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**THE PROLIFERATION OF AEROSPACE WEAPONS TECHNOLOGY:
BALLISTIC MISSILES AND THE CASE OF BRAZIL**

by

TERRENCE JOHN VOSSEN, B.A. (Hons.)

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of

Master of Arts (International Affairs)

Norman Paterson School of International Affairs

Carleton University

Ottawa, Canada

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**"THE PROLIFERATION OF AEROSPACE WEAPONS TECHNOLOGY:
BALLISTIC MISSILES AND THE CASE OF BRAZIL"**

Submitted by Terrence J. Vossen, B.A.
in partial fulfilment of the requirements for
the degree of Masters of Arts

Christopher J. Maule, thesis supervisor

Christopher J. Maule, Director,
The Norman Paterson School of International Affairs

Carleton University
May , 1993

ABSTRACT

This paper explains how and why Brazil developed its ballistic missile production capability. In order to ascertain the rationale behind development, it explores the political, military, and economic determinants of ballistic missile demand in Brazil. To ascertain how Brazil developed missile production capabilities, the paper explores the contributions of aerospace industries in industrialized states, Brazil's space programme, inter-LDC technology trade, and illicit trade in missile technology. The paper argues that missile development increasingly became a function of economic as opposed to security considerations, and that technologies transferred from developed country aerospace firms and Brazil's space programme were primarily responsible for the creation of production capabilities. The paper also contends that the proliferation of missile technology to Brazil was consistent with the workings of a system evident in the aerospace weapons technology market that sustains the horizontal spread of weapons production capabilities.

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INTRODUCTION

The past two decades have witnessed important changes in the international development and production of advanced aerospace technologies. The quality and quantity of advanced technologies transferred on the international market has increased, and the rate at which that technology is transferred has accelerated. Despite important military and security concerns of industrialized states, and their initial monopoly, potentially destabilizing weapons technology has proliferated at an increased rate. As a consequence, a growing number of Third World countries are now able to design, manufacture, and maintain sophisticated weapon systems such as ballistic missiles. Efforts by the United States, Canada, Japan, and several Western European nations, such as the establishment of the Missile Technology Control Regime (MTCR), have been undertaken in order to stem the proliferation of ballistic missiles (BMs), missile components, and associated production technologies to developing countries. However, for reasons subsequently discussed these efforts have only managed to slow proliferation, not stop it.

An initial examination of the proliferation of ballistic missile technology and the increased ability of Third World nations to produce these weapons raises questions revolving around two themes. The first set of questions centres on why developing states decide to undergo the political and economic costs of developing an indigenous ballistic missile capability or procuring foreign systems, and what they hope to gain as a result. The second set of questions centres on how developing countries actually achieve their missile capabilities.

In several developing countries, the motivation to acquire a ballistic missile capability is best understood in terms of the perceived military utility of ballistic missiles and foreign military threats to their national security. Several states can make strong cases for the acquisition of BMs on the grounds that they add to a country's overall military capability, or that they counter missile threats from neighbouring states. In the case of Iraq, the development of its missile forces could be viewed in the context of a military build up aimed at achieving regional military dominance. On the other hand, the construction of missile forces in Israel, India, Taiwan, South Korea, and Pakistan for example, can be seen in large part as a calculated response to what are perceived as prolonged or acute national security threats.

The means by which a number of developing states have acquired ballistic missiles is also straight-forward. During the 1960s, 1970s, and 1980s, a number of Third World countries simply received complete ballistic missile systems from the United States or the Soviet Union. At various points in their histories the superpowers were willing to transfer complete missile systems to developing states at little or no cost to their Third World allies as part of military assistance packages. If and when financial payments for missile systems or components were demanded by the United States or the Soviet Union in return, oil exporting clients for example, had little difficulty financing their purchases.

A certain number of other less developed countries, or LDCs, have also developed ballistic missile capabilities. These states however are not subject to acute security threats. They were non-aligned through the Cold War period, and did not receive missile systems or technology as part of superpower military assistance programmes. They also

lacked the benefits of large oil revenues or positive trade balances needed to fund foreign acquisitions. Brazil is such a country, and for countries like Brazil, a new set of answers to the questions surrounding why and how must be sought.

Brazil did not face acute military threats during the period of time in which its missile development programme reached its greatest extent. Nor did it receive direct assistance for its missile development programme or missile transfers from either superpower. Moreover, throughout the period of development, Brazil was characterized by social and economic underdevelopment. Its economy was burdened by a massive foreign debt, and the nation lacked a source of substantial export revenues. Nevertheless, Brazil made significant advances in the accumulation of missile technology and has acquired the production capabilities required to construct ballistic missiles.

When one considers the progress made by Brazil in acquiring missile production capabilities, two important research questions present themselves. The first is simply "Why?". Or, more precisely, what was the rationale, and what were the motives behind the Brazilian Government's efforts to gain a ballistic missile capability? The second is "How?". Or, in other words, what were the factors that allowed Brazil to construct a sophisticated aerospace industry, and how did it gain the ability to design, and potentially produce and export ballistic missile systems? The purpose of this paper is to answer these questions. To do so, two separate hypotheses are proposed and tested. The first relates to the question of "Why", and contends that Brazilian efforts to develop a ballistic missile capability were initially undertaken in order to counter potential nuclear threats to the country. However, as the probability of regional conflict subsided, and the

country's economic situation deteriorated, economic motivations for continued ballistic missile development became an equally important determinant. By the time ballistic missile development gained momentum in the 1980s, development efforts appear to have been undertaken primarily in response to endogenous economic imperatives, and in order to capture the economic benefits believed to be associated with the undertaking. The second hypothesis relates to the question of "How". It contends that Brazil's development of a ballistic missile capability was facilitated by interactions in the international aerospace technology market between demand and supply which promote weapon technology transfers and facilitate the proliferation of advanced weapons and weapons technology.

The immense body of security literature that has been written on the subject of missile proliferation has tended to focus on political and military determinants.¹ Much existing literature views proliferation largely as a result of national security problems and perceptions. Although a branch of the literature has focused on the potential economic benefits of creating indigenous arms industries, the underlying process of proliferation and the economic forces that drive it have largely been ignored. It is my intention to help reduce this lacuna in the literature by illustrating 1), that the process of ballistic missile proliferation is a self perpetuating "system"; 2), the means by which weapons technology proliferation takes place; and 3), how the interaction of demand and supply on the international aerospace technology market drives the process. In doing so, I hope to offer

¹See for example Mangus Clark, "Ballistic Missiles in the Third World and the Proliferation of Strategic Defence Technology," Arms Control 10:2 (September 1989), 120-136.; W. Seth Carus, Ballistic Missile Proliferation in the Third World: Threat and Response (New York, 1990); Martin Navias, "Ballistic Missiles in the Third World," Adelphi Papers No. 252 (Summer 1990).

an increased understanding of the process of proliferation and the system that drives it so that new solutions and possible alternatives to proliferation may be developed.

In order to address the above questions and to test the corresponding hypotheses, the paper proceeds in the following manner. In chapter one, the paper determines what variables play the greatest role in determining demand for advanced aerospace technologies among developing countries. This exercise provides the analytical tools and framework required later in the paper to test the first hypothesis and to answer the question of why Brazil embarked on ballistic missile production. Depending on the country in question, a particular variable or a combination of variables may play a role in determining demand for ballistic missile technology. The variables to be examined in chapter one include national political and security concerns; the perceived need for self sufficiency in arms production and the resulting type of defence industrialization programme; national monetary policy goals; and national fiscal policy or economic development goals.

In addition to direct superpower transfers of complete weapons systems, developing countries have secured missiles, missile components, and related production technologies through a number of channels. In order to ultimately understand how Brazil developed its ballistic missile capability, it is first necessary to define these sources. Chapter two does so by examining the sources of missile technology, systems, and components on the international market. The first section of chapter two focuses on the role Western aerospace industries play in the proliferation process by pointing out why severe export pressures exist within the industry and how these pressures have led to an

increasing supply of advanced aerospace weapons technology on the world market. The second section of the chapter explores the role of "dual use" rocket technologies used in Third World civilian space programmes as they pertain to the development of ballistic missiles. The third section highlights the significance of trade and scientific exchanges between Third World countries. The importance of private individuals, industrial consortia, and illicit activities in the transfer of weapons technology and production capabilities is examined in the fourth section.

Using the variables outlined in chapter one that influence national demand, and the variables discussed in chapter two which comprise the world's supply of ballistic missiles, missile components, and production technology, the paper proceeds to demonstrate how the interaction of demand and supply affects the international weapons technology market and facilitates missile proliferation. Chapter three explains this dynamic through the development of a "proliferation model" which illustrates that market transaction mechanisms between buyers and sellers comprise a system that in effect incites and facilitates the proliferation. In essence, due to the structure of the market, demand by one state inevitably augments its production capabilities, and thus world supply. Increased world supply then facilitates further demand.

It is important to point out however that the proliferation model should not be construed as a comprehensive explanation for all causes and processes of weapons proliferation. There are political, military, and strategic factors that promote weapons proliferation. What the model seeks to explain however, are the economic and commercial determinants of weapons proliferation, and the economic and commercial

factors that contribute to the process of weapons production technology proliferation. The model takes into account the political, military, and strategic determinants of ballistic missile demand. But its primary function is to explain how economic and commercial considerations affect national demand for ballistic missile technology and the behavior and role of missile technology producers and suppliers; how these in turn relate to market supply, market competition, market technology transfer mechanisms, and the ultimate creation of new weapons production centres. The establishment of new production centres in LDCs is just one means by which proliferation may occur, and commercial and economic motivation just one possible rationale behind weapon technology acquisition.

A case study of Brazil's development of a ballistic missile capability is conducted in the paper's final chapter in order to test the paper's two hypotheses. The study focuses on the period between 1960 and 1990. To test the paper's first hypothesis, the case study determines what factors were responsible for creating a Brazilian demand for ballistic missile technology. This is be done by weighing the economic, political, and security factors discussed in chapter one in the context of Brazil. Utilizing the proliferation model constructed from the market's components outlined in chapters one and two, and by weighing the importance of the various sources of supply outlined in chapter two as they pertained to Brazil, the case study will also test the paper's second hypothesis in order to determine how Brazil developed its capabilities. The final section of chapter four consists of concluding remarks. It reviews the applicability of the proliferation model to the case of Brazil. The relevance of the model to other cases of weapons technology transfer is discussed, and areas of further research are suggested.

CHAPTER 1: SOURCES OF MISSILE TECHNOLOGY DEMAND

The purpose of chapter one is to examine the factors driving Third World demand for ballistic missiles. A clear understanding of these factors is necessary as they are utilized in the construction of the proliferation model in chapter three, as well as in testing the paper's first hypothesis during the course of the case study conducted in chapter four. Before examining the determinants of ballistic missile technology demand however, a brief discussion of what constitutes ballistic missile technology is warranted.

Demand for ballistic missiles does not only encompass complete and functional missile systems. It also includes demand for "design technologies" which give a state the ability to design missile systems, and "production technologies" which allow states to construct missile systems. The operational characteristics of ballistic missile systems (range and payload characteristics) vary. However, all ballistic missiles are basically rockets fired into the upper atmosphere or outer space that fall back to earth once their fuel supply is exhausted. Due to their trajectories, ballistic missiles generally have ranges greater than 40 kilometres. They may or may not incorporate guidance systems which direct them towards their target². Depending on the capabilities of the user, they may be configured to carry either chemical, biological, nuclear, or conventional warheads.

Several components, as well as design and production technologies must be obtained in order to construct a ballistic missile. These include; 1), technologies associated with the production of various types of warheads; 2), guidance and flight

²Aaron Karp. "Ballistic Missile Proliferation in the Third World," SIPRI Yearbook 1989: World Armaments and Disarmament (Oxford, 1989), 289.

control systems (the most technically advanced subsystem in a ballistic missile); and 3), propulsion systems.³ In addition, since a modern BM may contain as many as 70,000 parts, a country must also develop the technical skills needed to integrate them.⁴

Figure 1 depicts a mobile two stage ballistic missile system and the major technologies involved in its design. Missile propulsion systems can utilize liquid or solid fuels. Solid fuels, being easier to handle and easier to produce, are more commonly used in mobile or less advanced systems. There are two kinds of solid fuels. "Double base" fuels are chemically similar to powders used in gun ammunition. The raw materials and production processes are basically the

Figure 1

same. The second type of solid fuels, "composite" types, are more difficult to manufacture, but are more dynamic. They are most effectively utilized by large rocket engines, but are also commonly in use in smaller artillery rockets. The production of the airframe, or body of a BM is more complex as light-weight composite and other high

³Azriel Lorber. "Tactical Missiles: Anyone Can Play," The Bulletin of the Atomic Scientists 48:2 (March 1992), p. 38.

⁴Lisbeth Gronlund and David C. Wright. "Building an ICBM," Bulletin of the Atomic Scientists, Vol. 48, No. 2 (March 1992), p.36.

strength materials that can withstand severe stress are required. However, if shorter ranges are acceptable, less advanced materials may be used in airframe construction.

Ballistic missiles can carry various types of warheads. Conventional warheads include the unitary high explosive type, various cluster or bomblet warheads, and fuel-air explosives - the technology for each type being in the public domain. Chemical weapons may also be deployed. Binary or unitary chemical agents needed for chemical warhead production can be manufactured by most chemical industries. Although nuclear weapons are the most difficult to construct and international export controls are stringent, a number of developing countries have demonstrated an ability to produce them as technology that is crude by Western standards may be employed. Detonation devices for example need not require sophisticated command-and-control or fail-safe devices.⁵ Regardless of type of warhead used, in order to increase accuracy, heat-shielding materials are needed to protect the missile's reentry vehicle from extreme heat and deformation during atmospheric reentry.

The final component of a BM is its guidance and control system. Guidance systems consist of inertial reference units traditionally based on an array of gyroscopes and accelerometers, an on-board computer, and battery power packs. The inertial reference unit in conjunction with the internal computer determines the position and course of the missile. Guidance systems may also utilize less expensive, commercially available electronic reference units similar to those used commercial aviation.⁶ As a

⁵Ibid., 38-39.

⁶Ibid., 39-40.

missile's flight trajectory and position are determined by the guidance system, instructions are sent to the missile's control systems. The control system consisting of stabilizers, ailerons, directional nozzles, and associated hydraulic systems, directs the missile towards a pre-determined target.

Due to technical similarities, an examination of ballistic missile technology must also encompass technologies associated with other types of military missiles and civilian or scientific rockets. Scientific sounding rockets (SRs), used in atmospheric research and data collection for example may be converted into surface to surface missiles. Short-range artillery rockets (ARs) can be modified in order to increase their range, thereby serving as the basis for larger ballistic missile development, while civilian space launch vehicles (SLVs) can be converted into long range ballistic missiles.⁷

There are also several production technologies associated with ballistic missile construction. In addition actual production equipment etc., production technologies encompass production processes, technique, and scientific know-how.⁸ Traditionally, production technology and know-how, as well as the ability to design BMs, has been acquired in stages as learning takes place. Indigenous weapons production of any kind usually begins with a limited ability to repair or maintain foreign built equipment. Maintenance capabilities are generally followed by the local assembly of imported sub-assemblies or parts into complete systems. After sufficient technical know-how is

⁷Aaron Karp. "Ballistic Missile Proliferation," SIPRI YEARBOOK 1990: World Armaments and Disarmament (Oxford, 1990), 369-94.

⁸Keith Krause. "The Political Economy of the International Arms Transfer System: the Diffusion of Military Technique via Arms Transfers," International Journal 45:3 (Summer 1990), 692-93.

acquired via assembly operations, local parts production may be initiated. Next, local manufacture of complete, although foreign designed, weapons systems may occur. Finally, indigenous weapons design and development capabilities develop.⁹

1.1 POLITICAL AND SECURITY MOTIVATIONS

1.1.1 Domestic and International Prestige

In discussing the determinants of Third World demand for ballistic missiles and associated design and production technologies, analysts often cite the pursuit of international prestige. Numerous authors have pointed out an apparent belief among Third World leaders that in a manner similar to the possession of national steel or airline industries, BMs confirm industrial modernization, self sufficiency and competence in critical or advanced technologies, and the possession of potent military tools.¹⁰ Possession of a particular weapons system may or may not confirm that these attributes actually exist. Nevertheless, as long as the possession of ballistic missiles enforces the perception among potential adversaries that certain of these national attributes exist among its rival, arguably then, ballistic missile possession enhances a country's bargaining power and perceived strength vis-à-vis others.

Since the possession of ballistic missiles or the establishment of a development programme increases the bargaining power and relative strength of a country, they may potentially be used as a means of pursuing broader political or military goals. However,

⁹Nicole Ball. Security and Economy in the Third World. (Princeton, N.J.,1988), 371.

¹⁰ W. Seth Carus Ballistic Missiles in the Third World: Threat and Response (New York, 1990), 4: and Martin Navias, "Ballistic Missile Proliferation in the Third World," Adelphi Papers No. 252, (Summer 1990), 10-11.

even in the absence of regional or international ambitions, political regimes may still view the acquisition of weapons technology as an effective means of increasing their prestige at home. The acquisition or production of advanced weapons may be seen as an indication that a political regime is able to overcome development barriers, reverse economic stagnation, or meet various security threats thereby enhancing its prestige and standing among the country's population.¹¹ As a result, potential gains in domestic prestige may well be a motive for the acquisition of advanced weapons or production technologies.

1.1.2 National Security

In order to counter potential security threats, states will wish to import or build weapons deemed crucial to national security. In addition to augmenting national prestige, if fitted with nuclear, chemical, biological, or conventional warheads, BMs may act to deter aggression. If hostilities do erupt, ballistic missiles are also proven and effective war-fighting instruments.

When used in wartime against tactical targets (eg. troop and tank formations), or strategic targets (eg. cities, transportation centres, and command posts), BMs hold a number of advantages. First, as targets up to 600 kilometres away can be reached in only seven minutes, ballistic missiles are ideal for launching surprise attacks or rapid counter-attacks.¹² Second, BMs can deliver enormous destructive power. Targeted against cities, nuclear-tipped BMs can kill hundreds of thousands. If used against unprotected

¹¹Andrew J. Pierre The Global Politics of Arms Sales (Princeton N.J., 1982), 236-37.

¹²John R. Harvey. "Regional Ballistic Missiles and Advanced Strike Aircraft: Comparing Military Effectiveness," International Security 17:2 (Fall 1992), 64.

civilian targets, ballistic missiles armed with chemical weapons can kill or injure thousands.¹³ Although conventional warheads are less lethal (only 6.5 deaths resulted from each conventionally-armed missile fired in the 1988 "War of the Cities"¹⁴), 1,100 to 2,200 pound high explosive warheads hitting urban centres can severely disrupt a nation's commerce and infrastructure, and undermine civilian moral.

Ballistic missiles also have advantages over alternative delivery vehicles, namely strike aircraft like the F-15E, Mirage 2000, or Mig-29. Effective anti-missile defenses have yet to be developed, and future systems like those proposed under the American Strategic Defence Initiative may be overcome. Multiple independently targeted reentry vehicles (MIRVs) can overwhelm missile defenses by sheer numbers, while missiles releasing decoy reentry vehicles or aerosol chaff while in flight can render anti-missile sensors ineffective.

Moreover, while BMs remain largely invulnerable, advanced strike aircraft are becoming increasingly vulnerable to easier to use, less expensive, more accurate, and more widely available anti-aircraft missiles. During the Vietnamese War for example, approximately 60 surface to air missiles or SAMs were required to down a single aircraft. During the Soviet-Afghan conflict the ratio had fallen to 3 to 1.¹⁵ Although the nature of air warfare varied in the two conflicts, the cases illustrate the trend.

¹³Mangus Clark. "Ballistic Missiles in the Third World," Arms Control 10:2 (September 1989) 122-23.

¹⁴Figure based on Iraqi 1988 attack on Iranian occupied village, see N. Chanda, "The Third World Race for Ballistic Missiles," Far Eastern Economic Review (2 June 1988), 22-4.

¹⁵Aaron Karp. "The Frantic Third World Quest for Ballistic Missiles," Bulletin of the Atomic Scientists (June 1988), 18.

The fourth major military attribute of ballistic missiles is a lower cost per unit in comparison to modern strike aircraft. A Scud missile for example can reportedly be obtained for \$US 1 million including several years operation and support costs. More advanced intermediate range missiles like the American Pershing cost approximately \$US 10 million.¹⁶ If one takes into account maintenance, spare parts, and pilot training, an average strike aircraft costs between \$US 30 and 40 million over its lifetime.¹⁷

The final attribute of ballistic missiles is that they diversify a country's overall military strike capability. Strike aircraft may be more reliable due to operational testing,¹⁸ and may be a more cost effective means of delivering large quantities of conventional ordinance since they can fly repeated sorties, carry multi-ton payloads, deliver weapons more accurately.¹⁹ However, during actual military conflicts, a LDC's advanced strike aircraft may not be available for deep strike missions. The majority of Third World air forces are able to afford or maintain a limited number of advanced strike aircraft. And due to the demands placed upon it, during a conflict, most LDC air commands would have to assign these aircraft to other roles such as air defence or ground support.

The final military rationale behind BM acquisition is simply that once one country establishes a credible and survivable missile deterrent, its neighbours may feel compelled

¹⁶Harvey, 64-71.

