## Chapter 20

# India's Steady Progress in Rockets and Satellites*

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## Introduction

India's development into a major economic and technological power is increasingly influencing the international system. India's civil and military space programs, which have greatly furthered India's progress in these dimensions, merit detailed historical study in their own right.

From its founding in 1947, independent India has long been determined to develop high technology in numerous fields, including that of aerospace, to safeguard its autonomy and to further its economic and social development. Over the past two decades, Indian rocket development has grown increasingly robust, both in civilian and military areas. Comparatively high rates of technological diffusion and exchange of human capital has meant that experience derived in one program often informs the other, thereby increasing India's return on its investments. India spent the 1960s and early 1970s establishing a basic space infrastructure. In

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the late 1970s and early 1980s, India began to construct and operate satellites and launchers.

To safeguard national security and foreign policy autonomy, India under Prime Minister Jawaharlal Nehru and physicist Dr. Homi Bhabha prioritized the development of nuclear technology.[1] Driven at least partially by nuclear development priorities, India developed a relatively capable missile industry overall by focusing material and human resources and thereby improving institutional information flow and technological absorption. Particularly successful has been the Indigenous Guided Missile Development Program (IGMDP), established by Dr. V. S. Arunachalam in 1983 with Prime Minister Indira Gandhi's approval.

At the same time, India's civil space program has followed the humanitarian vision of Dr. Vikram Sarabhai. By thus developing practical technologies to serve national development, New Delhi's space program has retained popular support while achieving particular competence in remote sensing, communications, and weather forecasting to improve land use, mitigate damage from natural disasters, and to further rural education, telemedicine, and poverty reduction.

This chapter will review Indian rocket and satellite development to date and contrast it with India's aircraft development, in order to better understand the prioritization of national goals and how so much has been achieved amid competing domestic imperatives in the world's largest democracy.

## India's Inherent Importance

India merits detailed comparative study in its own right. Too long neglected by Western analysts, its development as a regional power will have a major impact on the international system. According to a recent U.S. National Intelligence Council report,

> Because of the sheer size of China's and India's populations—projected by the U.S. Census Bureau to be 1.4 billion and almost 1.3 billion respectively by 2020—their standard of living need not approach Western levels for these countries to become important economic powers. . . . Only an abrupt reversal of the process of globalization or a major upheaval in [China or India] would prevent their rise. Yet how China and India exercise their growing power and whether they relate cooperatively or competitively to other powers in the international system are key uncertainties.[2]

In 2011, India's economy was the world's tenth largest in nominal GDP at US$1.8 trillion, and fourth largest with GDP adjusted for purchasing power parity at US$4.5 trillion.[3] Now, for "the first time since economic planning began in the 1950s. . . experts believe it possible to envision the elimination of absolute poverty in India within a single lifetime. Such opportunities, if seized, would move India into the ranks of the global economic powers, and constitute an achievement of historical importance."[4]

The China–India comparison will become increasingly salient.[5] Despite great achievements in information technology and pharmaceuticals, India lacks China's aggregate level of technological development. Large overseas diasporas provide both countries with critical talent, technology, and expertise, including knowledge of the best practices in Western financial and educational institutions. It is notable that increasing numbers of skilled and well-educated Chinese and Indians see returning to their respective homelands as a good career move. A generation ago, this was hardly imaginable. India's diaspora of 20 million is exceeded only by China's 34 million, which has access to substantial concentrations of technology and capital in Hong Kong, Taiwan, and Singapore. These overseas forces help provide China with the world's highest level of foreign direct investment ($61 billion in 2004, as compared with India's $5 billion). Major constraints on the growth of India's comprehensive national power are heretofore insufficient foreign direct investment and infrastructure. Both deficiencies have been blamed on slow, poorly coordinated policy changes, and bureaucratic implementation.

