 'Dynamics of Chinese Missile Proliferation', *Pacific Review* vol. 8 (1), 1995.

Muni, S.D., 'Third World Arms Control: Role of the Non-aligned Movement' in Thomas Ohlson, ed., *Arms Transfer Limitations and Third World Security* (New York: OUP, 1988).

Nag, B.D. Chaudhari, 'Impact of S&T on International Relations', *International Studies*, vol. 25 (2), 1988.

Nandakumar P, 'Space Research in India', *Indian and Foreign Review*, 1 November, 1977.

Neuman, E. Stephanie, 'International Stratification and the Third World Military Industries', *International Organisations* , vol. 38 (2), 1984.

Nolan, E. Janne and Albert D. Wheelon, 'Third World Ballistic Missiles', *Scientific American*, vol. 263, August 1990.

Nye, S. Joseph, 'Arms Control After the Cold War', *Foreign Policy*, vol. 68, Winter 1989/90.

Ollapally Deepa and Raja Ramanna, 'US-India Tensions: Misperceptions on Nuclear Proliferation' *Foreign Affairs*, vol. 74 (1) 1993.

Pande, Savita, 'MTCR and the Third World : Impact Assessment', *Strategic Analysis*, October 1993.

_____, 'India, China and the Export Control Regime: A Study in Approaches', *Strategic Analysis*, vol. XVII, August 1994.

Parthasarathy, A.V., 'India's Efforts to Build an Autonomous Capacity in S & T for Development', *Development Dialogue*, vol. 1, 1979.

_____and Baldev Singh, 'Science in India: The First Ten Years', *NMML*, Occasional Paper, No. xxix, Undated.

Pant, K.C, 'Philosophy of Indian Defence Industrial Transformation', *Strategic Analysis*, vol. 12, August 1989.

Patel, J. Surendra, 'Main Elements in Shaping Future Technology Policies for India', *Economic & Political Weekly*, 24 (9), March 1989.

Payne, B. Keith, 'Post Cold-War Deterrence and Missile Defence', *Orbis*, 39 (2), Spring, 1995.

Perkovich, George, 'A Nuclear Third Way in South Asia', *Foreign Policy*, vol. 91, Summer, 1993.

Pike, John and Eric Stambler, 'Constraints on the R&D and the Transfer of Ballistic Missile Defence Technology', in Hans Gunter Brauch and others, eds., *Controlling the Development and Spread of Missile Technology* (Amsterdam: VU University Press, 1992).

Potter, Michael, 'Swords into Ploughshares: Missiles as Commercial Launchers' *Space Policy*, vol. 7 (2) May 1991.

Potter C. William and Adam Stulberg, 'The Soviet Union and the Spread of Ballistic Missiles', *Survival*, vol. XXXII, (6), November/December 1990.

Raj, Ashok and C. Vishnumohan, 'INSAT: Evolution and Prospects', *Economic and Political Weekly*, 14 August 1982.

Raj, Ashok, 'US High-Tech Diplomacy and the Indian Supercomputer Deal', *Strategic Analysis*, September 1987.

Raj, N. Gopal, Scaling New Heights, *Frontline*, 9-22 June 1990.

_____, 'Sensing From the Sky: The IRS Success Story', *Frontline*, 14-27 September 1991.

_____, 'Satellite Success: Indigenous INSAT-2A is Operational', *Frontline*, 25 September 1992.

Raj K.N, 'Long term View of Self Reliance', *Yojana*, 10 October, 1965.

Rajan, Y.S., 'Benefits from Space Technology :A View from a Developing Country', *Space Policy*, vol. 4, August 1988.

Ramachandran, P.K. Lt. Col., 'Missile Defence', *The Artillery Journal* (New Delhi) 1996.

Ramanna, Raja, 'Development of Nuclear Energy in India 1947-73', *The Nehru Memorial & Museum Library Lecture*, Delivered on 29 July 1974.

____, 'Security, Deterrence and the Future', *Journal. of USI*, vol. 22, 1992.

____, 'Technology Transfer and Non proliferation', *Journal of Indian Ocean Studies*, March 1994.

Rao, R.V.R. Chandrasekhara, 'India and Nuclear Weapons Option: Eclipse of the Ethical Profile', *Swords and Ploughshares*, May 1987.

____, 'Strategic Thinking in India in the 1970s', in Robert O Neil and D.M. Horner, eds., *New Directions in Strategic Thinking* (George Allen and Unwin ,1981).

Rao U.R, Space and Industry Partnership, *ISRO*, Bangalore 1985.

_____, 'The Next 40 Years in Space- A View of Developing Countries', *The 40th Congress of the IAF*, Malga, Spain, October, 7-13, 1989, ISRO-SP- 46-89.