¹⁷Tai Ming Cheung. "China's Bargain Sale: Bangs for a Buck," Far Eastern Economic Review (2 June 1988), 23.

¹⁸Harvey, 50-60.

¹⁹Leonard S. Spector and Jacqueline R. Smith. Nuclear Ambitions: The Spread of Nuclear Weapons 1989-1990. (Boulder, Colorado, 1990), 22.

to follow suite. At present, only limited point defence systems such as the American Patriot missile exist. Moreover, few countries are able to afford these systems or more comprehensive missile defence systems that may be developed and marketed in the future.²⁰ Therefore, until such time as affordable missile defenses are developed, once country A for example acquires a ballistic missile force, regional security dilemmas are inevitable as its neighbours may feel compelled to acquire missile forces of its own. Pakistan for example has justified its ballistic missile program as an "antidote" for India's.²¹ India in turn justified its program as a deterrent to Pakistani and Chinese missiles. The development of Iran's missile programme was meant to ensure that "the very thought of an [Iraqi] attack with missiles will be eliminated".²² Iraq and Syria claim their missiles are meant to deter Israeli missile strikes. Saudi Arabia purchased Chinese DF-3 Missiles to counter Iranian and Iraqi missile threats, while Israel's missile programme is aimed at deterring the Arab missiles.

1.2 SELF SUFFICIENCY AND DEFENCE INDUSTRIALIZATION

Many developing nations have sought to reduce their dependency on foreign weapons, components, design capabilities, and production technologies with the aim of becoming self sufficient in arms production. Regardless of the type of weapon in question, the possession of strong armed forces supplied with locally produced arms has

²⁰Benoit F. Morel "Proliferation of Missile Capability," *Disarmament* 14:3 (1991), 26.

²¹Navias. "Ballistic Missile Proliferation in the Third World", 12.

²²Ibid., 12-3.

often been considered a prerequisite of political independence.²³ However, the pursuit of self sufficiency in military production has often been the result of an inability to import foreign equipment rather than a goal in itself.

After World War Two, most newly independent states possessed either very rudimentary arms industries, or lacked the ability to design or produce arms all together. Most found themselves partners in bilateral security relationships with either one of the superpowers or with their former colonial rulers, where arms were obtained as part of a system of outright equipment grants or transfers. Reasons varied, but inevitably, relations between many clients and patrons deteriorated, and decisions to initiate local arms production ensued as patrons restricted arms transfers.²⁴

Before domestic arms production was initiated however, most former clients first sought to diversify their sources of supply. The United States for example, had been Brazil's chief arms supplier in the decades immediately following WWII. However, U.S. imposed restrictions on arms transfers due to Brasilia's nuclear programme and human rights record led to the termination of military cooperation agreements and a policy of arms import diversification.²⁵ As a result, from 1973 to 1977, the U.S. found itself supplying only 30.1 percent of Brazilian arms imports while the share of various

²³Herbert Wulf. "Developing Countries," in The Structure of the Defense Industry: An International Survey ed. by Nicole Ball and Milton Leintenberg (Helm, London, 1983), 310.

²⁴Krause. "International Arms Transfer system", 691.

²⁵David B. Mussington and Andrew Richter. Supplier Recipient Relationships and the Indigenization of Defence Production Capabilities in Developing Countries ORAE Report No. 560 (August 1991), 84-6.

European countries increased to 69.9 percent.²⁶ Similarly, after relations cooled with Moscow in the mid 1970s, Iraq diversified its foreign weapons purchases among European suppliers, while Egypt adopted a policy of not buying more than 22 percent of its arms from any one supplier. Israeli and South African arms production was also preceded by rifts with traditional suppliers and periods of supplier diversification.²⁷

In the majority of LDCs, as supplier diversification took place, parallel moves towards defence industrialization were also undertaken. Two basic industrialization strategies exist, Import Substitution Industrialization (ISI), and Export Oriented Industrialization (EOI). ISI and EOI strategies each have two distinct phases: primary and secondary. Primary ISI entails the shift from imports to the local manufacture of basic consumer goods. Secondary ISI involves substituting domestic production for imports of consumer durables, intermediate goods such as steel and chemicals, and capital goods such as heavy equipment.²⁸ Primary EOI involves the production and export of labour-intensive manufactured goods, while secondary EOI involves the manufacture and export of higher value added more skill intensive manufactured goods.²⁹ The question of which strategy best serves Third World industrialization and economic development is not the focus here, but the phases of ISI and EOI offer insights into the process of establishing armament industries.

²⁶Helen Tuomi and Raimo Vayrynen. Transnational Corporations, Armaments and Development (New York, 1982), 149.

²⁷Mussington and Richter, 6-40.

²⁸Gary Gereffi. "Rethinking Development Theory: Insights from East Asia and Latin America," Sociology Forum 4:4 (1989), 515.

²⁹Ibid., 516.

In a manner similar to IS or EO industrialization, nations can pursue Import Substitution Defence Industrialization (ISDI), Export Oriented Defence Industrialization (EODI), or a combination of the strategies in different armament sectors at various stages in the development process.³⁰ Primary or secondary ISDI strategies attempt to substitute locally manufactured goods for imported military components or systems. Like primary ISI, primary ISDI aims to provide a local source of the most fundamental goods (eg. small arms, uniforms, and small arms munitions). Secondary ISDI strategies aim to displace imports of intermediate goods, heavy equipment, and more sophisticated weapons systems such as tanks, ships, aircraft, and missiles.

The overall goal of ISDI is to reduce import dependence and save foreign exchange, but employment creation, skills training, and the stimulation of domestic R&D are also recognized as potential benefits. However, as world production of crucial weapons components such as electronics becomes concentrated among established producers possessing cost advantages and production economies of scale, achieving self sufficiency in defence production becomes increasingly difficult and indigenous systems become comparatively more expensive.³¹ Moreover, while it may be possible to produce particular weapons at home and enjoy employment and skill development benefits, foreign exchange savings can be mitigated and other dependencies created as countries find it necessary to import raw materials, semi finished goods, or design and production

³⁰Wulf, 328.

³¹John Simpson. "Trends in the Proliferation Sophisticated Weapons and Missile Technology and Their Implications for International and Regional Security," Disarmament 14:4 (1991), 42-43.

technologies needed to establish ISDI.³² Even if a country manages to import the goods needed to undertake ISDI, ISDI policies will only allow producers to reduce import dependence and save foreign exchange in the long run, until such time as the domestic arms market becomes saturated. After saturation occurs, production economies of scale may no longer be possible unless excess arms production can be exported. In order to keep domestic assembly lines open, states may then be forced to adopt EODI strategies.³³

Like EOI, primary and secondary EODI policies also involves the production of goods for export. EODI strategies are based on the establishment of internationally integrated arms production carried out in close cooperation with established foreign producers. As pointed out earlier, the development of arms industries and weapons production capabilities, whether under the auspices of primary or secondary ISDI or EODI programmes, takes place in stages. And in each stage, multinational corporations (MNCs) play a large role. MNCs provide initial maintenance contracts; they issue licenses and act as the prime contractor in coproduction agreements; and act as development partners in codevelopment projects.³⁴ Thus, in the final analysis, whether EODI or ISDI programmes are pursued, a continuous demand for advanced weapons technologies is evident.

³²Wulf, 330-39.

³³Wulf, 328-9.

³⁴Ralph Sanders. Arms Industries: New Suppliers and Regional Security (Washington, D.C., 1990), 17-106.

1.3 MONETARY POLICY GOALS

1.3.1 Trade Balances and Foreign Exchange Earnings

Economic factors also stimulate state demand for weapons production capabilities. It has been argued that arms exports contribute little to a country's overall balance of payments.³⁵ In some developing countries, arms exports do comprise a large share of total exports. In Israel and North Korea for example, armaments comprise a large percentage of total exports: 15 to 19 percent in 1985. The North Korean and Israeli economies however have been on what can be described as war-footings for over forty years and a very large proportion of their economies are devoted to military production. This may be reflected in their export figures. Among the majority of developing countries however, arms production and arms exports have traditionally accounted for only a minor percentage of overall exports³⁶(see table I).

Table I

Arms exports as a percent of total exports in select LDCs (1985.)

China	6.3	Pakistan	1.1
Brazil	4.8	Israel	19.0
Turkey	4.0	Bangladesh	4.3'
North Korea	15.0	Argentina	1.0'
India	0.01		

*1984 (Source: Pierre, 26: Krause, 710: Ross, 7-11).

Nevertheless, arms production can make significant positive contributions to a

³⁵Pierre, 25-7.

³⁶Pierre, 26, and Krause, 710.

nation's balance of payments position. In addition to foregone imports and foreign exchange saved,³⁷ domestic arms production can earn foreign exchange through weapons exports. Foreign exchange earnings have been extremely important to developing states in light of lower commodity prices, and interest rate and energy price shocks. Few nations ignore the fact that the sale of advanced weapons can reap billions of dollars and go a long way in helping to alleviate negative trade balances. The currently proposed sale of 60 Dassault Mirage 2000 combat aircraft to Taiwan may earn France approximately \$4 billion for example.³⁸ Saudi Arabia reportedly paid Beijing \$3 to 3.5 billion for 120 DF-3 ballistic missiles, while in order to guarantee future deliveries, Libya was prepared to pay Brazil \$2 billion to support missile development.³⁹ Furthermore, in addition to initial export earnings, the sale of advanced weapons provides vendors with a continuous income stream through the sale of spare parts, ancillary equipment, construction services, personnel training, and maintenance contracts.⁴⁰

1.4 FISCAL POLICY AND ECONOMIC DEVELOPMENT GOALS

A major share of most government expenditure is directed towards projects that seek to promote economic or social development. Although it is often criticized for detracting from these goals, military spending may actually contribute to the achievement of fiscal policy goals. Military spending includes funds devoted to personnel, the

³⁷Saadet Deger. Military Expenditure in Third World Countries: The Economic Effects (London, 1986), 152-53.

³⁸Pierre Sparaco. "Sale of Mirage 2000-5s to China Wins Final Approval," Aviation Week and Space Technology 137:21 (23 November 1992), 32.

³⁹Chanda, 27.

⁴⁰John Stanley and Maurice Pearton. The International Trade in Arms (London, 1972), 124-26.

maintenance and operation of existing equipment, and the purchase of new equipment. As existing equipment ages, higher maintenance costs are incurred, and expenditures on personnel and new equipment must be forgone. Eventually, governments are faced with the choice of either reducing their military capabilities and commitments, or spending additional monies for new equipment. However, if major equipment acquisition is put off or delayed, when procurement does occur, it usually involves extremely large capital outlays.⁴¹

As a result, when these outlays occur, a comparatively large number of social or economic development programmes must be foregone.⁴² To compensate for these losses, besides taking cost and performance of military equipment into account, governments may also base their equipment choices on any potential benefits to the national economy. This has in fact occurred as countries have increasingly demanded local subcontracting, employment creation, and technology transfers from foreign manufactures in return for agreeing to purchase particular foreign weapon systems.⁴³ As these type of procurement agreements help diminish the financial costs as well as the opportunity costs associated with defence spending, they are referred to as "offset agreements", and in addition to providing military equipment, may be used to help achieve economic development goals.

Industrialization is one such economic development goal. Although countries

⁴¹John M. Treddenick. "The Arms Race and Military Keynesianism," Public Policy Analysis 11:1 (1985), 88.

⁴²Gavin Kennedy. Defence Economics (London, 1983), 181-82.

⁴³Treddenick, 89.

cannot support advanced arms production unless they possess a relatively diversified civilian industrial sector, the creation of local defence production may reinforce existing civilian sectors within the national economy.⁴⁴ Arms production is dependent on inputs from several sectors including the iron, steel, electronics, and transportation industries for example. Thus, the importation of weapons production technologies and the start of local arms production stimulates demand in these industries, and helps absorb excess capacity. Moreover, defence industrialization can inject funds needed for capital investment, and introduce new skills, processes, and production technologies into those industries. Investments in military satellite technology for example can inevitably contribute to civilian aerospace and communications firms.⁴⁵

Job creation is another potential advantage of defence industrialization. The actual number of jobs resulting from defence industrialization is always difficult to estimate however. Production may be carried out in factories owned and operated by a country's armed forces, defence firms may also produce civilian or dual purpose goods, and defence production activities may be kept secret.⁴⁶ Regardless, due to its capital intensive nature as well as licensing provisions stipulating exactly what production processes may be employed, weapons production is not a labour intensive industry,⁴⁷ and total employment generated by arms production is generally small compared to any given total industrial

⁴⁴Ball, Security and Economics, 358.

⁴⁵Janne E. Nolan. "Ballistic Missiles in the Third World: the Limits to Non-Proliferation," Arms Control Today (November 1989), 11.

⁴⁶Michael Brozoska and Thomas Ohlson. Arms Production in the Third World (London, 1986), 21.

⁴⁷Ball, Security and Economy, 365-6.

work force (see table II).

In addition to the direct employment effects however, indirect and induced employment may also result from arms production. Indirect employment effects occur when inputs are required from other national industries thereby creating additional jobs. Induced employment on the other hand, occurs when incomes earned by

Table II

Defence Employment as a percent of total industrial employment in select LDCs: early 1980s.

	Defence workers	% Industrial work force
India	280 000	0.5%
Brazil	75 000	0.4%
Pakistan	40 000	0.4%
Egypt	75 000	1.0%
Indonesia	26 000	0.2%
Israel	62 600	13.4%
S.Korea	45 000	0.01%

(Source: Brozoska & Ohlson, 22: OTA Global Arms Trade, 85: L'Etat Du Monde 1992).

defence production workers are spent within the local economy on consumer goods and services.⁴⁸ Moreover, in addition to indirect and induced employment, defence production may also be viewed as a means of introducing new skills and techniques into the work force. Assuming that workers are mobile, training workers for armaments production, and particularly engineers and technicians for work in the industry's high-tech aerospace or electronics segments, can induce modern skills throughout the economy. Even small arms production for example requires the training of skilled tool makers, machinists, press workers, and metallurgical specialists.⁴⁹

⁴⁸Treddenick, 82-3.

⁴⁹Wulf, 323.

The initiation of defence production is also cited as a means by which developing countries can raise productivity in non-industrial sectors such as agriculture by absorbing excess labour.⁵⁰ Defence industrialization can help create infrastructure such as roads, airports, and port facilities that can be used by civilian sectors of the economy.⁵¹ Finally, defence contracts can be awarded to firms and offset agreements negotiated in such a way as to target economically depressed regions of a country.⁵²

Defence induced development, employment creation, and regional development cannot satisfy the needs of an entire economy or population. Opportunities for workers and overall economic gains are limited, and growth in GNP resulting from defence industrialization does not automatically mean the entire population will benefit. National income distribution remains skewed.⁵³ Governments however, especially military ones, are also concerned with the maintenance of domestic tranquillity and political control. To achieve this, they often rely on the continued support of a small proportion of a national population, usually the urban middle class and the indigenous business and technical elite. The fact that defence industrialization may benefit only a small proportion of society may not be considered a problem then, as long as key political populations or

⁵⁰Ball, Security and Economy, 335.

⁵¹Kennedy, 19'.

⁵²David Whynes. The Economics of Third World Military Expenditure (London, 1979), 50-53.

⁵³Augusto Varas. "The Effects of Military Industrialization in Latin America," Disarmament 15:1 (1992), 88.

regions receive the benefits that are available.⁵⁴

⁵⁴Fredric S. Pearson. "The Priorities of Arms Importing States Reviewed," Arms Control Vol. 9 (1988), 180. and Pierre, 237.

CHAPTER II: SOURCES OF MISSILE TECHNOLOGY SUPPLY

Once demand has been established, Third World states acquire ballistic missile technology from a number of sources. These may include established aerospace industries or firms in developed countries as well as civilian space programmes utilizing "dual use" rocket technologies. In addition, developing states may acquire technology via inter-LDC trade or exchanges of scientific personnel, or through private individuals or engineering consortia. The purpose of chapter two is to outline the factors of supply on the international weapons technology market. These factors will be used in the development of the proliferation model in the following chapter and in the analysis of the Brazilian experience in missile development in order to test the paper's second hypothesis and to determine how Brazil acquires its ballistic missile capability.

2.1 ESTABLISHED AEROSPACE INDUSTRIES

Established aerospace industries in Industrialized Countries can potentially play a major role in the North-South transfer of missile technology. Four main factors have influenced the environment in which these industries operate. First, although established to curb missile technology transfers to the Third World, the Missile Technology Control Regime has allowed the international missile and missile technology market to remain in operation. Second, aerospace firms are promoted and protected by their home governments leading to industry overcapacity. Third, overall world demand for the military products of established aerospace firms has declined. Fourth, modern weapons production has come to be characterized by escalating R&D and unit production costs and the need to maintain production economies of scale.

2.1.1 Lack of an effective control regime

Various restrictions on technology transfers have always been seen as necessary due to national security concerns. It is not surprising that in 1987, after emerging Third World missile forces were recognized as potential military threats, Western Nations, joined later by the USSR, established the Missile Technology Control Regime.⁵⁵ The Regime established restrictions on the sale of two categories of missile components and technology. "Category I" items include complete rocket assemblies, whole rocket stages, engines, guidance systems, and reentry vehicles. "Category II" items include production technologies for components such as fuel, avionics, test equipment, software, and structural materials.

Nevertheless, North-South trade in missile technology and components has continued. To begin with, firms located in MTCR member states may still sell category I items if buyers make assurances that they will only be used for peaceful purposes. In addition, the regime allows category II items to be routinely sold unless a member state raises specific security concerns.⁵⁶ Moreover, the MTCR does not control the movement or activities of individuals who may market their missile design or production expertise, nor is it designed, nor intended, to constrain sales of rocket technology to Third World civilian space programmes. Another failing of the Regime is the fact that although additional Western countries and the USSR have entered the Regime since its initial conception, several producers and potential exporters of missile technology such as the

⁵⁵Karp, "Third World Quest", 14.

⁵⁶Ibid., 16.

PRC, India, Brazil, and North Korea have not. The final failing of the MTCR to effectively control the market relates to the fact that MTCR guidelines are subject to national interpretation and state adherence to its guidelines is voluntary.⁵⁷

2.1.2 State Promotion of the Industry

As is the case among developing countries, industrialized states also view defence production as a means of countering security threats, building national independence, and capturing economic benefits. In Western Europe for example, post war promotion and protection of the arms industry and aerospace firms in particular was seen as a means of stimulating industrialization, creating employment, and improving national balance of payments positions.⁵⁸ Industrialized states, and West European nations in particular, have also adopted the view that arms production could encourage post war economic reconstruction and expansion, enhance international competitiveness, and promote economic modernization.⁵⁹ Governments go to great lengths to promote, protect, and subsidize what they see as "strategic" industries, but since the majority of nations have small domestic military markets, once established, most national arms industries are characterized by excess production capacity.

2.1.3 Decreasing Weapons Demand and Increasing Unit Costs

Although the Cold War continued through the late 1980s, demand for weapons in

⁵⁷Nolan, "The Limits of Proliferation", 12-13.

⁵⁸Edward A. Kolodziej, "France," The Structure of the Defense Industry. An International Survey ed by Nicole Ball and Milton Leitenberg. (London, 1983), 91-96.

⁵⁹Edward A. Kolodziej, The Making and Marketing of Arms: the French Experience and Its Implications for the International System (Princeton, N.J., 1987), 397.

many regions of the world began to decline as early as the mid-1970s. By that time, European, North American, and many Third World defence markets become saturated and defence production became geared towards replacing worn or obsolete equipment rather than adding to previously growing weapons stocks. Moreover, the 1970s witnessed a period of East-West "Detente" that reduced the perceived need for further equipment acquisitions. The 1970s also saw the start of a series of economic recessions triggered and exacerbated by the oil price shocks of 1973 and 1979. Finally, reduced military tensions in Europe following Eastern political liberalization, Soviet troop withdrawals, and the implementation of the Conventional Forces Europe (CFE) Treaty for instance, allowed approximately 25 percent reductions in West European defence spending.⁶⁰ Despite an increased demand for weapons systems during the 1990-91 Gulf War, American demand for weaponry is also expected to continue to decline as previously announced post-Cold War defence cuts are implemented.⁶¹

Demand in many Third World markets for sophisticated front-line systems such as tanks, combat aircraft, helicopters and surface warships has also declined. Between 1980 and 1983 Third World purchases of these big ticket items pushed annual arms sales to unprecedented heights. But by the mid 1980s, an increasing inability to maintain complex equipment, mounting foreign debts, or falling oil revenues and commodity prices, forced buyers to forego new purchases. Moreover, faced with potential military scenarios involving wars of attrition similar to the Iran-Iraq War or protracted domestic

⁶⁰Congress of the United States Office of Technology Assessment. The Global Arms Trade: Commerce in Advanced Military Technology and Weapons (Washington D.C., 1991), 66.