While China currently seems to enjoy advantages in this area, however, it remains to be seen if its political system is sustainable. By contrast, India offers evidence that democracy *can* further aerospace development—even if it causes reprioritization of specific programs in the short run. Indeed, according to National Intelligence Council projections, "India would be hard-pressed to accelerate economic growth rates to levels above those reached by China in the past decade. But China's ability to sustain its current pace is probably more at risk than is India's; should China's growth slow by several percentage points, India could emerge as the world's fastest-growing economy as we head towards 2020."[6] While the growth of both economies have slowed recently, experts are generally more concerned about prospects for major deceleration with respect to China's.

Democratic India has had a similar experience to authoritarian China's missile/satellite launch vehicle (SLV) and satellite success and aircraft underachievement, albeit at a heretofore lower level of sophistication in keeping with its lower level of comprehensive national power. Like China, India under Prime Minister Jawaharlal Nehru and physicist Homi Bhabha prioritized development of the capacity to produce nuclear weapons. India's space program has adhered to the original mission articulated by Vikram Sarabhai of developing practical technologies to serve national development, and has thus retained popular support. India's space program has achieved particular competence in remote sensing, communications, and weather forecasting to improve land use, mitigate natural disasters, and further rural education and anti-poverty initiatives.

Studying India's experience offers valuable clues about which advantages and disadvantages China's aerospace sector is likely to encounter as Beijing evolves politically, potentially in a more democratic direction. For example, any impact of India's democratic political transitions on military spending and economic priorities may be relevant not only to India's aerospace industry but also to a future Chinese aerospace industry that relies on a government that might be more susceptible to populist pressures. India offers evidence that a developing democracy can support aerospace achievement in service of clear national objectives.

## Aerospace as a Path to Autonomy

From its founding in 1947, independent India valued high technology. Its leaders were conscious that India had been tragically defeated by British technology and organizational methods in the past.[7] In 1989, Prime Minister Rajiv Gandhi emphasized, "We must remember that technological backwardness always leads to subjugation. Never again will we allow our freedom to be so compromised."[8] New Delhi has long been determined to have the best in order to support India's "bid for regional hegemony and political independence, and its desire for technological advancement."[9] As Prime Minister Jawaharlal Nehru stated: "It is science alone that can solve the problems of hunger and poverty, insanitation and illiteracy, of superstition and deadening custom and traditions, of vast resources running to waste, of a rich country inhabited by starving people."[10]

Nehru's declaration represents a larger pattern in which "many in the Indian strategic elite would rather see their country fail on its own than succeed with the help of others."[11] This determination was recently echoed in the assertion of Dr. A. P. J. Abdul Kalam,[12] the father of India's missile program and India's President since 2002, that developed nations will not transfer their most advanced technology. This makes indigenous progress essential in a world in which "technology respects technology and strength respects strength."[13] India's bottom line, as articulated by former Foreign Minister Jaswant Singh, is that

> We cannot have a situation in which some countries say, 'We have a permanent right to these symbols of deterrence and power; all the rest of you. . . do not have that right. We will decide what your security is and how your are to deal with that security.' A country the size of India—not simply a sixth of the human race, but also an ancient civilization—cannot in this fashion abdicate its responsibility.[14]

Between independence and 1965, India purchased equipment from Great Britain and France. In 1965, the U.S. cut off arms to both India and Pakistan when war broke out between them. From 1965 until 1984, India attempted to develop domestic production capabilities by licensing from Great Britain and the USSR on one hand while pursuing indigenous programs in parallel. The Rajiv Gandhi government, which assumed power in 1984, supported large purchases while also emphasizing indigenous research and development, assembly, and integration, particularly involving the emerging electronics industry.[15] Since 1998, India has devoted increasing attention and resources to its nuclear weapons industry while also exploring methods of exploiting the capabilities of its increasingly capable private enterprises in the area of high technology.