_____, 'Indian Launch Vehicle Development', *Prof. Brahm Prakash Memorial Lectures*, Indian Institute of Metals, Bangalore Chapter, 21 August 1992.

_____, 'Space Technology for Achieving Socio-economic Revolution', *29th Founder Memorial Lecture*, Shriram Institute for Industrial Research Delhi, 1993.

Ram, Mohan, 'Bounty From High Orbit', *Far Eastern Economic Review*, vol. 124, 24 May 1984.

Richelson, T. Jeffrey, 'The Future of Space Reconnaissance', *Scientific American*, vol. 264, January 1991.

Richardson, Mark, 'United States Military Assistance to India: A Study of Economic Pressure: November 1963- November 1964', in Sidney Weintraub, ed., *Economic Coercion and US Foreign Policy: Implications of Case Studies From the Johnson Administration* (Boulder: Westview Press, 1982).

Richardson, C. Robert, 'Exploring Space in Peace and War', *Journal of Social, Political and Economic Studies*, vol. 14 (2), Summer, 1989.

Rizvi, Ali Abbas, 'Indian Missile Programme', *Asian Defence Journal*, May 1995.

Roberts, Darryl, 'Space and International Politics: Models of Growth and Constraints in Militarisation; A Review Essay', *Journal of Peace Research*, vol. 23 (3) 1986.

Roederer, J. R., 'Space Research Policies in Advanced and Developing Countries', in *Advances in Space Research* (Oxford: Pergamon Press, vol. 1&2, 1983).

Roman J Peter, 'Eisenhower and Ballistic Missiles Arm Control, 1958-1960: A Missed Opportunity?' *Journal of Strategic Studies*, vol. 19 (3), September 1996.

Rosen J Steven, 'The Proliferation of New Land Based Technologies: Implications for Local Military Balances' in Stephanie G Neuman and Robert E Harkavy, eds., *Arms transfer in the Third World* (New York: Praeger, 1979).

Rudolf, Peter, 'Non-proliferation and International Export Controls', *Assenpolitik*, IV, April 1991.

Sabharval, Mukesh, 'Indian Stance on the NPT and the MTCR', *Combat Journal*, 22(1) April 1995.

Santra P.C. Wing Comm., 'Guided Missiles or Manned Aircraft', *Journal of the United Services Institute of India*, April-June 1960.

Satish V. M., 'The Political Economy of Rocketry', *The Radical Humanist*,(formerly Independent India), vol. 56 (4), July 1992.

_____, 'The New World Technological Order', *The Radical Humanist*, vol. 56 (7), October 1992.

Schelling C Thomas, 'Abolition of Ballistic Missiles', *International Security*, vol. 12 (1), 1987.

Schultz, J. John, 'Riding the Nuclear Tiger: The Search for Security in South Asia', *Arms Control Today*, vol. 23, June 1993.

Schwartz B. Jonathan, 'Controlling Nuclear Proliferation: Legal Strategies of the United States', *Law and Policy in International Business*, vol. 20 (1), 1988.

Sen, S. Amir, 'Technology As a Substitute for Political Action: A Counterview of US Policy and Strategy and their Impact: View from India', *Comparative Strategy*, January/March 1995.

_____,'Future of Ballistic Missile Defence and its Derivatives—View from India', *Competitive Strategy*, June, 1995.

Shastri, Ravi, 'The Spread of Ballistic Missiles and its Implications', *Strategic Analysis*, May 1988.

Sherman, Robert, 'Deterrence Through a Ballistic Missile Test Ban', *Arms Control Today*, December 1987.

Sharma, Dhirendra, 'India's Lopsided Science', *The Bulletin of the Atomic Scientist*, 47, May 1991.

Simpson, John, 'Trends in the Proliferation of Sophisticated Weapons and Missile Technology and their Implications and Regional Security', *Disarmament*, vol. XIV (4), 1991.

Singh, Jasjit, 'The Strategic Deterrent Option', *Strategic Analysis*, vol. 12 (6), September 1989.

_____, 'The American Fallacy: Managing the Missile Menace', *Frontline*, 8 April 1994.

Singh, Pushpinder, 'Prithvi: SS 150/250-The Indian Battlefield Support Missile', *Asian Defence Journal*, vol. 10, October 1991.

Singh, Ravinder Pal, 'Missile Technology Control Regime: A Study of United States Technology Control Policy and Process', *Strategic Analysis*, March 1992.

_____,'Effects of Missile Technology Control Regime and Multilateral Politics of North South Technology Transfers', *Strategic Analysis*, July 1992.

Skons, Elisabeth, 'The SDI Programme and International Research Co-operation', SIPRI *World Armaments and Disarmament Yearbook 1986* (London: Oxford University Press, 1986).