⁶¹Office of Technology Assessment Global Arms Trade, 36

insurgencies, many developing countries cut back on purchases of sophisticated battlefield weapons and instead, have purchased greater quantities of lower-tech, less expensive hardware or para-military counter-insurgency equipment.⁶²

While demand has been falling, weapons production has also become more expensive. Modern weapons, and particularly missiles, entail far greater research and development efforts, involve higher production costs, and therefore entail greater unit production costs than the weapons they are replacing. Moreover, as newer aircraft, missiles, and weapons etc., tend to be "smarter" (more accurate), than older generation weapons, fewer replacement units are required.⁶³

2.1.4 Restructuring Attempts

By 1978, there were nineteen aerospace manufacturers producing for the European market. Although larger, the U.S. military aircraft market was served by a total of eight firms.⁶⁴ But because of reduced demand, excess capacity in the industry as a whole, and higher unit production costs, it became clear that firms would have to achieve production economies of scale in order to remain economically viable. European governments acknowledged the inadequate size of their national markets, increasing costs, and the fact that overcapacity existed as early as the 1950s. As a result, attempts to rectify the situation were undertaken through the creation of a series of National Champions.⁶⁵

⁶² Michael T. Klare, "Who's Arming Who?: The Arms Trade in the 1990s," Technology Review Vol 93 (May-June 1990), 44-45.

⁶³ Barry Buzan, An Introduction to Strategic Studies: Military Technology and International Relations (London, 1987), 41.

⁶⁴ Tuomi, 31.

⁶⁵ *Ibid.*, 18-19.

Several French firms were consolidated to form Aerospatiale. British Aircraft and Hawker Siddley were merged and formed British Aerospace, and Messerschmidt, Bolkow, and Blohm merged to form MBB which later merged with Krupp's VFW division.⁶⁶ Their governments bought large shares in these firms, provided substantial financial and R&D support, and followed preferential arms procurement policies.⁶⁷

Despite the consolidation efforts of the 1950s and 1960s, European markets remained too small to allow national champions to achieve production economies of scale. Consequent efforts in the late 1960s and 1970s then centred on the creation of several inter-European coproduction projects and collaborative efforts aimed at sharing technology and R&D costs, and lengthening production runs.⁶⁸ Projects included the Anglo-French Jaguar fighter, the Anglo-German-Italian Tornado strike aircraft, the Franco-German Alpha Jet, and the "Euro Missile".⁶⁹ However, contrary to expectations, in light of limited European defence equipment requirements, the combined European market was still not large enough to allow production economies.

In addition, differences over design and performance specifications in joint development efforts actually increased development costs.⁷⁰ Government insistence that firms from each participating country be awarded contracts regardless of the firm's cost

⁶⁶Kolodziej, "France", 84-85.

⁶⁷Theodore H. Moran and David C. Mowery, "Aerospace," *Dacdalus* 120:4 (Fall 1991), 138.

⁶⁸Martyn Bittleston, "Co-Production or Competition? Defence Procurement Options for the 1990s," *Adelphi Papers* No. 250 Spring 1990), 3. and Kolodziej, "France", 103.

⁶⁹Buzan, 41.

⁷⁰Moran and Mowery, "Aerospace", 140.

efficiency also meant that sub-contracting entailed a loss of efficiency.⁷¹ As collaboration conducted under the principle of Juste Retour failed to produce more affordable weapons systems or production economies of scale, it came to be argued that the adoption of unbiased and open procurement policies based on firm cost effectiveness would increase overall European efficiency as well as stretch procurement budgets. But due to potential increases in foreign dependencies and loss of potential national economic benefits, the introduction of free competition in the European arms industry has not been pursued.⁷² States continue to maintain national aerospace defence industries, and to date, there has been little political action taken towards the development of a system of joint production, collaboration, or procurement that allows firms to compete openly for production contracts in foreign countries.⁷³

Since inter-European collaboration also failed to provide production economies of scale, exports (in addition to aiding the capital accounts, off setting domestic procurement costs, funding defence equipment modernization, and supporting domestic R&D⁷⁴) came to be seen as the best way to achieve the economies of scale needed to keep European aerospace firms in operation. After markets initially became saturated, dependency on exports grew steadily. In 1960 for example, French industry as a whole

⁷¹Bittleston, 62-77.

⁷²Theodore H. Moran, "The Globalization of America's Defence Industry: Managing the Threat of Foreign Dependence," International Security 15:1 (Summer 1990), 94.

⁷³Paul Buteux, "Armaments Collaboration and the 'Europeanization' of European Defence," Canadian Defence Quarterly 20:4, Special Issue No. 1 (February 1991), 46.

⁷⁴Nayan Chanda, "The Third World Race for Ballistic Missiles," Far Eastern Economic Review (2 June, 1988), 22.

exported 7.6 percent of its total military production. By 1985, the figure had increased to 42.5 percent. By 1990, weapons exports had risen to over 50 percent of total arms production.⁷⁵ Export dependency in the aerospace sector of the French arms industry was even greater with 73 percent of weapons production being exported by 1980.⁷⁶

During the late 1980s renewed efforts towards consolidation were undertaken. Between 1987 and 1989, European industry witnessed over 130 acquisitions and mergers.⁷⁷ By 1988 European governments had privatized major national champions such as British Aerospace, Thomson-CSF, and MBB, allowing them to sell off unprofitable operations, consolidate, or diversify into civilian sectors. The period also witnessed a trend towards the formation of European and Trans-Atlantic strategic business alliances through stock swaps, joint acquisitions, teaming on specific projects and non-equity investments.⁷⁸ Nevertheless, despite moves toward institutionalized industrial integration under initiatives like the EC Independent European Program Group, which has approved a plan to establish a common European arms market pursuant to the Single European Act,⁷⁹ European procurement remains closed unless coproduction agreements with purchasing countries are concluded. The industry remains characterized by relatively small markets, high unit costs, excess capacity, and a reliance on exports in order to

⁷⁵Krause, 704-05.

⁷⁶Kolodziej, "France", 100.

⁷⁷Office of Technology Assessment, Global Arms Trade, 36-41.

⁷⁸Office of Technology Assessment, Arming Our Allies: Cooperation and Competition in Defence Technology (Washington, D.C., 1990), 16 & 73-74.

⁷⁹Office of Technology Assessment, Arming Our Allies, 16-54.

achieve production economies of scale.

Traditionally, American and Soviet firms did not have to export large quantities of weaponry in order to achieve scale economies. During the Cold War, the Warsaw Pact absorbed the majority of Soviet military production. However, as a result of Soviet/Russian procurement cuts (reportedly as high as 60 percent from 1991 to 1992 alone), and increased foreign exchange requirements, former Soviet and Eastern European firms have found increased arms exports to be necessary as well as attractive. In fact, after initial reductions in arms exports from \$19.6 billion in 1989 to only \$4 billion in 1991, Russian export goals for 1992 were revised upward to \$10 billion.⁸⁰

Cold War needs also absorbed the majority of American weapons production. While West European firms were exporting 60 to 70 percent of their production during the period 1982- 1985, the American government bought 89 percent of McDonald Douglas' military production; 90 percent of Northrop's; 96.5 percent of Lockheed's; and 97.5 percent of United Technology's.⁸¹ However, due to post Cold War defence cuts of as much as \$190 billion from FY90 to FY95,⁸² the U.S. aerospace industry has seen fit to reevaluate its activities in order to maintain healthy balance sheets and strong cash flows.⁸³ To become more competitive internationally, major U.S. defence contractors have sold off unprofitable operations, internalized higher value added activities such as

⁸⁰Peter Almquist and Edwin Bacon. "Arms Exports in the Post-Soviet Market," Arms Control Today 22:6 (July-August 1992), 12-4.

⁸¹Krause, 704.

⁸²Office of Technology Assessment. Arming Our Allies, 83.

⁸³Anthony L. Velocci. Aviation Week and Space Technology (25 May, 1992), 38.

R&D, and downsized work forces. In efforts to share R&D costs, maintain technological positions, and access foreign markets, an increasing number of U.S. contractors have also established joint ventures or strategic alliances with each other or with foreign firms.⁸⁴

To facilitate increased arms exports, American producers have sought deregulation of the U.S. arms industry, relaxed export controls, and government support in securing foreign contracts. Wishing to avoid large losses of American jobs in high-paying, high-technology sectors, and in order to assure a diverse defence industrial base, the American government accommodated industry. State Department efforts have been directed towards the promotion of U.S. weapons exports. U.S. Export-Import Bank loan guarantees have been proposed to back foreign arms purchases. The Bush administration proposed a defence GATT among U.S. allies, and the government authorized a series of large major arms deals with America's Middle Eastern allies following the Gulf War.⁸⁵

2.1.5 Impact on Technology Transfer

The environment in which established defence industries operate has had a profound effect on the nature and rate of North-South weapons technology transfer. Post-1945 aerospace and defence industries, and particularly those in Western Europe have been characterized by over capacity, increasing production costs, and the need to export excess production in order to remain economically viable. However, due to decreased weapons demand in developed and developing nations alike, intense competition between firms has developed in remaining export markets. As a result, as early as the 1970s, the

⁸⁴Office of Technology Assessment, Arming Our Allies, 14-27.

⁸⁵Office of Technology Assessment, Global Arms Trade, 21-60.

market had essentially become a buyers market.

After World War Two, arms transfers between the Superpowers and their allies, as well as North-South arms transfers, consisted primarily of outright grants of complete, albeit relatively dated or obsolete weapon systems. Over time however, rising production costs and mounting trade deficits led to the gradual commercialization of markets where financial payments were demanded by Western producers.⁸⁶ But as large quantities of foreign exchange are not always available, methods evolved where buyers of Western military equipment could offset the high cost of weapons imports.

Agreements of this type between producers and purchasers can take the form of indirect or direct offset agreements. Indirect offset agreements involve exchanges of commodities, manufactured goods, or services, for arms under barter or counter trade arrangements. Under these forms of arrangements, an arms producer may agree to use its resources to market goods received in return for weapons. Oil is usually the commodity of choice as far as arms producers are concerned, but divisions of U.S. aerospace companies for example have even found themselves marketing textiles, food products, and furniture.⁸⁷

Direct offset agreements are agreements where some form of production related to the weapon system being sold will take place in the purchasing country. Starting in the 1960s, the number of direct offset agreements between firms increased rapidly. By the 1970's, direct offset agreements came to accompany the majority of international arms

⁸⁶Tuomi and Vayrynen, 14.

⁸⁷Grant T. Hammond. "Offset, Arms, and Innovation," The Washington Quarterly 10:1 (Winter 1987) 173-185.

transfers.⁸⁸ Direct offsets take several forms. Sub-contracting occurs when a prime contractor in one country contracts with a foreign company to produce a specific number of parts or a portion of a weapon system. Formal licensing agreements may be signed where a country buys the rights to produce parts or weapons under specified conditions. Coproduction agreements may be reached where components for a foreign weapons system purchased by a recipient are produced in the buyer's country, exported, and later re-imported as part of an assembled system. Finally, various inter-firm codevelopment agreements may also be reached that involve joint design of new systems.

Codevelopment agreements take a number of forms. Joint-owned corporate entities may be established to pursue particular programmes. Strategic alliance, or non-equity investments may occur where collaboration takes place in a specific area of product development such as research, production, or marketing. Finally, consortiums may be formed where several partners agree to pursue a project using shared resources and share resulting revenues.⁸⁹

Technology is transferred in every type of direct offset arrangement and in each form of venture. How much, and what production technology "spin-offs" occur, depends on the structure of the venture and the industrial environment in which the venture takes place. Where ventures involve recipient firms that are vertically integrated, or where production of the military and other civilian goods for example takes place within the same company, factory, or on the same assembly line, technology is transferred relatively

⁸⁸Moran and Mowery, 142.

⁸⁹Office of Technology Assessment, Arming Our Allies, 15.

easily. Tightly segregated production on the other hand, tends to minimize technology flows to other areas.

When licensing is concerned, technology transfers result from the transfer of data packages and instructions which the licensee needs to produce a given part or component. In coproduction and codevelopment, personnel from the original designer of the system or collaborating firm are also transferred in order to ensure the resulting components meet system and integration requirements. The greater the level of collaboration, the greater the personal contacts, and thus the greater the potential for technological transfer and absorption.⁹⁰

International aerospace coproduction agreements first evolved between the U.S. and its European allies. Initially, American-European defence cooperation centred on coproduction agreements. And by 1990, approximately thirty American designed aircraft, missiles, and helicopters as well as numerous sub-systems and components had been manufactured by European firms under American license. This has allowed European firms to acquire substantial production capabilities. However, during the 1970s and 1980s an increasing number of American-European codevelopment agreements were entered into which allowed European firms to participate in greater upstream R&D and design activities.⁹¹

Later the process started to be repeated in the Third World. Since 1950, American, European, and Soviet firms have increasingly entered into licensing agreements

⁹⁰Ibid., 77-78.

⁹¹Moran and Mowery, 140-42.

with developing countries. Being forced by economic logic to "sell what they can",⁹² Western firms have entered into several coproduction projects. From 1950 to 1984, the American firms concluded over 30 licensing agreements with nine developing countries, while European firms entered into 60 agreements with 15 countries.⁹³ America for example has sold Turkey and South Korea the means to produce modern military aircraft, and has also sold Egypt the blueprints and equipment to make its M-1 main battle tank. The Soviets meanwhile furnished India with the technology to manufacture their T-72 tank and Mig-27 fighter, and West Germany for instance has helped Brazil, India, and South Korea build conventional submarines.⁹⁴

By the 1980s Western aerospace firms had also begun to enter into codevelopment agreements with LDCs. SNIA-BPD, the Italian manufacturer of the solid fuel rocket boosters for the "Ariane" rocket, was involved in codevelopment activities in the joint Egyptian-Argentine-Iraqi "Condor II" missile programme. France's SNPE provided the engines and worked with Egyptian firms to design the SAKR-80 missile. German firms initiated the Libyan missile programme, and worked with Iraq to construct the "SAAD 16" missile and related design facilities. In addition to providing the booster rockets, French and German firms helped design India's "Advanced Space Launch Vehicle".⁹⁵

Even if codevelopment does not occur, design technology can still be transferred.

⁹²W. Scott Thompson. "Security and Development in the Third World: Some Policy Perspective," in Defence, Security and Development ed. by Saadet Deger and Robert West (London, 1983), 104-5.

⁹³Ball, Security and Economy, 354.

⁹⁴Klare, 48.

⁹⁵Carus, 22-23.

Firms that have undertaken the expense of developing new technologies generally see the monopolization of that technology as being advantageous, and as a result, when engaged in licensed coproduction, may attempt to utilize techniques to protect "trade secrets" from partners who might become potential competitors. Efforts to do this include concealing vital technologies such as navigation or guidance packages in so called "black boxes", or attempts to obtain commitments from buyers which limit the independent use, modification, or resale of the technology for a specific period of time.⁹⁶ Suppliers may also simply refuse to license the technology to others. However, the denial of technology may not always be possible, or financially desirable due to the developer's need to recoup sunk R&D costs and mitigate production costs through foreign sales.⁹⁷

Once a technology, component, or system comes into the possession of a LDC production partner, the partner may also decipher a given technology through reverse engineering activities. Reverse engineering involves disassembling a component or a system, studying it, and then producing a copy. Once copies are acquired, Third World producers go a step further and engage in "add up" or "add on" engineering activities. "Add up" engineering involves modifying a particular system, while "add on" engineering involves combining components obtained from various sources into a new so called "indigenous" weapon system.

2.2 SPACE PROGRAMMES UTILIZING DUAL-USE TECHNOLOGIES

Civilian space and satellite launch programmes are another means by which

⁹⁶Moran and Mowery, 145.

⁹⁷Stephen Gill and David Law. The Global Political Economy. (Baltimore, 1989), 113.

developing countries may gain access to advanced aerospace technologies, and missile technology in particular. The MTCR is not designed to limit the development of Third World civilian space programmes or the exports of Western aerospace firms involved in the production of space launch and support systems. Any regulatory regime governing the transfer of rocket technology destined for civilian space programmes would be extremely difficult to maintain due to the dual use characteristics of the components involved. In short, the same guidance systems, heat shields, propellants, production process information, and engines used for civilian space programmes may also be used in the production of military ballistic missiles.⁹⁸

Space technology spreads through various channels including the purchase of space systems, expertise, or production technology from industrialized countries. As of 1992, China, Israel, and India possessed indigenous space launch capabilities. If re-configured as ICBMs through the addition of guidance packages and heat-shields, Chinese and Indian SLVs would have ranges of 13,000 kilometres, while the Israeli "Shavit" system would have a 5,000 kilometre range. Used in a surface to surface mode, Brazil's SLV, under development since 1977, would have a range of up to 6,000 kilometres. Had their development proceeded, Argentine and Egyptian SLVs would have had ranges in line with intermediate range ballistic missiles.⁹⁹ Several other developing countries including Taiwan, South Korea, South Africa, Pakistan, Indonesia, Mexico, Iran, and Turkey also

⁹⁸ Thomas G. Mahnken. "Why Third World Space Systems Matter," Orbis 35:4 (Fall 1991), 563-5.

⁹⁹ Lora Lumpe, Lisbeth Gronlund, and David C. Wright. "Third World Missiles Fall Short," Bulletin of the Atomic Scientists 48:2 (March 1992), 32.

have civilian space programmes.

Third World Space programmes have proven to be more than just theoretical sources of ballistic missile technology however. Brazil and Pakistan for example have both modified atmospheric sounding rockets for use as long range artillery rockets and have used sounding rockets as the basis of further missile development.¹⁰⁰ After French and German firms helped design India's "Advanced Space Launch Vehicle" the "SLV-3" and sold the country the booster rockets,¹⁰¹ India re-configured the vehicle to produce the "Angi" intermediate range ballistic missile: the Angi essentially being the first stage of the SLV-3.¹⁰²

2.3 INTER-LDC TRADE

In 1959 and 1960, America transferred short range "Honest John" missiles to Turkey, Taiwan, South Korea, and Greece. In 1975, it also sold Lance missiles to Israel. However since that time, with the exception of the 1991 transfer of Patriot missile batteries to Israel, American transfers of complete missile systems have been limited to its European allies. The Soviet Union on the other hand, continued to supply several ballistic systems to a number of Third World states throughout the 1970s and 1980s (see table III). However, due to increased threats posed by Third World ballistic missiles to its territory, desires to reach political accommodation with the West, and the implementation of the INF Treaty banning the sale of intermediate range missile, since

¹⁰⁰Carus, 12-15.

¹⁰¹Ibid., 22-23.

¹⁰²Almquist and Bacon, 14.

1988, the Soviet Union, and later Russia, has also refused to transfer complete ballistic missiles to Third World states.¹⁰³

Table III

Soviet ballistic missile transfers to the Third World

Country	System	Year	Country	System	Year
Afghan.	Scud-B	1989	N.Korea	Frog-5	1969
Algeria	Frog-7	1975		Frog-7	1969
Egypt	Frog-7	1968	Kuwait	Frog-7	1978
	Scud-B	1973	Syria	Frog-5	1973
Iran	Frog-7	1984		Frog-7	1973
	Scud-B	1984		Scud-B	1974
Iraq	Frog-7	1969		SS-21	1983
	Scud-B	1974	N. Yeman	SS-21	--
Libya	Frog-7	1978	S. Yeman	Frog-7	1979
	Scud-B	1976		Scud-B	1979

(Source: Karp, "Third World Quest", 19, and Nolan, "Ballistic Missiles in the Third World", 10).

Despite an end to Soviet transfers of complete missile systems, trade in complete missile systems has continued among Third World states (see table IV). Networks have been created where producers sell or exchange missile systems, technology, and production capabilities. Inter-Third World missile trade involves three basic commodities: Soviet missiles placed on the market by the original recipient; once developed, indigenous Third World missiles systems or components; and human capital in the form of missile expertise.

The resale of Soviet built Scud missiles has been particularly well documented.

¹⁰³ Navias, 21.

Soviet Scud-B and Frog-7 missiles for instance have been re-sold to Iran by Libya and Syria. Egypt has also sold several Soviet built Scuds to North Korea which in turn commenced production of an enhanced version of the missile with Chinese help.¹⁰⁴ North Korea has sold these weapons to Iran, and possibly Libya. It is also alleged that North Korea has helped Egypt, and Iran (in conjunction with China and Israel) to establish Scud production facilities of their own. Israel is believed to have sold American Lance missiles to Taiwan which served as the basis for Taiwan's "Green Bee" missile.¹⁰⁵

India, Israel, and China originally developed their missile capabilities with Soviet and/or Western help. However, having developed these industries, China and Israel have become major suppliers indigenous missiles and missile technology to other Third World countries. Israel has for example sold Jericho 2 ballistic missiles to South Africa. China has sold DF-3 missiles to Saudi Arabia, HY-2 Silkworm missiles to Iran and Iraq, and C-801 anti-ship missiles to Iran. Iraq's "Teheran Rocket" is believed to have been imported from China or possibly Brazil. China has also considered selling Pakistan, Syria, and Libya the intermediate range M-9 ballistic missile, while Brazil is known to have equipped Saudi Arabia and Iraq with various long range artillery rocket systems, and has provided training to Iraqi missile forces. Examples such as the recent sale of Chinese guidance systems to Brazil also point to a growing Third World trade in missile

¹⁰⁴Aaron Karp. "Ballistic Missile Proliferation," SIPRI Yearbook 1991: World Armaments and Disarmament (Oxford, 1991), p. 319-30.

¹⁰⁵Marie-France Desjardins. "Ballistic Missile Proliferation," CJIPS Background Paper No. 34, (September 1990), 3.