In a telling example of colonial subjugation, Indians were originally excluded from military aviation in their own country.[16] The Indian Air Force was established on 8 October 1932.[17] By this time, an elite group of Indians was being educated at Great Britain's Royal Air Force Training College, and India's Air Force was 60 percent Indian by February 1944.[18] Following independence in August 1947, the first three Air Force Chiefs of Staff were British. In April 1954, Air Marshal S. Mukherjee became India's first indigenous Chief of Staff.[19]

Unlike China, India started with a rudimentary aircraft production base. Hindustan Aeronautics Limited (HAL) began assembling trainers shortly after its founding on 24 December 1940,[20] and developed overhaul and repair capabilities.[21] During World War II, the United States provided substantial assistance to India's defense sector. By the war's end, 14,000 Indian workers had overhauled 1,100 aircraft and 3,800 engines.[22] In March 1946, New Delhi invited an aircraft mission from London to survey the prospects for an Indian aircraft industry. The mission's recommendations, which were implemented at the time of India's independence in 1947 and would shape Indian aircraft development for the duration of the Cold War, were as follows: India's

> . . . aircraft industry would have to be largely based on the manufacture of military aircraft and the purchases of civil aircraft would have to be a by-product; purchases of the aircraft for [the Indian Air Force] should be made in a manner as to make the aircraft industry in India prosperous. . . . The only sound method for laying foundation of a design and development unit is for original design of a suitable aeroplane to be undertaken locally. On the other hand, a cautious approach is required on engine development and manufacture.[23]

New Delhi subsequently imported planes and equipment from Great Britain to avoid dependence on the United States.[24] These tendencies toward aerospace autonomy were enhanced by two major events. In 1951 London attempted to diffuse Indo–Pakistani tensions by delaying the shipment of *Goblin* jet engines for the *Vampire* fighters that India was producing under license.[25] In 1954 Pakistan joined the Southeast Asia Treaty Organization (SEATO) and received substantial U.S. armaments in return.[26] India embarked on a period of ambitious aircraft acquisition:

> India's arms industry . . . began an extremely ambitious series of aerospace projects. . . . The Air Force received priority for equipment and funds. . . . At the end of 1952, the Air Force received permission to expand to 15 squadrons. Procurement in this period included the purchase of highly sophisticated Hunter fighters from the UK over the objection of both the armed services and the Finance Ministry. . . . Responding first to Pakistan's acquisition of F-104A Starfighters, and later to the experience of the Himalayan War with China, India considered purchasing F-104s, British BAE Lightnings, and French Mirage IIIs before ultimately settling on the Soviet MiG-21. From 1952–1962, the InAF [Indian Air Force] more than doubled in size and substantially increased its potential capabilities through the acquisition of advanced fighter and bomber aircraft.[27]

After becoming Defense Minister in 1957, V. K. Krishna Menon strove to build a self-sufficient aerospace industry with a large industrial infrastructure centering on HAL. Soviet technology transfer to India's aircraft industry, he believed, would furnish "a foundation for an Indian aircraft industry that would be as technologically advanced as those of the Western nations."[28] In 1964, in an effort to centralize Indian aircraft production capacity, all major aircraft production facilities would be consolidated under the aegis of HAL.[29] Menon would later be excoriated for devoting insufficient resources to prepare India's Army for the 1962 war with China. Reportedly, Menon "tried to run the Ministry single-handedly and did not allow any planning against China because he did not believe it would attack India."[30]