Smith, K. Roger, 'Explaining the Non proliferation Regime: Anomalies for Contemporary International Relations Theory', *International Organisation*, vol. 41, Spring, 1987.

Sobczak, Tom, 'Technology Transfer: Who, What, Where and How', *Defence Electronics*, January, 1995.

Sondhi, Sunil, 'India's Quest for Autonomous Capability in Space Technology', *The UP Journal of Political Science*, vol. 5 (1-2), January/December 1993.

Song and Young, 'Voluntary Export Restraints and Strategic Technology Transfers', *Journal of International Economics*, vol. 40 (1-2) February 1996.

Stares, B. Paul, 'Space Technology-Security Related Developments', *Disarmament*, vol. XIII (1),1990.
Starr, Barbara, 'Ballistic Missile Proliferation: A Basis for Control', *International Defence Review* ,vol. 23. March 1990.
Steinberg, M Gerald, 'Two Missiles in Every Garage' *Bulletin of Atomic Scientist*, October 1983.
Sterner, Eric, 'International Competition and Co-operation: Civil Space Programs in Transition', *The Washington Quarterly,* 16 (3) Summer, 1993.
Subrahmanyam K, 'A Saudi-Pak Missile Threat', *Frontline*, 30 April-13 May 1988.
_____, 'An Unequal Opportunity NPT', *The Bulletin of the Atomic Scientists,* June 1993.
_____, 'Export Controls and the North-South Controversy', *The Washington Quarterly,* Spring, 1993.
Sunderji, K. Gen., 'Nuclear Defence: Doctrine for India', *Trishul*, Professional Journal of Defence Services Staff College, Wellington, July, 1993.
Sunderesan, P, 'ISRO and Indian Industry: A Growing Partnership', in R.K. Mishra, ed., *Indian Industries: Problems and Prospects* ,1986-87, United India Periodicals, Patriot Pub., New Delhi, 1987.
(Symposium), Technology in Space, Journal of International Affairs, vol. 39, Summer 1985. P1-174.
Tanham, George, 'Indian Strategic Culture', *The Washington Quarterly*, vol. 15, Winter, 1992.
Thomas, G.C. Raju, 'South Asian Security in the 1990s', *Adelphi* Paper No. 278, July, 1993.
_____, 'India's Nuclear and Space Programmes: Defence or Development', *World Politics,* vol. 38, January, 1986.
_____, 'US Transfer of "Dual Use" Technologies to India', *Asian Survey*, Vol. XXX, September 1990.
Tolchin, S, 'Halting the Erosion of Americas Critical Assets', *Issues in Science and Technology*, vol. 9, Spring 1993.
Tripathi, K.S. Fly Officer, 'The IAF in the Space Age' *Journal of the USI*, January-March 1961.
Ustinov, A.V., 'Export of Missile Technologies: Will Russia Enter the World Market?', *Comparative Strategy*, vol. 13, 1994.
Van de Klundert and Sjak Smulders, 'North-South Knowledge Spillovers and Competition: Convergence vs. Divergence', *Journal of Development Economics*, vol. 50 (20), August 1996.
Velupilli, David, 'ISRO: India's Ambitious Space Agency', *Flight International,* 14 June 1986.
Von Welck, F. Stephen, 'India's Space Policy: A Developing Country in the Space Club', *Space Policy*, vol. 3, November 1987.
_____, 'The Export of Space Technology :Prospects and Dangers', *Space Policy*, vol. 3 (3), 1987.
_____, 'Dominance in Space-A New Means of Exercising Global Power?', *Space Policy,* November, 1988.
Warwick, Graham, 'Satellite Launch Directory', *Flight International*, 11 January 1986.
Welch, T. Thomas, 'Technology, Change and Security', *The Washington Quarterly*, Spring, 1990.
Wray, D. William, 'Japanese Space Enterprise: The Problem of Autonomous Development', *Pacific Affair*, vol. 64, Winter 1991-92.
Wulf, Herbert, 'Arms Industry Unlimited: The Economic Impact of the Arms Sector in Developing Countries', *Peace and Development*, vol. 5 (1), 1984.
Zaloga, Steven, 'Ballistic Missiles in the Third World: Scud and Beyond', *International Defence Review*, vol. 11, November 1988.
Zimmerman, Peter, 'Proliferation: Bronze Metal Technology is Enough', *Orbis,* Winter, 1994.
Zuberi Martin and S Kalyanaraman, 'Science and Technology for Development :India's Space Programme', *Strategic Analysis*, vol. XVII (11), February 1995.

News Papers

Asian Age (Bombay).
Hindu (New Delhi).
New York Times.
The Hindustan Times (New Delhi)
The Nagpur Times.
The Times of India (New Delhi and Bangalore).
Washington Post.