Table IV

Third World ballistic missile technology transfers

<u>Recipient</u>	<u>System</u>	<u>Contributor</u>
Argentina	Condor 2 Condor 1	Iraq & Egypt Iraq & Egypt
Egypt	Condor 2 Scud 100*	Argentina N. Korea, PRC
Iran	Scud-B* Oghab Nazeat Shanin 2	N. Korea, Libya, Syria PRC PRC PRC
Iraq	Al-Abbas Condor 2 Al-Husayn	Brazil, Egypt Argentina Egypt, Brazil
N. Korea	Scud-B*	Egypt
S. Africa	SLV Jericho*	Israel, Taiwan Israel
Syria	Scud-B*	Libya
Taiwan	Green Bee	Israel
Saudi Arabia	DF-3*	PRC

* Complete system (Source: Navias, p. 29-31).

components.¹⁰⁶

Third World missile development is also facilitated by scientific exchanges and technical cooperation between developing nations. Pakistan's "Haft 2" missile for

¹⁰⁶Janne E. Nolan and Albert Wheelon. "Third World Ballistic Missiles," Scientific American 263:2 (August 1990), 39.

example, which is reportedly capable of lofting a 1,100 pound warhead 180 miles, has allegedly been developed with Chinese assistance.¹⁰⁷ Iran allegedly received assistance from China for the production of the "Iran-130" missile. Egypt cooperated with Iraq on the production of the Sakr-80 short range ballistic missile. Argentina's defunct Condor II missile project received substantial financial support from Egypt and Iraq, while Chinese and Brazilian firms have formed joint ventures to develop space launch capabilities.

2.4 INDIVIDUALS AND CONSORTIA

In addition to official government agencies, unauthorized individuals or firms have also provided Third World countries with missile guidance, control, propulsion, and test systems. The emergence of "private" suppliers was made possible by a growing number of technical experts worldwide, the inability of international law to control such activities, growth in the number of potential buyers, and the potential for very large profits. Individuals or firms act in various ways to transfer technology. Scientists or engineers may be hired directly as technical experts by a Third World state. But in addition, consortiums or firms may participate in unauthorized development, production, or the illicit export of missile components or technology. Finally, individuals or firms may actually carry out illicit operations such as theft, smuggling, or espionage in order to obtain and ultimately transfer missile technology to developing countries.¹⁰⁸

The earliest example of a private missile consortium being developed occurred in

¹⁰⁷Nolan, and Wheelon, 38.

¹⁰⁸Jeff Gerth. "5 Charged in Plot to Export Arms," New York Times (September 20, 1990), A7.

the 1960s when a group of German engineers were hired by Egypt to build V-2 type rockets. Israeli action ended the project. Later, before being dismantled in the 1970s, ORTAG, a West German business consortium, initiated the Libyan missile programme,¹⁰⁹ established its own launch facilities in Zaire, and tested a prototype rocket.¹¹⁰

In the 1980s, members of the "Consen Group", another missile consortium, agreed to act as the technical consultant for Iraq's national missile programme. Consen has sent personnel with experience in European space projects to work on Argentina's Condor ballistic missile project, and in 1984 and 1988 Consen firms financed or made illegal attempts to obtain U.S. missile technology. The Consen Group is also alleged to have encouraged other European firms to contravene export laws and transfer missile technology to Iraq.¹¹¹ After American made triggers for nuclear weapons bound for Iraq were intercepted in England in 1990, dozens of such companies came under investigation.

¹⁰⁹Carus, 22-23.

¹¹⁰Navias, 26.

¹¹¹Ibid., 26.

CHAPTER III: THE PROLIFERATION MODEL

The paper's second hypothesis states that Brazil's development of a ballistic missile capacity was facilitated by interactions in the international aerospace technology market between demand and supply, which in turn promote weapons technology transfers and facilitate the proliferation of advanced weapon technology. In order to test this hypothesis, it is first necessary to determine the characteristics of the international aerospace technology market. The purpose of chapter three is to develop a model depicting the market which explains what interactions take place between demand and supply; how they promote technology transfers; and how they have facilitated the proliferation of ballistic missile technologies. The model is referred to as the "proliferation model".

The model is derived from the factors contributing to the demand for ballistic missiles or missile technology outlined in chapter one, the factors contributing to supply outlined in chapter two, and market transaction mechanisms that have come to characterize the market. Through the course of its development, the model will demonstrate that the linkages between market demand, supply, and transaction mechanisms in the market, comprise a system that facilitates ballistic missile proliferation. In the case study conducted in chapter four, the usefulness of the model in explaining events and developments in Brazil will be tested, and the model utilized as a framework to test the paper's second hypothesis.

As with other markets, the market for missile systems, components, sub-assemblies, and production and design technologies, is characterized by the presence of

buyers and sellers (or a supply and demand), a market price, and a given quantity which is produced. Demand for, and the supply of particular technologies dictate the price and the quantity made available.

Although the special nature of the arms trade would be expected to distort prices as politics comes into play, the missile market appears to function along the lines of traditional markets as it is characterized by several buyers and sellers. If this were not the case, the missile technology market may behave much more like the international crude oil market where strategic interaction between buyers and sellers, the USA and Saudi Arabia for example, largely determine the price and quantity produced. As outlined in chapter one, although the demand for ballistic missiles is determined primarily by governments, there are potentially hundreds of potential buyers of missile technology, components, expertise, and parts on the market. This is especially true when one considers the dual-use nature of many missile components. Thus, buyers include national military establishments, state owned or privately operated national arms industries, countless aerospace, communications, electronics, and computer firms, and numerous government scientific research agencies, national space programmes and so forth.

The market is also characterized by a multitude of potential sellers. North American, East and West European, and several newly industrialized Asian governments are capable of selling components, dual-use technologies or complete rocket assemblies. Several developing nations may also be considered potential technology sellers owing to the possession of missiles obtained from the superpowers, each other, or via development of indigenous systems or parts. Numerous public or private aerospace, communications,

electronics, and chemical firms, as well as national space programmes also produce missile related hardware and know-how and can be considered potential sellers. Private individuals are also known to have peddled expertise or components. Competition among sellers from all sectors is fierce and commercial sectors are open to new entrants.

The workings of the aerospace weapons technology market can be illustrated graphically in a hypothetical model. In this model, we plot the market's demand and supply curves against the price of technology and the total quantity of missile technology produced. In the proliferation model, the demand curve is a representation of total demand for ballistic missiles, related parts, components, and production technologies. To quantify total demand or to attach a specific value to it is likely impossible. Literally thousands of parts and components, and hundreds of different skills are required to construct a ballistic missile. There are simply too many individual items to allow one to calculate a specific aggregate demand for all technologies and skills associated with BM production. Therefore, the demand curve in the proliferation model is not intended to show an actual quantity of a particular missile system, technological item or service demanded. Instead, the demand curve in the proliferation model illustrates the general level of demand for all ballistic missile technologies on the market at a particular point of time, as well as the overall effect on the market resulting from increases in missile technology demand. Based on the assumption that at a higher price less of a particular item making up a ballistic missile will be demanded, the demand curve is downward sloping.

It also needs to be stressed that in the proliferation model, the supply curve is a

representation of the total supply of ballistic missiles, missile sub assemblies, components, parts, production technology and skills, and design expertise. Like demand, it is likely an impossible feat to quantify total world supply of ballistic missile related hardware, skills and technology due to the vast number of components and the vast number of potential sellers on the market. Therefore, the supply curve in the proliferation model is not intended to illustrate a quantified or specific amount of a particular system, component, or skill available on the market. Instead, the supply curve in the proliferation model illustrates the general level of the supply of all technologies with ballistic missile applications available on the market at a given time. Shifts in the supply curve represent the overall effect on the market of increases or decreases of total technology available.

It must also be emphasized that price of missile technology indicated on the model's vertical axis does not represent a specific monetary figure or a quantified amount. Instead, the vertical axis represents the general price level of ballistic missile systems or the technologies and skills needed in their construction. A higher price level is indicated at points towards the top of the scale, and lower price levels are indicative of points towards the bottom. Even though complete missile systems have been sold, it is impossible to set a specific price to a ballistic missile. First, no two systems are the same. The characteristics of the Chinese DF-3 and the Soviet Scud-B for example differ greatly. Second, each missile project entails different costs. A missile system transferred to one country may have the advantage of being able to operate within a well developed national scientific and defence infrastructure. In another country however, the same system may entail further hidden costs due to a less efficient support infrastructure, or

because the support infrastructure has to be built from the ground up.

In cases where indigenous development occurs and missile components must be imported or developed locally, problems also arise in setting a price for ballistic missiles. In short, when indigenous development is concerned, there is no price for finished systems, just prices for individual components. When these components are produced however, their exact price is difficult to determine because financial payments made by governments to foreign suppliers or domestic producers are offset by employment, technological, industrial, or potential export benefits. As exact prices on systems and components are impossible to determine, the vertical axis of the proliferation model indicates the general price level of technologies and skills associated with ballistic missile production or deployment, and the effect on that level of increases or decreases in demand or supply.

Finally, it must also be pointed out that in the proliferation model, the horizontal axis does not give an indication of the actual numbers of a particular part or system that has been placed on the market. Instead, the scale on the horizontal axis marks the general level of technology available; technology in this case being missile systems, parts, components, and production and design expertise. Points to the left of the scale simply indicate a smaller amount of these technologies are available on the market at a given time, while points towards the right of the scale indicate that a greater amount of these technologies are available on the market.

Figure 2 depicts the market in a state of equilibrium where the supply of technology on the market equals demand. In a familiar pattern, the price of technology

is indicated on the vertical axis: price again being comprised of actual financial payments minus any economic, industrial and technological benefits received as a result of the purchase. The total quantity of missile technology (components, expertise, manufacturing

Figure 2

equipment etc) available for sale on the market is indicated on the horizontal axis.

In the proliferation model, the upward sloping supply curve, *S1*, represents the potential supply on the market, at any given price. The downward sloping demand curve, *D1*, represents demand for missiles or missile technology encompassing all buyers/importers/recipients on the market at any given price. With the curves intersecting at point *E1*, the market is at a point of equilibrium where a total quantity of *Q1* missile technology is placed on the market at a price of *P1*.

3.1 DEMAND

Markets seldom remain in equilibrium. Market equilibrium can be upset by either an increase or decrease in demand for missile technology or by an increase or decrease supply. As outlined in chapter one, the forces accounting for increased demand for missiles or missile technology include perceived gains in domestic and international

political prestige, the military utility of ballistic missiles and their deterrent capability, as well as a state's desire to become self sufficient in defence production. Economic motivations to establish domestic production also drive demand. These motivations include the desire to improve the national balance of payments situation by foregoing foreign exchange expenditures, or by earning foreign exchange through the export of domestically produced weapons. Economic motivations also include potential qualitative and quantitative gains in employment, the creation of new manufacturing capabilities and industries, regional development, industrial modernization through the transfer of new production technologies and methods, and the absorption of excess capacity in related industrial sectors.

Third World demand for **Table V**

ballistic missiles and related production technologies can be shown to exist by the fact that several LDCs have deployed ballistic missiles or have initiated development programmes. By 1990, twenty-one LDCs could be considered ballistic missile states (see table V). Moreover, demand has not remained static over time.

LDCs with BMs or development programmes by 1990

Afghanistan	Libya
Algeria	North Korea
Argentina	Pakistan
Brazil	Saudi Arabia
Cuba	South Africa
Egypt	South Korea
India	Syria
Iran	Taiwan
Iraq	Turkey
Israel	Yemen
Kuwait	

(SIPRI Yearbook, 1989, 1990).

The number of LDCs demanding ballistic missile technology has increased steadily since

Table VI

1960, as has the number of LDCs that have undertaken efforts to deploy space launch vehicles (SLVs) and scientific sounding rockets (SRs) which employ dual use technologies (see table VI). Another indication of an increasing LDC ballistic missile technology demand over time is the total number of BM systems	LDCs with BMs, SLVs, or SRs; versus LDCs with BMs: 1960-1990.		
	Year	Number LDCs With BMs, SLVs, or SRs.	Number LDCs with BM capabilities.
	1960	4	2
	1965	5	4
	1970	9	6
	1975	15	10
	1980	18	13
	1985	20	16
	1990	24	21
	(SIPRI Yearbook 1989, 1990).		

deployed. In 1960 for example,

only two different ballistic missile systems were deployed by various Third World states. By 1990, the number had grown steadily to thirty-one (see table VII). Similarly, in 1960 indigenously designed BMs were not produced in the Third World. By 1990 the number of indigenously produced LDC systems had reached seventeen.

In the proliferation model, increases in demand over time that are triggered by any of the factors outlined in chapter one, constitute an increase in market demand. Such an increase can be illustrated graphically by an upwards shift in the market's demand curve. An upward shift implies that at any given price level, more missile technology is demanded by a particular country or countries than had been the case in a previous period. A hypothetical increase in overall demand and a corresponding outward shift of the market's demand curve is illustrated in Figure 3.

Table VII

Total number BM systems deployed compared to indigenous LDC BM systems:
1960-1990

Year	Total Systems Deployed	Indigenous Systems Deployed
1960	2	0
1965	4	2
1970	6	1
1975	9	2
1980	15	5
1985	17	5
1990	31	17

(Source: SIPRI Yearbook 1989 & 1990).

3.2 SUPPLY

Increases in the supply of a commodity or good also upset market equilibrium. Several factors contribute to an increased supply of ballistic missile technology. As outlined in chapter two, potential sources of supply

Figure 3

include established aerospace firms in industrialized countries (which in this case includes China), civilian space programmes where SLVs and SRs utilizing dual-use rocket technologies are employed, inter-LDC trade, private individuals, consortia, and illicit

trade. An actual source of supply for missile technology on the market can be shown to exist as in addition to suppliers in industrialized countries, several LDCs now produce ballistic missile, SLVs, SRs, or other missiles whose technology is applicable to ballistic missile construction (see table VIII). Table VIII lists the countries in addition to the industrialized Northern producers and China that as of 1990 had gained the ability to produce indigenous BM systems or rockets whose technology is applicable to BM construction. As of 1990, thirteen LDCs had gained such capabilities.

Moreover, in addition to **Table VIII**

industrialized states, a number of LDCs have also developed a capacity to export ballistic missiles (see table IX). Table IX, lists the developing countries that as of 1990 are known to have exported indigenous ballistic missiles, or as in the case of

BM, SLV, SR, or AR* producers 1990

Argentina	Israel
Brazil	North Korea
Egypt	Pakistan
India	South Korea
Indonesia	Taiwan
Iran	Turkey
Iraq	

* Artillery Rocket
(SIPRI Yearbook 1989 & 1990)

Syria, Libya, and Egypt, countries that are known to have re-exported missiles originally sold them by the U.S.S.R. As of 1990, a total of seven LDCs could be classified as missile "exporters".

Like demand, the supply of missile technology has also increased steadily over time. Table X lists the number of LDC ballistic missile producers between 1960 and 1990. In 1965 for example, only one developing country - Egypt, largely due to the help

Table IX**LDC Ballistic Missile Exporters**

Country	System	Date Sold	Recipient
Israel	Jericho 2B	1989	South Africa
North Korea	Scud-B	1985	Iran
Brazil	SS-60	1985	Iraq
	SS-60	1985	Saudi Arabia
Syria	Scud-B	1985	Iran
	Frog-7	1985	Iran
Libya	Scud-B	1985	Iran
	Frog-7	1985	Iran
Argentina	Condor 2	1985	Iraq
Egypt	Scud-B	1976	North Korea

(SIPRI Yearbook 1989 & 1990; Karp, "Third World Quest", 19).

of West German scientists - had any form of production capabilities. By 1990, ten LDCs had developed various BM production capabilities.

During the same period, the number of indigenously designed or engineered ballistic missile systems also increased. In 1960 there were no indigenous Third World missiles. In 1965, only two: again Egyptian systems constructed largely with assistance from private West German concerns. By 1990 however, over seventeen indigenous LDC ballistic missile systems were reported to be in operation: more if one includes artillery rockets such as Brazil's SS-60 with ranges approaching 70 kilometres.

The period 1960-1990 also saw a corresponding increase in the number of developing countries exporting ballistic missiles or missile technology. Table XI illustrates this trend. From 1960 to 1975, although several LDCs deployed or produced missiles, there were no LDC missiles or missile technology exporters operating in the market. In

Table X

Indigenous LDC BM production: 1960-1990.

Year	Total LDC Systems	System and Producer
1960	0	
1965	2	Al Kahir & Al Zafir (Egypt).
1970	1	Jericho I (Israel).
1975	2	Jericho I (Israel); Devil (India).
1980	5	Jericho I & II, Flower (Israel); Cheng Feng (Taiwan); NHK I/II (Sth. Korea).
1985	5	Jericho I & II (Israel); Cheng Feng (Taiwan); NHK I/II (Sth. Korea); Condor I (Argentina).
1990	17	Jericho I & II; Cheng Feng (Taiwan); NHK I/II (Sth. Korea); Condor I (Argentina); Haft I & Haft II (Pakistan); Al Hussein & Al Abbas & Laith (Iraq); Jericho 2B (Israel); Sakr 80 (Egypt); Scud-100/PIP (North Korea); Nazeat & Shahin 2 (Iran); Prithvi & Agni (India).

(SIPRI Yearbook 1989, 1990).

1980 only one LDC was classified as a missile exporter. By 1990, seven LDCs could be classified as missile exporters, and eight LDCs as missile technology exporters. In the proliferation model, when increases in supply occur from one period of time to the next, they can be illustrated graphically by an outward shift in the model's supply curve. An

outward shift implies that at any given price level, more missile technology is supplied or available on the market than had been the case in a previous period. A hypothetical increase in the overall supply on the market and the corresponding shift in the model's supply curve is illustrated in Figure 4.

Figure 4

3.3 DEVELOPMENT OF PRODUCTION CAPABILITIES

Ironically, increased Third World demand for ballistic missiles has led to the creation of production capabilities among several developing states. In the past, Third World BM acquisition has occurred through the sale of complete systems. This trend however appears to have come to an end as the last reported sales of complete BMs took place in 1988 when Chinese ballistic missiles were sold to Saudi Arabia, and Soviet missiles were transferred to Afghanistan. The MTCR has essentially halted the sale of complete systems by Western and Russian producers, while Western political pressure has apparently stopped further ballistic missile sales by Beijing. Nevertheless, missile technology and production technology transfers to the Third World continue. Inter-LDC

and the covert trade in missile systems and technology has continued.¹¹² But more importantly, certain missile technology from industrialized countries has remained available to LDCs.

Table XI

Number of LDC missile producers versus exporters

Year	Missile Producers	Missile Exporters	Missile Exporters
1960	0	0	0
1965	0	0	0
1970	3	0	0
1975	5	0	0
1980	7	1	1
1985	7	6	6
1990	13	7	8

(Spector and Smith, p. 20-22; SIPRI Yearbook 1989 & 1990; Karp, "Third World Quest", p. 19).

Technologies and components which remain available include those used in

SLVs and scientific sounding rockets, as well as unrestricted MTCR category II items such as fuel, avionics, software, test equipment, and structural materials.¹¹³ Other sources of industrialized country missile technology that remain open include foreign military sales of artillery rockets (ARs), surface to air missiles (SAMs), anti-tank missiles (ATMs), air-to-air missiles (AAMs), ship-to-ship missiles (ShSMs), and anti-tactical ballistic missiles (ATBMs) such as the American Patriot Missile. It is when these systems, in addition to SLVs and SRs are sold on a North-South basis, that potential benefits from offset agreements may be sought, and the transfer of production capabilities may result.

¹¹² Recent examples include the 1992 Israeli passage of Patriot anti-Ballistic Missile propulsion and guidance technology to the PRC in return for information on the Chinese export line of M-series ballistic missiles. See, David A. Fulghum, "Defence Department Confirms that Patriot Technology Diverted," Aviation Week and Space Technology Vol 138, No. 5 (1 February 1993), 26.

¹¹³Karp, "Third World Quest", p. 16.

Licensed production **Table XII**

agreements have proven to be the most common type of offset agreement and have come to account for the largest part of LDC arms production. The total number of North-South production licensing agreements for all major weapons systems has increased markedly since the early 1960s (see table XII).

Licensed production of major conventional systems by LDCs: 1960-1988.

Year	Number	Year	Number
1960	2	1976	60
1962	8	1978	78
1964	11	1980	87
1966	12	1982	90
1968	17	1984	94
1970	27	1986	84
1972	40	1988	87
1974	51		

(OTA, Global Arms Trade).

Through the transfer of production technology and manufacturing equipment needed to initiate production, licensed production generates new military production and for many LDCs has been the main vehicle for creating defence industries.¹¹⁴

Licensed production of **Table XIII**

complete ballistic missile systems has not, nor is it likely to occur.

However, licensed production of artillery rockets, ATMs, SAMs, AAMs, and ShSMs does occur (see table XIII). Unfortunately, data

Number of LDC recipients of major missile system licenses: 1977-1983

ATMs	6
SAMs	4
AAMs	3
ShSMs	1

(Louscher and Naylor Schwarz, 50).

¹¹⁴ David J. Louscher, and Anne Naylor Schwarz. "Patterns of Third World Military Technology Acquisition." in Kwang-II Beak, Ronald D. McLaurin, and Chung-in Moon eds., The Dilemma of Third World Arms Industries: Supplier Control or Recipient Autonomy? (Boulder, Colorado, 1989), 43

concerning missile licensing agreements is incomplete. First, only licensing involving complete or major weapon systems is generally reported and does encompass production agreements involving dual-use components. Second, the exact nature and details of licensed production agreements are rarely made public as firms and recipients consider the information to be sensitive.¹¹⁵

Nevertheless, available data illustrates the fact that licensing of missile technology occurs, and that missile production capabilities applicable to BM production are inevitably transferred. Rarely is technology of a "revolutionary" nature transferred in this manner. LDCs are often unable, or financially unwilling to purchase the most advanced production technology as part of offset packages. However, even dated, less advanced, technology can be useful in light of "add up" and "add on" engineering and the ability of countries or firms to adapt or modify production equipment and methods.¹¹⁶ Production technology, equipment, processes, and expertise transferred to LDCs via civilian space programmes, inter-LDC trade in missiles and technology, or through illicit means, act to supplement these production capabilities. By combining production technologies, equipment, acquired expertise, and components accumulated through any of these means and through additional reverse, add up, and add on engineering activities, missile production capabilities are acquired.

¹¹⁵Ibid., 45-46.

¹¹⁶Ronald D. McLaurin. "Technology Acquisition: A case Study of the Supply Side," in The Dilemma of Third World Defence Industries: Supplier Control or Recipient Autonomy? ed. by, Kwang-II Beak, Ronald D. McLaurin, and Chung-in Moon. (Boulder, Colorado, 1989), 59.

3.4 EXPORT PRESSURES ON NEW TECHNOLOGY RECIPIENTS

Once LDC firms or Government agencies acquire advanced aerospace production capabilities, economic pressures dictate exports. Economic pressures on developing countries to export weapon systems are similar to those facing well established aerospace firms in the West, the former Soviet Union, and the People's Republic of China. Once arms production is established, excess capacity inevitably develops. As in industrialized states, Third World governments may subsidize and promote armament and aerospace industries in order to balance trade deficits, gain employment benefits, assure self sufficiency in weapons production, and stimulate industrial/economic modernization and development. Domestic demand for weapons systems is essentially finite however, and increasingly accurate and effective weapons means fewer and fewer units are required by a country's military services.

Third World missile producers also face increasing unit costs because of rising R&D and production costs attributed to the increasing technological and performance demands placed on modern military systems by domestic or potential foreign buyers. In addition, as missile systems require foreign inputs (expertise, components, production equipment etc.), domestic arms production, even if conducted under the auspices of various offset agreements, requires foreign exchange expenditures and therefore foreign exchange earnings.

The combination of excess production capacity, increasing unit costs, and foreign exchange requirements among LDC producers dictates that weapons produced locally be exported. As is the case in industrialized states, arms exports by the second tier of

emerging LDC producers help to fund development, aid domestic procurement, and earn foreign exchange needed for inputs. They assist in keeping production lines open by allowing production economies of scale, and they allow for an emergency surge capacity to be maintained.¹¹⁷ Although they have captured only a limited portion of the international arms trade, LDC producers have shown their ability to penetrate the market and act as successful suppliers. This success has been based on five factors. First, because of the Third World's abundant supply of increasingly skilled labour, LDC arms producers have been able to offer products comparable to those of industrialized states at a lower cost. Second, several Third World producers have carved out a market niche by modifying foreign equipment or designing and producing new equipment that owing to its ease of operation, maintenance, and repair, is popular among developing states. Third, LDCs have generally marketed equipment with "no strings attached" on end uses or resale by the recipient. Fourth, by acquiring foreign technology, LDC armament industries have been able to construct their defence industries on proven, standardized technology.¹¹⁸ Fifth, licensed production, coproduction, and other offset agreements that accompany weapons acquisitions give LDC producers access to international aerospace technology markets via distribution networks established by their senior production partners in the developed world.¹¹⁹

¹¹⁷Louscher and Naylor Schwarz, 39.

¹¹⁸Andrew L. Ross, "Full Circle: Proliferation, the International Arms Trade, and Third World Arms Export," in Kwang-II Beak, Ronald D. McLaurin, and Chung-in Moon eds., The Dilemma of Third World Arms Industries: Supplier Control or Recipient Autonomy? (Boulder, Colorado), 19-20.

¹¹⁹Louscher and Naylor Schwarz, 42.

The entrance of the first of a series of LDC producers onto the export market during the 1970s and 1980s can be viewed as part of a continuing pattern of world weapons technology proliferation. Immediately following WWII, the United States and the USSR were the world's primary sources of weapons technology. The United States transferred vast amounts of weapons production technology to its European allies in order to strengthen the Western Alliance's defensive capabilities; Soviet production technology transfers to its allies were less marked.

As West European production commenced, their domestic markets became saturated, and the economic imperatives of arms exports became clear. The entrance of European suppliers introduced a strong element of competition into the market, and as a result, offset production agreements entailing the transfer of production technology could be extracted by developing countries wishing to establish arms industries. Once LDC weapons production commenced, the same economic pressures again dictated that a segment of production be exported. The creation of this second tier of exporters (the USA, USSR, Western Europe and the PRC comprising the first), again increased market competition, and has added to the ability of yet further countries (a potential third tier) to demand production technologies in conjunction with foreign military purchases.

The pattern of world wide weapons technology proliferation appears to be continuous due to the existence of a "market feed-back mechanism". This mechanism exists due to competition on the market and the accompanying need of producers to transfer technology in order to secure foreign sales. This translates into the fact that increased missile demand is only partially met through the absorption of existing excess

capacity among existing producers. The existence of offsets entailing production technology transfers and market competition has meant that increased demand is met largely by the creation of new industries. As this occurs, the overall potential world supply of production technology becomes greater, competition increases, and potential quantity and quality of technology flows to further recipients is greater. The rule appears to be that over time, as production technologies acquired through weapons acquisition are brought on line, increased weapons demand leads to the creation of additional sources of supply and further horizontal proliferation of weapons production technology.

This feed-back mechanism can be illustrated graphically in the next phase of the construction of the proliferation model (see Figure 5). Figure five is the same as those presented earlier except for the addition of (*t*), or time, on the horizontal axis. Assume first

Figure 5

that the market is at an equilibrium point *E1*. At point *t1*, a total quantity of *Q1* is supplied at a price level of *P1*.

As the demand for missile technology increases, an outward shift in the demand curve occurs moving the curve from *D1* to *D2*. At point *t2*, market equilibrium is re-

established at **E2**. A quantity of **Q2** will be supplied through the utilization of existing industrial capacity or surplus stocks of equipment at a higher price of **P2**. Even if inventories of surplus equipment are transferred by governments of industrialized states to fill LDC demand, technological concessions can and likely will be demanded by LDC purchasers. More importantly however, as demand leads to new production capabilities via licensing or other forms of direct offsets, once these new production capabilities come on line, the total available supply on the market will increase in period **t3**. At this point, an outward shift in the supply curve occurs moving the curve from **S1** to **S2**, and new market equilibrium is established at **E3**. The price level decreases to **P3** (in this case the same level as **P1**), and the total quantity of missile technology supplied on the market increases further to point **Q3**: a point where potential supply is greater than if a transfer of production technologies had not occurred.

Newly derived production and export capabilities among the first series of LDC weapons producers has led to potentially greater access to weapons and weapon production technologies among additional countries. As new LDC exporters entered the international arms technology market, competition among all firms, be they in the developed or developing world increased. Increased competition for foreign military equipment sales may result in efforts by firms to produce at lower costs, provide higher quality weapons, or provide new - more effective - generations of weapons. But in order to secure foreign procurement contracts, additional competition also means that additional offset incentives including the transfer of production technology must be included as part of any foreign equipment sale. In short, increased competition means an overall increase

in the necessity of firms to supply production technology as part of offset agreements.

Increased production capabilities and resulting competition among firms has also meant that the price level of weapons technology does not increase to the extent that would be expected with associated increases in demand. Instead, the price of technology returns to a lower level as a result of new suppliers entering the market in addition to its effective subsidization through the existence of offset agreements. Paradoxically, in the long run, although it is impossible to quantify exactly for reasons discussed earlier, the overall price level of weapons and weapons production technology may remain constant or may even be reduced in the face of increased demand.

The increasingly complex technical nature of modern weapons systems and the resulting higher development and production costs of new generations of weapon systems may mean producing firms are faced with higher unit production costs. However, the financial payments that accompany their foreign military sales, or the price of military technology on the market, is reduced as far as the buyer is concerned by the benefits the purchaser receives via offsets agreements involving the establishment of local production. A recipient's calculation of the price of foreign weapons technology include employment created via localized production; potential industrial benefits acquired through the transfer of modern production technologies, excess capacity absorbed from other economic sectors, the satisfaction of regional development goals, and potential foreign exchange savings or earnings etc. Therefore, by creating employment, industrial, and other benefits, offset agreements involving the establishment of local production also act to stabilize or reduce the price level of weapon and weapons production technology. This is evident in

figure 5 by the return of the price level over the long run from P_2 to FIP_3 .

Overall increases in **Table XIV**

production capabilities and the
resulting competition among
firms has of course also meant

Number of BM Systems Present
in LDCs: 1960-1990.

that the total quantity of weapons
technology supplied on the
market has increased over time.

Year Number of BM Systems
Present or Deployed

As mentioned earlier, total

1960	2
1965	4
1970	6
1975	9
1980	15
1985	17
1990	31

technology available is not easily

(SIPRI Yearbook 1989, 1990).

quantified, as "technology" in this

case encompasses complete missiles, missile components, dual-use technologies, and production expertise and machinery etc. However, the number of BM systems deployed in LDCs between 1960 and 1990 (see table XIV), and the number of states that have utilized available technology to acquire or construct BMs, SLVs, and SRs (table VI) are indications of the quantity of technology available on the market and the fact that the amount available increases over time. Although incomplete due to state secrecy and uncertainty surrounding exact missile deployments, data presented in Appendix A.1, A.2, and A.3 on the known number of actual LDC missiles deployed is also an indication of the extent of the quantity of missile technology that has been made available.

Although the exact quantity of technology transferred remains ambiguous, what is clear however, is the fact that the transfer of production technology to the first series

of LDC producers during the 1970s and 1980s has led to increased market competition as new production centres come on line, and to increases in the potential overall supply of technology on the market. Moreover, tendencies for the general price level to increase are counter balanced by greater competition among established producers and a willingness to provide offsets. This has meant that access to production technology has become easier for future weapons purchasers.

The result on the weapons technology market is illustrated in the final phase in the construction of the proliferation model (see Figure 6). In Figure 6, an initial increase in demand and the subsequent increase in market supply has occurred shifting the demand and

Figure 6

supply curves to *D2* and *S2*. As new demand develops among additional countries, the demand curve shifts outward to *D3*. Demand is again met through the transfer of production technologies via the offsets agreements furnished by competing firms. As this is the case, over time, demand will again lead to an increased world supply. At the point of time when these new production capabilities come on line (*t4*), overall potential supply again increases and the market's supply curve moves to *S3*. World wide production of

weapons technology increases to *Q4*, and as supply and competition have again increased, the price level once again declines to point *P1*.

Any future increase in demand for weapons and weapons production technology beyond those described above will repeat the process. As the proliferation model shows, in addition to an increase in overall demand, the long term effect on the market as a whole will be an increase in overall world supply, and a price level that tends to remain constant. The quantity of weapons and weapons production technology offered on the market will increase, and further horizontal proliferation of production technologies will occur.

The process of proliferation laid out in the model should continue as long as there is a sustained demand for missile technology, and as long as the supply of missile technology continues to increase as a result. As far as the supply side is concerned, the process of horizontal proliferation would run out of steam if demand by one state no longer led to the creation of additional production centres. If supply was finite, which would entail an end to offset agreements and the transfer of production technology, increases in demand would result in an increase of the general price level of technology and greater financial disincentives to indigenous production would arise. In order to reduce the frequency of offsets entailing technology transfers, methods would need to be developed to reduce excess capacity and competition among existing aerospace firms. If technological offsets persist, the number of potential new production centres and overall supply will continue to increase.

The other force driving proliferation is demand. Demand for weapons production

technology is determined by any one of a number of motivations discussed earlier in the paper. How to reduce a military's perceived need for ballistic missiles, or the attractiveness of the foreign exchange earnings that can result from weapons exports for example, is beyond the scope of this paper. But as long as states determine that weapons such as ballistic missiles are desirable assets and production capabilities are transferred, demand, and proliferation will continue.

The paper's second hypothesis states that Brazil's development of a ballistic missile production capacity was facilitated by interactions on the international aerospace technology market between demand and supply that promote weapons technology transfers and facilitates the proliferation of advanced weapon technology. The paper has determined what the interactions (or the feed-back mechanism) between demand and supply are, and has developed a model illustrating how they cause the market to behave as a system sustaining proliferation. When initial increases in demand occur, the overall supply of missile technology on the market increases as a number of potential sellers in the industrialized world release surplus equipment, utilize excess industrial capacity, or create new production facilities.

However, as weapons sales now take place primarily through offset agreements between the seller and purchasers, weapons production technology is also transferred. After production technologies have been imported to the purchaser's country as part of weapons procurement, indigenous production in the recipient country may begin. Once production capabilities are developed and facilities are in place, the same pressure to export that faces established producers becomes evident among new LDC producers.

With additional LDC technology free to be exported and released on the market, the market's supply curve shifts further to the right. Prices, measured in what recipients must pay and what benefits they receive in return, return to lower levels, and the overall quantity of missile related technology available increases. When demand among additional states arises, the transfer process repeats itself; only the greater number of potential sellers on the market results in even freer technology flows with potential greater access for additional states. By examining events in Brazil through the period of the early 1960s to 1990 in the following case study, the usefulness of this model in explaining the processes which facilitated Brazilian ballistic missile development will be addressed. In doing so, the paper's second hypothesis can be tested and the question as to how Brazil gained its ability to produce, and potentially export ballistic missile technology can be answered. Before turning to this task however, the case study addresses and tests the paper's first hypothesis and determines why the Brazilian government chose to develop its ballistic missile capability.

CHAPTER IV: CASE STUDY OF BRAZIL

Chapter four consists of a case study of Brazil's development of its ballistic missile capacity. The case study is divided into two sections. The first deals with the rationale behind missile development. It examines the variables outlined in chapter one in a Brazilian context, it tests the paper's first hypothesis, and answers questions as to why Brazil sought to develop BM production capabilities. The paper's second research question asks how Brazil developed its BM production capability. The paper's second hypothesis contends that Brazil's ballistic missile capability was facilitated by interactions in the international aerospace technology market between supply and demand which promote weapon technology transfers and facilitate the proliferation of advanced weapons and weapons technology. As outlined in the proliferation model, these interactions constitute a feed-back mechanism where, due to market competition and the existence of offset production agreements, demand by one country leads to the creation of an additional production centres, increased world supply, and hence even greater potential weapons technology flows and potential weapons proliferation.

In the second section of the case study the potential sources of missile technology outlined in chapter two as they pertained to Brazilian ballistic missile development are examined. The section shows that in a manner consistent with the proliferation model, Brazilian demand for technology led to the transfer of production technology on the international market to Brazil, the creation of greater overall world production capabilities, an increased supply of missile technology on the market, and hence potentially freer and greater production technology flows and weapons proliferation. In doing so, the second

part of the case study shows what sources of technology proved the most important, how the market facilitated the transfer of technology, and as a result, how Brazil developed a ballistic missile capability.

4.1 MOTIVATIONS BEHIND DEVELOPMENT

The first hypothesis contends that Brazilian efforts to develop a ballistic missile capability were initially undertaken in order to counter potential nuclear threats to the country. But as the probability of regional conflict subsided and the country's economic situation deteriorated, economic motivations for continued ballistic missile development became an equally important determinant which ultimately overshadowed the original military rationale. In order to test this hypothesis and definitively answer why Brazil pursued development, the first section of the case study examines the political, security, and economic motivations behind Brazil's missile development efforts.

4.1.1 Prestige and Weapons Production

The pursuit of prestige is often cited as a motivation among states seeking to acquire a ballistic missile capability¹²⁰. The acquisition of advanced weapons systems can contribute to the international as well as the domestic prestige of a state and its government. In the first instance, the possession of ballistic missiles for example, confirms industrial modernization, a strong self sufficient military, a largely independent foreign policy, and a position of strength vis-à-vis other states. In Brazil, a certain level of international prestige was undoubtedly gained by the development of a ballistic missile potential. However, missile development in Brazil, and the development of an extensive

¹²⁰Carus, 4; Navias, 10-11; Krause, 709.

military industrial complex in general, also played an indirect role in bolstering the domestic prestige of the country's regimes.

In Brazil, particularly during the period of military rule (1964-1985), technological accomplishments translating into economic growth were viewed as being imperative to national security. This view was evident as early as 1964 when Brazil's officer corps toppled the civilian government of President Joao Goulart, and installed General Humberto Castello Branco (1964-1967) as President.¹²¹ Military doctrine throughout the period held that a number of Brazilian "insecurities",¹²² foremost among them a lack of resources, under industrialization, and financial underdevelopment, had to be overcome in order to allow the country to secure its international security interests. In a nutshell, Brazil's military leadership saw economic development as crucial to the country's security.¹²³ In order to allow economic development to occur, the military also believed that domestic tranquillity had to be maintained. However in Brazil, during the period of military rule, the maintenance of tranquillity meant the suspension of civil rights and political repression.

Despite the existence of a repressive state apparatus and effective controls on the press, labour unions, and political opposition, the military remained dependent on the cooperation of the country's business and technical elite in the running and smooth day

¹²¹Patrice Franko-Jones. The Brazilian Defence Industry (Boulder, Colorado, 1992), 56.

¹²² Brazil's Escola Superior de Guerra, the Superior War College lists three types of insecurities causing security threats: 1) national insecurities (a lack of resources, under industrialization, and financial underdevelopment); 2) cultural insecurities ("ignorance of some sectors when they partake in the political process"); and 3) moral insecurities brought on by generational, class and ideological conflicts.

¹²³David J. Myers "Brazil," in Security Policies in Developing Countries ed. by, Edward A. Kolodziej and Robert E. Harkavy (D.C. Heath and Company, Lexington, Mass., 1982), 54.

to day operation of the nation.¹²⁴ Successive military regimes also needed to maintain a degree of acceptability among the population at large. But in order to do this, Brazilian military regimes needed to provide high rates of economic growth, jobs, and rising living standards in exchange for the political freedoms they had withdrawn.¹²⁵

Thus, continued economic growth was extremely important to Brazilian military regimes. Not only was growth needed in order to overcome the "insecurities" that were seen as denying Brazil its place in the sun, but growth was needed to keep the country's workers, shopkeepers, and technocrats happy during the process. However, as the local Brazilian business community was unable or disinclined to raise the amounts of capital needed to get Brazilian industry and the economy moving, and as many economic sectors were too profitable or sensitive to be allowed to fall into the hands of the multinationals, Brazilian governments stepped in to play the leading role in the industrialization process.¹²⁶

In Brazil, several economic sectors and industries were targeted for government support in order to increase overall economic growth. However, the Brazilian arms industry, and the high-technology sectors within that industry which encompassed missile development for example, were seen as having a particular ability to contribute to the overall industrialization, the industrial modernization process, and hence economic growth.

¹²⁴Pierre, 237.

¹²⁵Ronald M. Schneider. Order and Progress: A Political History of Brazil (Boulder, Colorado, 1991), 265.

¹²⁶Jeff Frieden. "Third World Indebted Industrialization: International Finance and State Capitalism in Mexico, Brazil, Algeria, and South Korea," International Organization 35:3 (Summer 1981), 421.

To the extent that ballistic missile development aided the industrialization process and hence economic growth, missile development can be said to have indirectly contributed to the domestic prestige of regimes as well as to domestic perceptions of their technological sophistication and competence.

4.1.2 The Military Utility of Ballistic Missiles

In addition to their perceived ability to contribute to the political status of various regimes, successive Brazilian governments also desired ballistic missiles due to their potential effective weapons delivery platforms. Traditionally, Argentina has remained Brazil's only rival in the region and posed its only serious potential external security threat. Thus, after Argentina initiated a nuclear weapons development programme in the late 1960s, the Brazilian military was forced to give the nuclear weapons option serious consideration.¹²⁷ Given their role as potential delivery vehicles, Brazilian interest in ballistic missiles was initially linked to the development of a nuclear weapons capability.

Indirectly, the 1973 oil price shock placed Brazil on the path toward becoming a nuclear power. After the price of its oil imports rose from \$409 million in 1972 to \$2.84 billion in 1974,¹²⁸ Brazil's oil import bill prompted the nation to consider acquiring a nuclear electric generating capability.¹²⁹ A 1975 agreement with the West German firm Siemens to build nuclear electric generating stations had the added advantage of giving

¹²⁷David J. Myers. "Brazil: The Quest for South American Leadership," in Regional Hegemons: Threat Perceptions and Strategic Responses ed. by, David J. Myers. (Boulder, Colorado, 1991), 237.

¹²⁸Jose L. Carvalho. "Commercial Policy In Brazil: an Overview," in The Brazilian Economy in the Eighties ed. by, Jorge Salazar-Carrillo and Roberto Fendt Jr. (New York, 1985), 90.

¹²⁹Thomas E. Skidmore. The Politics of Military Rule in Brazil: 1964-1985 (New York, 1988), 193.

Brazil access to uranium enrichment technologies crucial to nuclear weapons production.¹³⁰ The same year Brazil was able to launch its clandestine nuclear weapons programme codenamed "Solimoes".¹³¹

By 1979, knowing that Buenos Aires had accelerated its more advanced nuclear programme in response to the Brazil-Siemens deal, the military government of General Joao Figueiredo (1979-1985) decided to seek cooperation and political reconciliation with Argentina rather than enter into a costly nuclear development race that the Brazilian military felt it might well lose.¹³² In 1979 the long-standing La Plate River Basin water rights dispute with Argentina was resolved, and in 1981, a Brazilian-Argentine Nuclear Cooperation treaty was signed.¹³³ Although pressures mounted within the Brazilian military to accelerate nuclear weapons development¹³⁴ due to renewed pressures to do so within the Argentine military following the Falklands-Malvinas war,¹³⁵ renewed nuclear competition was avoided as an increased British military presence in the South Atlantic and Washington's refusal to side with the Latin American power in the struggle had the effect of promoting regional solidarity and cooperation.¹³⁶

¹³⁰Rodney W. Jones and Steven A. Hildreth. Modern Weapons and the Third World (Boulder, Colorado, 1984), 45.

¹³¹Ian Kemp. et al. "JDW Country Survey: Brazil," Jane's Defence Weekly (9 May 1992), 815.

¹³²Myers, Security Policies, 60-62.

¹³³Ibid.

¹³⁴David J. Myers. "Brazil: Reluctant Pursuit of the Nuclear Option," Orbis 27:4 (Winter 1984), 881.

¹³⁵Myers, Regional Hegemons, 237.

¹³⁶Virgin Gambia-Stonehouse. Strategy in the Southern Oceans: A South American View. (London, 1989), 105.

Although Brazil continued its clandestine nuclear weapons programme into the late 1980s,¹³⁷ the perceived need for nuclear weapons and a rationale for the creation of a ballistic missile production capability continued to decline as Brazilian-Argentine political cooperation and economic integration increased.¹³⁸ By 1990, Brazil's democratically elected President Fernando Collor de Mello had reaffirmed the need to use nuclear energy peacefully,¹³⁹ publicly acknowledged the existence of the Solimoes nuclear weapons programme,¹⁴⁰ agreed to a 1985 Argentine proposal for bilateral inspections of nuclear facilities, and signed the Brazilian-Argentine Nuclear Exchange and Safeguards Agreement.¹⁴¹ By 1991, Brazil opened its nuclear facilities to International Atomic Energy Agency, or IAEA inspections,¹⁴² and signed the 1967 Tlatelolco treaty calling for the creation of a Latin American Nuclear Free Zone.¹⁴³

Nevertheless, although the nuclear competition with Argentina and the need for nuclear capable ballistic missiles declined during the 1980s, potential military scenarios

¹³⁷: In 1986 Brazil announced it had gained the capability to produce plutonium on a laboratory-scale. Work also continued on uranium enrichment using a "jet-nozzle" process, while a "gas centrifuge" uranium enrichment facility was established in 1988. See Etal Solingen "Brazil: Technology Countertrade, and Nuclear Exports," in The International Nuclear Trade and Non-Proliferation: The Challenge of Emerging Suppliers ed. by, William C. Potter. (Lexington, Mass., 1990), 111-112.

¹³⁸Myers, Regional Hegemons, 238.

¹³⁹Jorge Morelli Pando. "Some Regional Aspects of the Nuclear Non-Proliferation Regime," Disarmament 13:3 (1990), 99-113.

¹⁴⁰Kemp, 815.

¹⁴¹Mussington and Richter, 94.

¹⁴²Kemp, 815.

¹⁴³Mussington and Richter, 94.

requiring conventionally armed ballistic missiles remained evident, thus generating an alternative military rationale for BM development. Future conflicts fought with conventional weapons with Argentina or Brazil's northern neighbours for example could not be precluded. During the early and mid-1980s a spill over of the East-West conflict into the South Atlantic Region was seen as a distinct possibility.¹⁴⁴ The potential for future conflicts with the West given the Falklands-Malvinas experience and Washington's support of London could not be totally ignored in Brazilian military planning.¹⁴⁵

Perhaps the best indication that ballistic missiles continued to play a role albeit a diminished one in Brazilian military planning through the 1980s, was the fact that Brazilian ballistic missiles being designed and under development during the period became geared towards the delivery of conventional as opposed to nuclear payloads. In addition to its nuclear and missile programmes, Brazil also endeavored to develop the ability to produce modern high explosives many times more powerful than TNT, and a capacity to produce incendiaries weapons and fuel-air explosives; all of which can be delivered by ballistic missiles.¹⁴⁶ As missile guidance and control capabilities were refined and perfected, future Brazilian ballistic missiles, even if tipped with conventional munitions, became potentially much more effective and destructive weapons. It was hoped for example, that the Avibras SS-300, a mobile BM capable of firing a 2,200

¹⁴⁴Myers, Security Policies, 58.

¹⁴⁵Myers, Regional Hegemons, 244.

¹⁴⁶Congressional Research Service: The Library of Congress. CRS Report for Congress. Missile Proliferation: Survey of Emerging Missile Forces Robert D. Shucy et. al. (Washington, D.C., Feb. 9, 1989), 23-24.

pound warhead 300 kilometres (the engines of which underwent test firings in 1986), could be made accurate enough for use as an effective conventional weapon. The missile was specifically designed to carry anti-personnel, anti-tank, and anti-fortification submunitions or cluster bombs.¹⁴⁷ As a result of the growing military utility of conventionally armed ballistic missiles, despite warming relations with Argentina and the end of the South American nuclear rivalry, BMs continued to have a role in Brazilian defence planning during the 1980s as BM development got under way in earnest. Thus the perceived military utility of ballistic missiles continued to be a motivational force behind their development.

4.1.3 Self-Sufficiency in Defence Production

The inability to import complete missile systems or ballistic missile components from abroad was another motivational force behind the decision to pursue indigenous ballistic missile production capabilities in Brazil. In fact, Brazil's armament industry in general was developed largely in response to unreliable sources of foreign equipment and technology. For example, Brazil, like South Africa, faced a series of technological embargoes, implicit at first and then explicit.

As mentioned earlier, from the end of the Second World War to the mid-1960s, America supplied the majority of Brazil's military equipment under the 1952 Brazil-U.S. Military Agreement. By the early 1960s however, it became necessary to replace much of Brazil's aging U.S. supplied equipment.¹⁴⁸ This however occurred at a time when

¹⁴⁷Ibid., 89.

¹⁴⁸William Perry. "Brazil: A local Leviathan" in Emerging Powers: Defense and Security in the Third World ed. by, Rodney W. Jones, and Steven A. Hildreth (New York, 1986), 327.

America's own equipment needs in Indochina meant overall reductions in U.S. arms transfers to its allies.¹⁴⁹ In face of pending equipment shortages, Brazil sought to diversify its arms purchases among other suppliers.¹⁵⁰

Following the Vietnamese War, U.S arms shipments to Brazil were curtailed once again under the Carter Administration through the implementation of the Harkin Amendment which tied U.S. foreign aid to the human rights record of the potential recipients,¹⁵¹ and the Glenn-Symington Amendment which prohibited U.S. military assistance non-signatories of the Nuclear Non-Proliferation Treaty or the NPT.¹⁵² In the mid-1980s, the establishment of the MTCR and accompanying U.S. State and Commerce Department restrictions on missile technology transfer to Brazilian defence firms,¹⁵³ reenforced and expanded the defacto American technological embargo.

With technological restrictions and embargoes in place, Brazil was unable to import complete missile systems or ballistic missile components from abroad. Initially embargoes implicitly covered conventional systems. Later embargoes became explicit, covering nuclear weapons and missile technologies. Either way, Brazil had difficulty obtaining equipment and systems it deemed as necessary to allow its armed forces to meet

¹⁴⁹Clovis Brigagao. "The Brazilian Arms Industry" Journal of International Affairs 40:1 (Summer 1986), 104.

¹⁵⁰Tuomi and Vayrynen, 149.

¹⁵¹Skidmore, 196-97.

¹⁵²Report to the Committee on Science, Space, and Technology: U.S. House of Representatives Oversight Review of South American Science, Space, and Technology (U.S. Government Printing Office, Washington, D.C., June 1988), 6.

¹⁵³Office of Technology Assessment, Global Arms Trade 150

2 OF 2

PM-1 3 1/2" x 4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

their operational objectives. Thus through the 1960's, 1970s, and 1980s, Brazil sought to diversify its arms purchases among numerous suppliers while seeking technological concessions through offset agreements that would allow it to create a degree of self sufficiency in all areas of defence production. As ballistic missiles fit into the strategic planning of the Brazilian military and as foreign sources did not exist, indigenous ballistic missile production capabilities also had to be developed.

4.1.4 Fiscal Policy Motivations for Development

Economic factors also influenced Brazil's decision to pursue ballistic missile development. These factors can be classified as either fiscal or monetary motivations. Fiscal motivations, being tied to government spending, included the desire to promote overall industrialization, the desire to stimulate economic activity, and the desire to modernize the economy through the introduction of new technologies, products, processes, and skills. Other potential fiscal motivations included regional development and employment creation.

Brazilian ballistic missile development however was only part of total Brazilian aerospace activity, and Brazilian aerospace activity constituted only part of total defence production activity during the period in question. As a result, it is difficult to determine if efforts to develop ballistic missiles were undertaken with the explicit aim of aiding economic development. But by asking whether the development of overall military production capabilities - which encompass ballistic missiles capabilities - was carried out to promote industrialization, or modernize the economy, et cetera, one gets an indication of the strength of fiscal motivations behind Brazilian missile development efforts.

After taking power in 1964, the military continued the tradition established in the 1930s of utilizing State Owned Enterprises (SOEs) to promote economic development.¹⁵⁴ Serious efforts to develop Brazil's defence industrial base and its military aerospace capabilities were initiated by General Medici in the late 1960s and early 1970s, and by General Ernesto Geisel during his tenure as president from 1973-1979.¹⁵⁵ Like other SOEs, the original role of state owned or state promoted defence firms created by Medici and Geisel was to introduce capital and expertise into sectors where private enterprise was unable to do so.¹⁵⁶ In addition, Brazil's military government also viewed arms production as a means of generating technology for use in the development of other industrial sectors.¹⁵⁷ How efficiently technology obtained through missile or other aerospace projects for example can be transferred from military to civilian sectors depended on the linkages between those sectors. In Brazil however, the linkages between sectors was well established and the civilian sector well situated to take advantage of innovations in the military sector.

In Brazil, the majority of the firms producing military equipment maintained a diversified product mix whereby they continued to produce goods for the civilian as well

¹⁵⁴Perry, 327.

¹⁵⁵Myers, Regional Hegemons, 257.

¹⁵⁶Thomas J. Trebat, Brazil's State Owned Enterprises: A Case Study of the State as Entrepreneur (London, 1983), 236.

¹⁵⁷Domicio Proença Junior, "Guns and Butter? Arms Industry, Technology and Democracy in Brazil," Bulletin of Peace Proposals 21:1 (1990), 49.

as military market.¹⁵⁸ Thus, new processes introduced through aerospace, missile, or other weapons development programmes, for example, could be used to produce civilian products manufactured along side military goods. In this manner, Embraer, a major Brazilian aerospace defence contractor for example, was able to utilize technology, as well as organizational, procurement, and quality control skills acquired through a military aircraft coproduction agreement with Italian firms in the modernization of its civilian production technologies and in the manufacture of its successful line of civilian aircraft.¹⁵⁹

Defence companies that produced both civilian and military goods were also able to take advantage of dual use technology supplied by the civilian sector.¹⁶⁰ Through experience and technology acquired in the civilian avionics sector for example, Brazilian aerospace firms acquired essential missile development skills including airframes, propulsion, fuel mixing, electronics, testing and quality control.¹⁶¹ Avibras, another major aerospace contractor for example, was able to use the skills and technology it obtained through scientific sounding rocket development in its military missile projects.¹⁶²

¹⁵⁸Rene Luria. "The Brazilian Defence Industry: An Excellent Producer of Conventional Equipment," International Defence Review 22 (August 1988), 1079.

¹⁵⁹Ravi Ramamurti. State Owned Enterprise in High Technology Industries: Studies in India and Brazil (New York, 1987), 185.

¹⁶⁰Office of Technology Assessment, Arming Our Allies, 23.

¹⁶¹Aaron Karp. "Space Technology in the Third World," Space Policy 2:2 (May 1986), 160.

¹⁶²Raul De Gouvea Neto. "The Role of Transnational Companies in the Brazilian Defence Tripod," Journal of Latin American Studies 23 (1991), 584.

In addition to supplying new skills, products, and processes to the civilian sector, the Brazilian aerospace-defence industry also stimulated demand and absorbed excess industrial capacity in civilian industries. The use of arms production as a means of stimulating civilian industry in Brazil, has its roots in the 1930s when President Getulio Vargas (1930-1945 & 1951-1954) established three state armaments factories arguing that they would stimulate the steel industry.¹⁶³ In the mid-1960s, entire automobile, heavy equipment, textile, medical supply, electronics, and aeronautics factories left idle by economic recession were converted to military production.¹⁶⁴ Automotive assembly lines were adapted to produce tanks, commercial aviation factories were converted to manufacture military aircraft, and petrochemical facilities were converted to produce rocket fuel.¹⁶⁵ More recently, by specializing in the production of weapons based on dual-use components manufactured in the civilian sector, the construction of Brazilian weapon systems has been used to stimulate production among numerous private firms. In summary, if Brazilian missile development is viewed as being part of overall military aerospace activities and as part of a larger defence industrial base, then a number of potential industrial benefits were evident, and an economic motivation for missile development can be identified.

Regional economic development is another potential fiscal policy goal involving the promotion of industrialization in a particular geographic region. In Brazil however,

¹⁶³Patrice Franko-Jones. "Public Private Partnership: Lessons from the Brazilian Armaments Industry," *Journal of Interamerican Studies and World Affairs* 29:4 (Winter 1987-88), 48.

¹⁶⁴Brigagao, 106.

¹⁶⁵Myers, *Security Policies*, 68.

even though industrialization was seen as a potential economic benefit resulting from defence production, defence industrialization in general, and missile development in particular, it does not appear to have been seriously promoted as a regional development tool outside the politically important area of the industrial South-East. Regional development, particularly in the impoverished North-East and the Amazon regions of Brazil, has traditionally been viewed as important in securing territorial claims and halting mass migration to the South-East.¹⁶⁶ Yet despite the efforts of eighteen State Industrial Federations created to attract regional defence investment and production, only a small proportion of defence work has migrated outside of the Rio de Janeiro - Sao Paulo region. Defence industries including the missile development activities of Avibras and Orbita, a subsidiary of Embraer and Engesa (the main defence contractor for the Brazilian Army), have remained concentrated in a "cluster" centred on the supporting industries and infrastructure of the Sao Jose de Campos Industrial Park situated between Rio and Sao Paulo. The infrastructure associated with missile development that does exist in north-eastern Brazil and in the Amazon region for example, can be attributed to the proximity of launch facilities and data collection platforms to equatorial earth orbits,¹⁶⁷ rather than to efforts to develop industry or create employment opportunities in remote areas.

Employment creation is the final potential fiscal motivation for creating arms or missile production capabilities. However, due to its technical and capital intensive nature

¹⁶⁶*Ibid.*, 62-63.

¹⁶⁷ Clifford P. Graham. "The Brazilian Space Programme - an Overview" *Space Policy* 7:1 (February 1991), 74.

and the relatively small number of personnel involved, direct employment creation could never have been accepted as a serious rationale for missile development in Brazil. The employment figures of the three firms ultimately responsible for Brazilian missile production highlight this fact. At the peak of its activity in the mid-1980s, Avibras, producer of the widely exported Astros II artillery rocket, designer of the SS-300, SS-600, and SS-1000 ballistic missile series, and owner of one of the world's largest rocket factories,¹⁶⁸ never employed more than 6,000 personnel.¹⁶⁹ Embraer and Engesa, joint owners of Orbita, Brazil's other major rocket producer in the 1980s, also employed limited manpower. Engesa's total work force hovered between 3,000 to 5,000 from 1982 to the mid-1980s,¹⁷⁰ and Embraer's between 7,000 in 1982¹⁷¹ to 11,000 in 1988-1989.¹⁷² Considering Brazil's large and rapidly growing population, 121 million in 1980 and 150 million in 1990, employment generated by Brazil's missile producers was extremely small even if one ignores the fact that these firms also produced a wide range of other military and civilian products at the time.¹⁷³

For the most part, the role of large Brazilian arms manufactures was to encourage product development, carry out final assembly operations of components produced by sub-

¹⁶⁸Mussington and Richter, 90.

¹⁶⁹Brazilian Defence Equipment: 1988-1989 (Funacao Visconde de Cabo Frio, Brasilia, 1989).

¹⁷⁰Brozoska and Ohlson, and De Gouvea Neto.

¹⁷¹Brigagao, 103.

¹⁷²Brazilian Defence Equipment.

¹⁷³Ibid.

contractors, and to act as marketing agents.¹⁷⁴ Rather than creating direct employment, the major Brazilian defence contractors responsible for missile development, helped to create indirect employment opportunities among sub-contractors and suppliers.¹⁷⁵ Brazilian missile developers and producers are really just the tip of a military industrial iceberg that in the 1980s was estimated to contain between 350 firms employing 100,000,¹⁷⁶ to 600 firms employing approximately 150,000 workers.¹⁷⁷ Total employment figures attributed to defence production - and the proportion of that amount linked to missile development - would no doubt be greater if indirect and induced employment effects could be calculated.

However, exactly what proportion of total arms production missile development represents, and how much direct, indirect and induced employment it created is difficult to ascertain. Technician may work on civil and military projects simultaneously, official employment figures may be exaggerated to give a false impression of strength or reduced to mask covert projects. Moreover, despite any indirect or induced employment effects that may result from missile development, total quantitative employment benefits can account for only a small part of total defence industrial base employment and only a fraction of total industrial employment. Missile development remains extremely capital and R&D intensive, is still largely experimental in LDCs, and would rarely, if ever,

¹⁷⁴De Gouvea Neto, 590-95.

¹⁷⁵Trebat, 241.

¹⁷⁶P. Lock. "Brazil: Arms for Export," in Arms Production in the Third World ed. by, Michael Brozoska and Thomas Ohlson. (London, 1986), 82.

¹⁷⁷De Gouvea Neto, 583-84.

involve mass production. In sum, despite an extensive Brazilian defence industrial base, employment creation can only be seen as constituting a very weak justification for missile development. However, in a developing country attempting to modernize its economy, the creation of a small number of highly skilled engineers and technicians who may eventually transfer their skills to other industries, may be as important a goal as the creation of a larger number of less skilled jobs.

4.1.5 Monetary Policy Motivations

Domestic weapons production can also serve national monetary goals. Monetary goals include equalizing national trade balances and national current account deficits, and the generation of foreign exchange needed to meet foreign debt obligations. Weapons production helps meet these goals by substituting domestic arms for imported systems, or by earning foreign exchange through arms exports. The question here however, is whether ballistic missile development in Brazil was undertaken to this end.

In order to determine if there was a monetary rationale behind missile development, one has to understand Brazil's evolving monetary needs. Prior to 1973, monetary considerations were not a major rationale behind Brazilian defence industrialization. Prior to the military taking power, Brazil pursued a secondary ISI strategy. But on taking power, the military aligned the economy toward the foreign sector. Secondary ISI policies were continued,¹⁷⁸ but a policy of diversified export promotion backed by lower tariffs and export subsidies was introduced.¹⁷⁹

¹⁷⁸Brigagao, 107.

¹⁷⁹Gereffi, 517.

Between 1964 and 1973, the dual-track, ISI-EOI policy led to the so-called "economic miracle" as economic growth rates remained in the double digits between 1968 and 1973.¹⁸⁰ Manufactured exports increased ten fold between 1964 to 1972,¹⁸¹ and foreign exchange reserves increased from \$660 million to \$6.4 billion.¹⁸² Although the external debt nearly doubled from \$3.4 billion in 1967 to \$6.2 billion in 1971, the debt appeared manageable due to rising capital inflows.¹⁸³ With rapidly increasing manufactured and commodity exports Brazil enjoyed a generally healthy monetary situation during the period, and the primary goal of defence industrialization was to create self sufficiency in arms production within the context of an ISDI policy.¹⁸⁴ In 1975 for example, arms exports totalled a mere \$25 million.¹⁸⁵

The 1970s oil price shocks however, effectively ended the "economic miracle", and forced Brazil to increase its foreign exchange earnings through any means possible. Between 1972 and 1974 the price of oil imports rose from \$409 million to \$2.8 billion.¹⁸⁶ The balance of trade and current account deficits soared. Foreign exchange reserves dropped by \$1.2 billion, and the national debt reached \$17.2 billion.¹⁸⁷

¹⁸⁰Schneider, 262-65.

¹⁸¹Carvalho, 87.

¹⁸²Schneider, 265.

¹⁸³Ibid., 266.

¹⁸⁴Brigagao, 109.

¹⁸⁵Franko-Jones, "Public Private Partnership", 43.

¹⁸⁶Carvalho, 90.

¹⁸⁷Schneider, 277.

In an attempt to maintain economic growth rates, the Geisel government deepened import substitution in the intermediate and capital goods sector. Measures limiting oil and other imports were introduced, and export diversification and promotion was intensified.¹⁸⁸ However, the deepening of ISI and the expansion of export promotion was financed by borrowed petro dollars, and by 1979 the national debt reached \$49.9 billion. Brazil's monetary problems were further compounded by the oil price shock of 1979, and the interest rate shock of 1981. Oil imports rose from \$3.5 billion in 1976 to \$9.8 billion in 1979, and interest payments on Brazil's foreign debt rose from \$2.7 billion in 1978 to \$7.5 billion in 1980. Foreign exchange reserves dropped from a 1978 high of \$12 billion, to a 1980 level of \$6.9 billion.¹⁸⁹

As a result, Brazil further restricted imports and attempted to reinvigorate exports.¹⁹⁰ Understandably, the arms industry, with its linkages to the civilian manufacturing economy, and a growing market in the Middle East, became a favoured sector in the export drive. EODI policies in Brazil moved into full gear during this time as major defence firms such as Embraer and Avibras started to export in earnest.¹⁹¹ The data presented in Table XV shows that Brazilian weapons exports were capable of contributing substantial amounts of foreign exchange to the Brazilian economy. Uncertainties exist over the exact value of Brazilian arms exports. On the one hand,

¹⁸⁸Bela Balassa. "Incentive Policies in Brazil," World Development Vol.7 (1979), 1028.

¹⁸⁹Schneider, 288-89.

¹⁹⁰Tarciso Afonso. Import Substitution and Export Expansion in Brazil's Manufacturing Sector, 1970-1980: An Input-Output Study. (New York, 1991), 229.

¹⁹¹Ramamurti, 177.

export figures may be exaggerated.

But on the other, Brazil is known to have classified exports of gun barrels as reinforced steel tubes, and military transport planes as cargo aircraft for example.¹⁹²

Nevertheless, Brazilian arms export revenues were of a magnitude where they were capable of contributing to the state monetary goals. This was

Table XV

Estimated Brazilian arms exports 1975-1989.
(\$ US billion)

Year	Amount	Year	Amount
1975	0.025	1983	0.6 - 2.6
1976	0.154	1984	0.75 - 3.0
1977	0.130	1985	1.0 - 3.0
1978	0.120	1986	1.0 - 3.0
1979	0.112	1987	0.50
1980	1.0	1988	0.35
1981	1.0	1989	0.20
1982	1.0		

Sources: (1975-79) Franko-Jones, "Private-Public Partnership", 43; (1980-86) de Gouvea Neto, 576; (1987-89) Franko-Jones, The Brazilian Defence Industry, 141.

particularly true in the 1980 to 1986 period when according even to conservative estimates, Brazilian arms exports averaged nearly \$1 billion per annum. Although arms exports constitute a small portion of total exports, approximately \$1 out of \$20 billion in 1980 for example, arms export revenues could be seen as reducing that year's potential trade deficit by 25 percent.¹⁹³

Even though Brazilian missile development did not proceed beyond design, prototype, and testing stages in the 1980s, the potential for foreign exchange earnings through potential exports of systems, technology, or components was evident, and can therefore be considered a factor behind continued missile development. In 1988, Libya

¹⁹²Luria, 1080.

¹⁹³Schneider, 289.

for example, was known to have offered \$2 billion to Orbita in order to guarantee development of the MB/EE-150 ballistic missile and access to it once development was complete. Similarly, Iraq injected funds into Avibras' SS-300 development programme.¹⁹⁴ Although international pressure, including American hints of sanctions and the possible use of force,¹⁹⁵ ended Brazil's ballistic missile deals with Libya and Iraq, the potential revenues from such transactions in light of the country's financial situation cannot be overlooked as a motive behind development.

4.2 THE DEVELOPMENT PROCESS

The paper's second research question asks how Brazil developed its BM production capability. In order to answer this question, section 4.2 first examines potential sources of missile technology on the market as they pertained to the case of Brazilian development. The how question having been answered, section 4.3 reviews the usefulness of the proliferation in explaining events in Brazil, and shows that the development process and associated missile technology transfers were consistent with the paper's second hypothesis and the workings of the proliferation model.

4.2.1 The Role of Developed Country Firms in Brazilian Missile Development

The proliferation model illustrates that an initial increase in the demand for ballistic missile technology is required in order to upset initial market equilibrium and set the proliferation process in motion. In the first half of the case study, it has been pointed out that decisions to embark on a course of missile development for the reasons outlined

¹⁹⁴Karp, "Ballistic missile Proliferation", 293.

¹⁹⁵Proenca Junior, 54.

above, constituted an initial increase in market demand, and in the proliferation model, an outward shift in the demand curve. The next step then is to determine if in fact the process of proliferation outlined in the model was initiated by Brazil's technology demands. Once an initial increase in demand occurs, the proliferation model predicts that due to the utilization of offset agreements in market transaction, production technologies are transferred, and over time, production capabilities are established in the recipient country. By looking at the four main potential sources of missile technology supply outlined in chapter two as they pertained to Brazilian missile development, one can then ascertain whether or not the model is accurate in explaining events in Brazil up to the point where transferred production capabilities come on line.

Aided and encouraged by investment incentives, Western firms played a significant role in the development of Brazil's aerospace industry and as a result, its ballistic missile production potential. In order to promote industrial development, Brazil's military governments adopted a basic strategy of enticing multinational corporations to invest and locate in Brazil.¹⁹⁶ Inducements were aimed at defence as well as general industrialization, and included a series of tax breaks and reduced tariffs on imports, tax holidays on profits from exports, and liberal regulations concerning the repatriation of profit.¹⁹⁷ In addition, government policy limited its military equipment purchases to foreign companies that would set up plants in Brazil.¹⁹⁸

¹⁹⁶ Myers, "Brazil", 57.

¹⁹⁷ Benedict J. Clements, Foreign Trade Strategies, Employment, and Income Distribution in Brazil. (New York, 1988), 14.

¹⁹⁸ Robert Wesson, The United States and Brazil: Limits of Influence (New York, 1981), 66-67

Brazilian incentive policies were very successful in encouraging MNC defence activity in Brazil. During the period of the 1968-1974 economic miracle for example, EM Ericsson, Phillips, General Electric, Siemens, Texas instruments, and ITT, which were already involved in the Brazilian civilian economy, initiated defence production activities. Moreover, other defence MNCs, including France's Thomson CSF for example, established production facilities in Brazil.¹⁹⁹ After the oil price and interest rate shocks, incentive policies continued and were intensified. In 1982, "Law No 1946" for example, gave all defence producers tax exempt status on their imports.²⁰⁰ Apart from increasing overall defence production, policies to attract as many MNCs as possible also had the effect of increasing the leverage of the Brazilian government in persuading various MNCs to agree to alternative forms of technology generating investment such as licensing agreements or joint ventures with Brazilian firms.

The government also actively encouraged foreign MNCs to use Brazilian subcontractors,²⁰¹ and between 1967 and 1978, over one hundred joint ventures were signed with European defence firms alone.²⁰² The competition that resulted from the presence of numerous foreign producers in Brazil, each bidding for government approval to participate in these joint ventures, allowed the government to choose the foreign producer that could offer Brazil the greatest technological benefits.²⁰³ Moreover, the

¹⁹⁹Tuomi and Vayrynen, 153.

²⁰⁰Lock, 83.

²⁰¹Tuomi and Vayrynen, 153.

²⁰²Brigagao, 108.

²⁰³De Gouvea Neto, 595.

myriad of joint ventures was constructed in such a way as to maximize technology flows between foreign and Brazilian firms. First, as MNCs were encouraged to produce major sub-assemblies and use Brazilian subcontractors to supply needed parts and components, technology flowed upstream to small Brazilian subcontractors. But in addition, as final assembly and integration operations were concentrated in the hands of large privately or publicly owned Brazilian defence firms²⁰⁴ (eg. Embraer, Avibras, Engesa), technology also flowed from foreign defence MNCs to the major Brazilian arms corporations downstream. The system was mutually beneficial and foreign technology was defused throughout the system.

With the defence MNCs network in place, foreign military rocket technology started to flow into Brazil. In the 1970s, Brazil's Centre for Aerospace Technology (CTA) purchased several West German licenses for Surface to Air, Air-to-Air, and Anti-tank missiles. In 1976 West Germany's MBB licensed production of its Cobra ATM, and a French-German consortium licensed production of the "Roland" ATM in 1982.²⁰⁵ In 1987, Orbita entered into agreements with British Aerospace to coproduce a high speed SAM, and started development of a replacement for the aging Cobra missile in conjunction with the Italian firm Oto Melara.²⁰⁶ Traditionally, missile production licensing agreements have involved small operation missiles such as ATMs, SAMs, and anti-ship missiles (ASHMs) et cetera, as opposed to larger surface to surface systems.

²⁰⁴Ibid., 595.

²⁰⁵Pierre, 237.

²⁰⁶Varas, 101.

However, as Brazilian ballistic missile programmes gained prominence in the mid-1980s,²⁰⁷ some Brazilian SAMs, ATMs, and ASHMs, manufactured under license, came to use sophisticated European technology such as infrared and laser guidance systems. Through "add up" and "add on" engineering and modification, these, and other operational missile technology have potential uses in the development of terminal guidance and other ballistic components.²⁰⁸

In addition to refurbishing technology with direct ballistic missile applications, foreign multinationals have also made indirect contributions to Brazilian missile capabilities by helping to develop the basic production capabilities and competence in the Brazilian aerospace industry as a whole. As Brazil's major aerospace firms were also responsible for missile development, civilian oriented joint ventures between Brazilian and Western firms were also important to the development of BM production capabilities. Through them, the Brazilian aerospace industry built up its technological capabilities and overall level of competence. The 1974 coproduction agreement between Embraer and America's Piper Aircraft to produce small and medium sized commuter aircraft for example proved instrumental in getting the firm off the ground, and in helping it to develop its fundamental skills and production capabilities.²⁰⁹ A subsequent joint venture between Embraer and Italy's Aeritalia and Aermacchi to produce the AMX fighter aircraft for example, further modernized the firm's production capabilities through the transfer of

²⁰⁷Karp, SIPRI Yearbook: 1989, 292.

²⁰⁸Congressional Research Service, 93.

²⁰⁹Ramamurti, 206.

modern aerospace technologies, advanced production processes, modern machinery, managerial and technical skills,²¹⁰ and most importantly, experience in modern airframe, propulsion, navigation, and systems integration technologies.

4.2.2 Brazil's Civilian Space Programme and BM Development

Brazilian space research activities began in the 1950s but Brazil's space programme was not officially launched until 1966. In the first years of its rule, Brazil's military regime initiated several bilateral space cooperation treaties.²¹¹ Initially the United States supplied the sounding rockets Brazil needed to conduct atmospheric research, and trained the country's launch technicians.²¹² At the same time however, indigenous development of sounding rockets commenced under the auspices of CTA's Institute for Space Activity, or the (IAE). In 1970, Avibras, a privately owned Brazilian aerospace concern, was contracted to take over production of a series of sounding rockets known as the Sonda I, II, and III,²¹³ and in 1979 the firm started development of the Sonda IV, a seven ton, two stage rocket with a potential surface to surface range of 600 to 1000 km.

Avibras' sounding rocket projects were greatly facilitated by foreign assistance channelled directly to the company or through the IAE. Cooperation between Avibras and West German firms was extensive throughout all Sonda projects.²¹⁴ France, having

²¹⁰Office of Technology Assessment, Global Arms Trade, 147.

²¹¹Lock, 88.

²¹²Graham, 73.

²¹³Office of Technology Assessment, Global Arms Trade, 149.

²¹⁴Lock, 88.

invested heavily in the Brazilian aerospace sector is also known to have made substantial contributions to the programmes.²¹⁵ United States government agencies provided training assistance for the Sonda III project.²¹⁶ Canada, the United States, the U.S.S.R., and the PRC gave official assistance, to the Sonda IV project, while the European Space Agency, and a number of other West European firms were also involved.²¹⁷

As well as gathering atmospheric data however, early sounding rockets also served as the basis for a series of Brazilian military rockets. In the early 1970s, Avibras diverted the technology and skills it amassed in the development of the Sonda series to a series of parallel military programmes.²¹⁸ The Sonda I which entered service in 1965, had a 4.2 kilogram payload capacity: it served as the basis for the Avibras SS-07, an artillery rocket capable of fielding a 4 kilogram warhead. In 1967 the Sonda II, with a 44 kilogram payload capacity entered service: that system served as the basis for the SS-40, an artillery rocket with a 40 kilogram warhead.

As pointed out earlier, scientific sounding rockets and space launch vehicles (SLVs), can also be utilized as BM prototypes due to their technological similarity. If guidance systems, control packages,²¹⁹ and heat shields protecting the warhead during atmospheric reentry are added, only trajectories and payloads differ. Moreover, the process of converting rockets to missiles is relatively straight forward. Building heat

²¹⁵Spector, 85, and Richter and Mussington, 95.

²¹⁶Karp, SIPRI Yearbook: 1991, 337

²¹⁷Spector, 84. Karp, SIPRI Yearbook: 1989, 293.

²¹⁸De Gouvea Neto, 584.

²¹⁹Mahnken, 565.

resistant reentry vehicles does not pose significant technological problems even for developing aerospace industries, scientific and mechanical theory behind guidance is in the public domain, and components used in modern missile guidance systems are increasingly sold commercially in military or civilian aircraft navigation systems.²²⁰

Thus, through basic add on and add up engineering, the Sonda series also contributed to ballistic missile development. In 1976, Avibras test fired the Sonda III capable of lifting a 140 kilogram payload. Modifications produced the SS-60 - a widely exported short range ballistic missile integrated into the popular Astros II artillery saturation rocket system which earned Brazil an estimated \$1 billion in export revenues.²²¹

Having entered service in 1984, the Sonda IV was also used to develop military systems. With a guidance system purchased from France's SAGEM corporation,²²² a Brazilian flight control system allowing it to follow a preestablished trajectory, and capable of travelling 940 kilometres, the Sonda IV lent itself to several BM development projects. It served as the technological basis for Avibras' SS-300 and SS-1000 ballistic missile development programmes. Having been established in 1986, Orbita used the system as the basis for its MB/EE-150²²³ project, and formulated plans to convert the rocket into the 600 kilometre MB/EE-600 for export.²²⁴

²²⁰Congressional Research Service, 19-22.

²²¹Karp, SIPRI Yearbook: 1989, 293.

²²²Congressional Research Service, 93.

²²³Congressional Research Centre, 89-92.

²²⁴Spector, 84.

In addition to scientific sounding rockets used in atmospheric research, developing countries, especially those with large territories, also have legitimate needs for satellite launch capabilities. Remote sensing can aid resource exploitation and management, while satellite communications can help spread literacy, promote the national identity, and aid overall business activities.²²⁵ Bearing their development needs in mind, Brazil launched the Complete Space Mission Programme, or MECB in 1981.

The MECB project foresees a series of indigenously designed communication satellites as well as an indigenous satellite launch vehicle. Work on Brazil's SLV, Known as the VLS, was commissioned in the mid-1980s.²²⁶ However, if the four-stage VLS were outfitted with a terminal guidance package and heat shielding, the system could potentially be used as an ICBM with a 3000 to 6000 kilometre range.²²⁷ Nevertheless, as the VLS is officially considered a scientific rocket, a number of foreign interests, including NASA, Canada's Department of Communications, as well as various Soviet and Chinese agencies contributed to the MECB project.²²⁸

Foreign participation in the MECB programme was greatly facilitated by the commercialization of the space industry in the 1980s. Prior to that time, the superpowers held a monopoly on space launch technology services. But between 1957 when the Soviets launched Sputnik, and the mid 1980s, over 2,500 orbital launches had taken

²²⁵Karp, Space Policy, 158.

²²⁶Oversight Review, 13.

²²⁷Richter and Mussington, 95.

²²⁸Ibid., 74-74.

place.²²⁹ As a result, SLV technology essentially became a mature technology,²³⁰ and regardless of U.S. intentions, SLV capabilities spread to Western Europe and Japanese, as well as to the PRC.

In 1984, in order to allow American firms to meet this new competition, the U.S. government began to dismantle regulations that had discouraged private ventures and established the Office of Commercial Space Transportation to encourage private space launch enterprises.²³¹ The 1986 Challenger space shuttle disaster and subsequent moves by the Reagan Administration to restrict future shuttle flights to military missions, acted as a further enticement for U.S. firms to enter the SLV industry.²³² As a result, by the mid-1980s, in addition to European, Japanese, and Chinese agencies, several major U.S. firms, as well as several American newcomers entered the civilian SLV industry.²³³ Unfortunately for the industry, the rash of new entrants coincided with the advent of fibre-optics telecommunications which effectively reduced world demand for orbital communications satellites and launch services.²³⁴

Just as increased competition and excess capacity among developed country arms producers had benefitted the Brazilian defence industry, increased competition and

²²⁹Karp, Space Policy, 159-62.

²³⁰Patrick Dubarle. "The Commercialization of Space," The OECD Observer Vol. 153 (August-September 1988), 4-7.

²³¹ Aviation Week and Space Technology (22 October, 1984), 15.

²³²Dubarle, 4-7.

²³³Karp, Space Policy, 163-64.

²³⁴Dubarle, 7.

decreased demand in the SLV segment of the international aerospace industry benefitted Brazil's MECB programme. Commercialization meant that Brazil no longer had to deal directly with national governments. Instead, it could deal with aerospace firms operating under different national export regulations. Moreover, in theory at least, it was easier to convince profit motivated firms to transfer technology and components, act as training grounds for technicians, or to contravene export regulations.²³⁵ Thus through the mid to late-1980s, firms from several countries, including the United States,²³⁶ France, Italy, and Japan sold airframe, propulsion, and guidance technologies to LDCs with increasing frequency. To beat the competition, they were also increasingly willing to submit to LDC demands for technology transfers.

Increased competition in the SLV industry and increased missile technology flows acted as an impetus for the establishment of the MTCR, and its imposition has limited Western technology transfers to the SLV component of Brazil's MECB project. U.S. pressure led France for example to renegotiate a deal to provide Brazil with Viking rocket engine technology from the Ariane programme as part of an offset package. However, with Western embargoes in place, Brazil followed the familiar pattern of diversification and signed space cooperation agreements with the U.S.S.R and China which promptly diverted advanced space technologies to the MECB programme.²³⁷

Despite Western technology restrictions on SLV technology, severe budget cuts,

²³⁵Karp, Space Policy, 162-65.

²³⁶Graham, 73-74.

²³⁷Mahnken, 570.

and a series of unsuccessful tests that postponed the VLS's original launch date by several years, the MECB programme continued through the 1980s. In the early 1990s, renewed progress was facilitated by the apparent willingness of Brazilian civilian governments to act in accordance with the MTCR.²³⁸ After Brazil offered assurances to the U.S. for example, American officials agreed to sell Brazil advanced technology such as super-computers that are potentially very useful in SLV and missile design.²³⁹ In addition, Brazil's cooperative policy has led to American authorization of Brazil's use of private American launch services. In February 1993 for example, Orbital Sciences Corporation was contracted to launch one of four MECB satellites from the Alcantara launch facility in north eastern Brazil thereby opening the door for potential technological offsets.²⁴⁰ Exactly what technological offsets Brazil received in return for the contract are as yet unclear.

4.2.3 Inter-LDC Trade, Individuals, Rogues, and Missile Development

For the most part, developing countries with ballistic missile or civilian space programmes, have traditionally relied on the assistance and technology supplied by industrialized nation: the United States, France, West Germany, and the Soviet Union being the chief suppliers. Beginning in the 1980s however, Third World dependency on technology from developed countries began to decrease. In virtually all developing countries with active space or missile programmes, with the exception of Israel and India,

²³⁸Franko-Jones, Brazilian Defence Industry, 203.

²³⁹Karp, SIPRI Yearbook: 1991, 329.

²⁴⁰Conversation with Brazilian Embassy Official, February 10, 1993.

missile and rocket programmes are increasingly relying on other LDC programmes.²⁴¹

As far as missile technology trade between Brazil and other LDCs is concerned, the most striking examples of technology inflows result from trade with the PRC. As mentioned earlier, Sino-Brazilian space cooperation became wide spread. In 1986, Brazil and China reportedly agreed to a deal where Brazil was to receive liquid rocket fuel and missile guidance technology from China in return for providing Beijing with solid rocket fuel technology.²⁴² In the late 1980s, the two nations also established joint ventures to market space launch vehicles (when developed), launch services, satellites, and earth stations and antennas. Further cooperative schemes included Sino-Brazilian plans to undertake joint production remote sensing satellites to be launched in China aboard its "Long March" booster.²⁴³

Apart from cooperation with China, the only known instances of Inter-LDC trade in missile technology involving Brazil, are instances of proposed financing offered by Libya and Iraq. For the most part however, these deals, had they gone through, would have primarily involved the transfer of technology out of Brazil. Although no Brazilian missiles were transferred, Iraq for example, is believed to have acquired technologies enabling it to increase the range of its Soviet Scud-B from Brazil.²⁴⁴ Moreover, Iraqi and Libyan technology transfers may have been a two way street as speculation has arisen

²⁴¹Spector, 78.

²⁴²Ibid., 85.

²⁴³Mahnken, 570.

²⁴⁴Chanda, 23.

that Avibras' SS-300 ballistic missile that Libya reportedly helped fund, may have been based on a Soviet Scud as opposed to indigenously developed Sonda sounding rockets.²⁴⁵

The final source of missile technology that can theoretically contribute to the ballistic missile development programmes of developing countries is comprised by two groups of actors. The first group consists of private firms, consortia or individuals that purposely evade national export regulations and deliberately work outside of laws or norms prohibiting missile technology transfers. The second group is comprised of consultants, engineers or technicians with missile expertise who in compliance with the provisions of the MTCR, exercise their individual rights and decide to accept positions within Third World missile programmes.

In the past, consortiums such as West Germany's ORTAG and the Consen group have contributed to Libyan and Iraqi missile programmes while operating outside the letter of the law. However, it is unclear if, and to what extent, similar firms or individuals may have helped Brazil's missile development. Technology thieves, smugglers, and firms who violate national export regulations do not report their activities. Moreover, as far as private individuals exercising their right to employment are concerned, there are no international agencies (apart from national security establishments perhaps) that monitor the activities of expatriate engineers. Thus the precise role, if any, of illicit trade and expatriate missile experts in aiding Brazil's missile programme remains speculation.

²⁴⁵Karp, "Third World Quest", 19.:Spector, 85.

4.3 CONSISTENCY WITH THE PROLIFERATION MODEL

In a nutshell, the proliferation model developed in chapter three purports that the demand for weapons technology results in the transfer of weapons production capabilities. Once demand is evident, part of the technology transferred may come from the existing stocks or excess capacity among existing firms, but production capabilities are also transferred through coproduction or other types of offset agreements. Once production starts in the recipient country, the same pressure to export that face established producers becomes evident. Additional LDC production capabilities increase the potential technology supply on the world market, and as a result, if and when further demand arises among additional LDCs, the potential for technology transfer is even greater.

Thus far, the discussion has shown that Brazil's missile development occurred in a manner consistent with the model. Factors discussed earlier in the chapter, namely Brazil's perceived need for nuclear and conventional delivery systems and perceived monetary benefits resulting from potential exports, created a new source of ballistic missile technology demand on the international market. In the early years of demand, missile technology was transferred in the form of complete smaller operational missiles (ATMs etc), and scientific sounding rockets without the accompanying production technologies.

By the early 1970s however, missile production technologies came to be transferred through various offset agreements including coproduction, joint ventures, and subcontracting. As pointed out later in the chapter, the primary sources of production technology transfer were western defence firms and Brazil's national space programme.

In the defence and aerospace industries, foreign firms contributed to missile production capabilities by transferring prerequisite managerial and technical skills, capital goods, and production experience to the Brazilian aerospace sector; as well as basic missile technology in the form of operational missiles produced under license. Foreign firms and government agencies played a more direct role in the transfer of missile technology to Brazil through the country's civilian space programme, as technologies with direct ballistic missile applications were transferred through cooperative ventures aimed at developing the Sonda series of sounding rockets and the VLS. The extent of technological contributions to Brazil's ballistic missile production capabilities of inter-LDC trade excluding the PRC, and illicit trade in missile technology are less clear.

Through these transfers, Brazil developed the technology needed and the ability to potential construct ballistic missiles. The fact that operational versions of ballistic missiles have not been produced en mass, deployed, or exported is more a function of budgetary constraints,²⁴⁶ political will, and foreign pressure not to do so,²⁴⁷ as opposed to a real lack of technological capabilities or know-how. Through its missile development efforts, Brazil has proven it has mastered basic missile technology as evident in the production of numerous operational missiles, a successful series of sounding rockets, and the production and export of the Astros II artillery rocket system which utilizes the 68 kilometre short range SS-60 ballistic missile. Major missile development achievements to 1990 are summarized in Table XVI.

²⁴⁶Karp, SIPRI Yearbook: 1991, 328.

²⁴⁷Mussington and Richter, 92-93.

Table XVI**Brazilian missile development progress to 1990**

System	Type	Range Km.	Year Fired	1990 Status
Sonda II	SR		1967	test vehicle
Sonda III	SR	80	1976	in service
Sonda IV	SR	600-1000	1984	in service
SS-60	AR*	68	1983	in service
SS-300	BM	300	--	under development
SS-1000	BM	1000	--	under development
MB/EE-150	BM	150	--	under development
MB/EE-350	BM	350	--	under development
MB/EE-600	BM	600	--	planned
MB/EE 1000	BM	1000	--	planned
VLS	SLV	3000-6000	--	under development

* the SS-60 is also classified as a short-range BM.

(SIPRI Yearbook:1990; Lock, 89-90; Lumpe, Grönlund, Wright, 36)

After production capabilities have been established in a recipient country, the proliferation model suggests that pressures to export weapons production arise, a new source of weapons technology is created, and the models supply curve shifts to the right. The result is a greater available amount of weapons technology on the market, and due to an increased number of sellers, greater competition for sales in developing markets. Additional states wishing to develop production capabilities theoretically then have an easier time of it as increased competition among sellers means that more generous technological offsets must be offered in order to secure sales.

In Brazil, as the model would suggest, once the country's design and production

capabilities had been developed, the Brazilian aerospace-defence industry came to face the export pressures evident among all producers. First, not facing an immediate or serious security threat from its neighbours or from any other foreign power, the Brazilian armed forces could only provide a limited market for the nations weapon production.²⁴⁸ Government procurement has traditionally offered little support to the Brazilian defence industry as total defence spending averaged only 1.3 percent of GDP between 1968 and 1988.²⁴⁹ In order to maintain production economies of scale and reasonable unit costs, firms needed to explore export markets. Second, the development of the Brazilian aerospace industry and its integration into the world market, created the need to acquire increased volumes of technological inputs. The demand for foreign technological inputs in fact was so great that exports were not sufficient to cover the import bill.²⁵⁰ Finally, Brazilian fiscal goals, and its deteriorating monetary situation, also served to stimulate arms and weapon technology exports.

The Brazilian defence industry in fact, is a prime example of a new producer forced to turn exporter. Whereas most Brazilian manufacturing sectors exported less than 5 percent of production,²⁵¹ the defence industry has on occasion, exported up to 95 percent of yearly production.²⁵² In the aerospace sector, Embraer exported almost 50 percent of production in 1982 and 65 percent in 1986. During the same period, Avibras

²⁴⁸Proenca Junior, 52.

²⁴⁹ Congressional Research Service, Global Arms Trade, 143.

²⁵⁰Tuomi and Vayrynen, 157.

²⁵¹Clements, 107.

²⁵²De Gouvea Neto, 576.

exported 90 percent.²⁵³

Not only was Brazilian defence production being exported, Brazilian firms also became exporters of missile and other defence production technologies. In order to compete, Brazil too has had to offer offsets to its customers, and Embraer for example, was obliged to negotiate offset agreements for its exports.²⁵⁴ As a result of Brazil entering the export market, additional developing countries that may wish to acquire missile technology have an additional source from which to chose. The greater number of producers of missile technology on the market means competition for sales and the willingness to offer production technology offsets has also increased. Thus, barring the implementation of broader and more stringent international export controls, as the proliferation model suggest, the advent of new suppliers like Brazil facilitates the proliferation of missile production technology to additional centres.

4.4 CONCLUSIONS

The commercialization of the international defence, aerospace and civilian space industries, and the advent of offset agreements as the primary means by which international weapons transfers take place, has meant that the transfer of weapons production technology now accompanies virtually all weapons and weapons technology sales. As a result, a growing number of LDCs have gained the ability produce sophisticated weapon systems including ballistic missiles. Efforts to control the spread of missile technology such as the MTCR have simply not been able to keep pace with the

²⁵³Franko-Jones, Public Private Alliance, 58-59.

²⁵⁴Office of Technology Assessment, Global Arms Trade, 147.

establishment of new production centres, the creation of new suppliers on the international market, and the diffusion of technology.

In order that solutions to the problem of missile proliferation may be developed in future, two processes have to be understood. First, one needs to develop an awareness of the forces that drive demand for ballistic missile systems among states. Second, one has to understand how states acquire ballistic missile systems, and how they develop indigenous missile production capabilities. This paper has explored these issues in respect to Brazil, and has proposed and tested two hypotheses and a theoretical model of the behaviour of the international missile technology market in order to explain events.

To explain the motivations behind ballistic missile development in Brazil, the contributions of missile development to the political prestige of Brazilian regimes, the military utility of ballistic missiles, their contributions to the achievement of fiscal policy goals, and their contributions to monetary policy goals were examined. First, ballistic missile development was believed to contribute to the political goal of general industrial and economic growth; the achievement of which was important to the domestic standing of Brazil's military regimes. Missile development however (and the creation of a large national arms industry in general), was only one of a number of potential tools that could have been used to inject new technology into Brazilian industries, spur economic activity, and portray an image of competence. As Brazil's nuclear electric programme for example, could arguably be seen as having the same result, ballistic missile development undertaken to promote general economic growth and the domestic standing of political regimes in Brazil can not be viewed as having been a major rationale behind

development.

The military utility of ballistic missiles was the strongest political rationale behind development. During the 1970s when Argentina was a potential nuclear threat, motivations existed to develop ballistic missiles for use with future Brazilian nuclear weapons. However, rapprochement with Argentina and decline of South America's nuclear competition in the 1980s, effectively put an end to this rationale. Nevertheless, increasingly accurate, conventional missiles gained a place in Brazilian military planning thereby offering a continued security rationale.

Fiscal motivations behind development were also present to the degree that programmes helped generate technical skills and introduce new techniques and processes to various Brazilian firms and industries. The use of arms production to specifically induce new manufacturing processes and promote industrialization appears to have been most important in the period up to the 1973 oil price shock and the end of Brazil's economic miracle. Direct employment generation and regional development do not appear to have been serious motivations behind development.

After 1973 monetary goals became a major motive behind weapons production and missile development. Although ballistic missiles development did not progress past the prototype and testing stage in many cases, and although complete ballistic missile systems other than short range ballistic missiles deployed in the Astros II artillery rocket saturation systems were not exported, the potential for large export earnings was not overlooked. Known offers by potential buyers amounted to billions of dollars, and sales could help reduce trade deficits, help balance the current account, and contribute to amortization

payments of the country's massive foreign debt for example.

The preceding study then confirms the paper's first hypothesis that ballistic missile development efforts in Brazil were initially driven by national security concerns, but over time, military motives behind missile development came to be complemented by equally important economic motivations. The military rationale for ballistic missiles continued with the emphasis placed on systems designed to carry conventional as opposed to nuclear weapons. But as security risks decreased and the country's economic conditions worsened, economic motivations to produce weapons systems for export came to be a major force behind Brazilian development efforts.

Pertaining to the question of how Brazil developed its missile production capability, the paper's second hypothesis contends that development was facilitated by interactions in the international aerospace technology market between demand and supply which promote weapons technology transfers and facilitate the proliferation of advanced weapons technology. The proliferation model was developed in order to illustrate the interactions in the international market which promote these transfers, and to serve as a framework for understanding the process resulting from commercial and economic factors in the market that promote the proliferation of weapons production technology. By determining why demand arose, what sources of technology were key to Brazilian missile development programmes, how production capabilities were developed, and why pressures for Brazil to export arose, the paper has shown that development in Brazil as it related to inputs from the commercial sector was consistent with the processes laid out in the proliferation model.

As the model suggests, once demand arose, competition among potential suppliers resulted in sales that encompassed the transfer of weapons production technology. As a result, Brazilian demand inevitably led to the establishment of a new missile production centre, and once segments of Brazil's total production capabilities came on line, economic motivations at the level of the firm and at the level of the government dictated that export markets be sought. With a new supplier on the market, demand by additional states for missiles or production technology is more easily met, and further proliferation may take place with greater ease.

In determining how Brazil developed its ballistic missile production capabilities, the paper has also determined what factors contributed to the development of Brazil's missile production capabilities. Coproduction and licensing agreements with aerospace industries in industrialized countries helped build up Brazil's basic aerospace capabilities and expertise. These agreements also resulted in a net transfer of basic missile technology to Brazil in the form of smaller operational missiles, technologies that were later used as the basis for ballistic missile development.

The second major contribution of industrialized states to Brazilian ballistic missile development occurred as a result of cooperation in Brazil's civilian space programme. Although the technology transferred was intended to be utilized in civilian projects, the technical similarity of sounding rockets and SLVs to ballistic missiles allowed the technologies obtained in this way to play a significant role in ballistic missile programmes. Moreover, the study has shown that inter-LDC trade proved to be an additional source of ballistic missile technology. The role of private business consortia,

expatriate engineers, and illicit trade remains unclear.

In addition to explaining the process by which Brazil developed its ballistic missile production capability, the proliferation model may also serve a framework to understand cases of weapons proliferation in other countries and concerning other weapons systems. Once demand for a particular system is established in a particular country, demand in the market in general increases. Competition among existing producers of the system or its components to fill that demand will result in the transfer of production technology related to the system as well as actual weapons hardware. Once transferred production capabilities come on line, new centres of production are established and economic incentives to export arise meaning that new suppliers enter the market. The market's supply curve depicted in the proliferation model shifts to the right, the price level of the system experiences downward pressures, and the total quantity of weapons technology potentially available on the market increases. Although the actual channels through which weapons technology is transferred and initial motivations for acquisition vary from case to case, whether ballistic missiles in Brazil, or cruise missiles or advanced strike aircraft for example in another country, proliferation should proceed in the same manner.

The intent of this paper, its examination of the case of Brazilian ballistic missile development, and the construction of the proliferation model has been to increase the general level of understanding surrounding the importance of economic determinants of proliferation, and the process by which proliferation of weapons production capabilities takes place. However, in order to actually stem the proliferation of weapons production technologies, additional research needs to be conducted in several areas so that policies

to effectively counter proliferation may be developed. The findings of this study point out four such areas.

First, effective means by which to reduce or remove economic incentives and imperatives to export production technology must be explored. More specifically, means of convincing governments that employment generation, industrial modernization, regional development, and skill formation in the work force can be better served by investment in civilian as opposed to military sectors must be explored. Methods that promote open procurement between countries, consolidate existing defence markets, allow governments to let unprofitable firms to exit the industry and that allow remaining firms to achieve production economies of scale also need to be explored.

Second, additional research efforts need to be directed towards developing means to assure civilian space programmes in developing countries are not used as technological pools for ballistic missile development. Means need to be found which on the one hand allow LDCs to realize the benefits of space based communication, resource management, and atmospheric monitoring systems, but on the other, prevent technologies from being diverted to military programmes. Research may for example focus on the possibility of establishing an international space agency where the benefits of space activities are available to all participating states, and various localized activities are monitored by an organization similar to the IAEA.

Third, practical means of expanding the MTCR's membership must be brought to light. This includes means of including all existing missile technology producers, as well as states that are now in the early stages of developing missile or space launch

capabilities. Possible incentives promoting state adherence to the regime's guidelines must be investigated, and ways of facilitating the transition of the regime's rules and norms into a binding international legal instrument must be explored.

Finally, additional research needs to be conducted into ways to limit the demand for ballistic missiles and associated production technologies among states. First, in addition to work aiming to promote the NPT, Comprehensive Nuclear Test Ban, and the Chemical Weapons Convention, methods of limiting the military utility of conventionally armed ballistic missiles through qualitative and quantitative regional arms control and reductions need to be given serious attention. Secondly, as demand for weapons technology is often based on the need for intermediate inputs to produce indigenous weapon systems, and since countries often produce these systems for export with the specific aim of increasing foreign exchange earnings, means that facilitate export earnings in non-military sectors must continue to receive attention. In short, research must continue to explore ways to increase LDC commodity and manufactured good access to developed country markets.

APPENDICES

APPENDIX A.1

Third World Ballistic Missiles: 1990

Country	System	Date First Fired/ Transferred	Number of known missiles	Status
Afghanistan	Scud-B	1988	1000	Operational
Algeria	Frog-7	1975	32	Operational
Argentina	Condor I	1985	--	Cancelled
	Condor II	1987	--	Cancelled
Brazil	EE-150	--	--	Unknown
	SS-300	--	--	Unknown
	EE-350	--	--	Under development
	EE-600	--	--	Planned
	SS-1000	--	--	Planned
Cuba	Frog-4	1960	30	Operational
	Frog-7	1985	36	Operational
Egypt	Al Kahir	1962	--	Cancelled
	Al Zafir	1962	--	Cancelled
	Frog-4	1968	--	Operational
	Frog-5	1968	--	Operational
	Frog-7	1971	72	Operational
	Scud-B	1973	>100	Operational
	Sakr-80	1987	>100	Operational
	Scud-100	1988	--	Under Development
	Condor II	--	--	Cancelled
Greece	Honest John	1959	24	Operational
India	Devil	1972	--	Cancelled
	Prithvi	1988	--	Under Development
	Angi	1989	--	Under Development
Iran	Shahin II	1988	--	Operational
	Nazeat	1988	>200	Operational
	Nazeat II	--	--	Under Development
Iraq	Scud-B	1985	100	Operational
	Frog-7		>90	Operational
	Laith	1988	--	Under Development
	Scud-B		>360	Operational
	Fahd	--	--	Under Development

	Al Hussein	1987	<500	Operational
	Al Abbas	1988	--	Under Development
	Condor II	--	--	Cancelled
	Tammuz-1	1989	--	Unknown
	Nissan	--	--	Under Development
	Kassir	--	--	Under Development
	Al Abed	--	--	Unknown
Israel	Flower	1977		Cancelled
	Lance	1973	160	Operational
	Jericho I	1968	50	Operational
	Jericho II	1985	100	Operational
North Korea	Frog-5	1973	50	Operational
	Frog-7	1973	54	Operational
	Scud-B	1980	>200	Operational
	Scud-PIP	1988	--	Under Development
South Korea	Honest John	1959	36	Operational
	NHK-I/II	1978	100	Operational
Kuwait	Frog-7	1980	12	Operational
Libya	Frog-7	1975	>144	Operational
	Scud-B	1975	>240	Operational
	Ittisalt	--	--	Under Development
Pakistan	Haft I	1988	--	Operational
	Haft II	1988	--	Operational
	Haft III	--	--	Under Development
Saudi Arabia	DF-3	1987	120	Operational
South Africa	Jericho 2B	1989	--	Under Development
Syria	Frog-7	1973	96	Operational
	SS-21	1983	36	Operational
	Scud-B	1974	54	Operational
Taiwan	Honest John	1961	37	Operational
	Ching-Feng	1978	--	Terminated
Turkey	Honest John	1960	54	Retired late 1980s
Yemen	Frog-7	1979	36	Operational
(after	SS-21	1988	24	Operational
unification)	Scud-B	1979	18	Operational

(Source: Karp SIPRI Yearbook 1989, 1990; The Military Balance 1969-70, 1975-76, 1980-81, 1985-86, 1989-90, 1992-93; Navais: Spector and Smith; Desjardins).

APPENDIX A.2

LDC Sounding Rockets, and Long Range Artillery Rockets: 1990

Country	Type	System	Status
Argentina	SR	Belier-Centaur	Retired
	SR	Castor	Retired
	SR	CAM	Cancelled
Brazil	SR	Sonda III	Operational
	SR	Sonda IV	Operational
	AR	SS-60	Operational
	AR	X-40	Operational
India	SR	Rohini	Operational
	SR	Centaur	Operational
Iran	AR	Oghab	Operational
Iraq	AR	Ababil 50	Under Development
	AR	SS-60	Operational
	AR	Sijeer	Under Development
	AR	Ababil 100	Under Development
Israel	AR	MARS 30	Operational
Pakistan	SR	Shahpar	Operational
	SR	SUPARCO	Operational
Philippines	AR	Bong Bong	Cancelled
Saudi Arabia	AR	SS-60	Operational
Thailand	AR	Thanu Fan	Under Development
Turkey	AR	MLRS	Operational

(Source: Karp SIPRI Yearbook 1989, 1990; The Military Balance 1969-70, 1975-76, 1980-81, 1985-86, 1989-90, 1992-93; Navais; Spector and Smith; Desjardins).

APPENDIX A.3

LDC Space Launch Vehicles and Programmes: 1990

Country	System	Potential Range	Status
Brazil	VLS	6,000 km	Under development
India	SLV 3	1,200 km	Operational
	ASLV	4,000 km	Under development
	PSLV	8,000 km	Planned
	GSLV	14,000 km	Planned
Indonesia	SLV	1,500 km	Planned
Iraq	Al Abed	6,000 km	Unknown
Israel	Shavit	7,500 km	Operational
South Korea	Centaur	1,500 km	Cancelled 1980
	SLV	4,000 km	Planned
Pakistan	SLV	1,200 km	Planned
South Africa	SLV	--	Planned
Taiwan	SLV	--	Under development

(Source: Karp SIPRI Yearbook 1989, 1990; The Military Balance 1969-70, 1975-76, 1980-81, 1985-86, 1989-90, 1992-93; Navais; Spector and Smith; Desjardins).

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