In response to the conflict with China, Washington promised New Delhi transport aircraft and other equipment. While Pakistan had already received massive military aid, however, including advanced aircraft, under the SEATO alliance starting in 1954, U.S. aid to India was suspended during the 1965 India–Pakistan war.[31] India's 1962 defeat caused profound concerns about national security and autonomy, and triggered a doubling of defense spending. Aircraft development would remain a priority,[32] albeit with increasing Soviet assistance beginning in 1965. On 9 August 1971, driven by concerns about Sino-American rapprochement and the consequences for China's strategic position against India, New Delhi would move beyond its nonalignment policy to sign a Twenty-Year Treaty of Peace and Friendship with Moscow.[33] By this time, 40 percent of the Indian Air Force's aircraft were of Soviet origin.[34] The treaty had substance as well as symbolism: an "Indo–Soviet Commission, established in November 1972, began the process of institutionalizing the treaty provisions for economic, scientific, and technical cooperation. . . ."[35] In the 1980s, New Delhi's defense budget doubled, and it became the "world's largest arms importer."[36] Soviet collapse would later cause great uncertainty concerning Indian aerospace production, but in 1995 a $1 billion aerospace purchase agreement with Moscow (including MiG-29 fighters, *Tunguska* surface-to-air missiles or SAMs, and spare parts) reestablished a high level of cooperation. The following year, India arranged to spend $1.66 billion on 40 Su-30 fighters and upgraded its 150 MiG-21 *bis* fighters.[37] On 18 August 1999, following nuclear tests the previous year,[38] India's National Security Board outlined a potential nuclear doctrine, which "called for a strategic defense system based on a triad of delivery systems including land-based missiles, planes and submarines."[39]

In contrast to China and Brazil, India has not had a history of substantial arms exports. This has been partly for political and ideological reasons. In the 1980s, New Delhi declined $150 million in defense contracts with Iraq, as well as Libyan investment overtures.[40] In the 1990s, annual arms exports averaged only $5 million, in sharp contrast to China's $600 million.[41] Recently, however, India has engaged in joint projects with Israel and wants to sell high technology armaments on the world market. So far, India has not found a major market niche, but has already had some success with space product and service exports.[42] India has launched more than twenty-six foreign satellites and has sold commercial imagery from its own satellites.[43]

## Rocket and Satellite Development

India has not matched China in missile development, yet has achieved greater success here than in the aircraft sector. India initially lacked two major impetuses that had galvanized Chinese missile production: the need to deliver an atomic bomb,[44] and a desire to measure up to and deter military attack from Moscow. Furthermore, India's principal strategic target, Pakistan, was easily accessible even by aircraft with relatively short ranges.[45] Indian development of atomic weapons and missile delivery systems therefore proceeded slowly, constrained by politics and resource shortages. New Delhi also enjoyed improving relations with Moscow, as well as some financial and technological aid from Western countries, including the United States.

Nevertheless, early advocacy by physicist Homi Bhabha,[46] who became Department of Atomic Energy secretary in 1954,[47] had convinced Prime Minister Nehru to permit development of the capability to produce atomic weapons, as well as potential aerospace delivery systems.[48] Vikram Sarabhai, who would succeed Bhabha on the latter's death in 1966, was reportedly less enthusiastic about nuclear weapons. He was concerned about the costs involved and did not believe that they could give India power out of proportion to its then limited internal development.[49] Delivery capabilities would also require substantial infrastructure.[50] Sarabhai failed, however, to prevent his subordinates from pursuing nuclear weapons capabilities, or "peaceful nuclear explosives" (PNEs) as they were then envisioned.[51] In the 1950s, with some U.S. assistance, India launched numerous sounding rockets. In the 1960s, however, in response to growing concerns about Indian nuclear ambitions, Washington terminated space-related assistance. India became increasingly determined to build its own space launch vehicles.

Like China in the 1950s and 1960s, India developed a relatively capable missile industry by focusing material and human resources and thereby improving institutional information flow and technological absorption. In 1983, with Prime Minister Indira Gandhi's approval, Dr. V. S. Arunachalam established the Indigenous Guided Missile Development Program (IGMDP).[52] IGMDP was charged with developing a full spectrum of missiles, in part because "limited access to technology transfer and sanctions forced a higher priority for indigenous research and development than in other defense-related projects."[53] This is one of India's few programs that has united research and production by connecting the arms industry, the private sector, and—for the first time ever—private institutions and universities.[54] IGMDP's comprehensive capabilities were "probably unparalleled in any other area of development and manufacture in India, military or civilian."[55] Moreover, "a conscious effort was made to avoid duplication of effort and maximize commonality of subsystems."[56] This, in turn, helped to avoid bureaucratic competition with existing programs.[57] From an organizational standpoint, IGMDP was unprecedented: its

> 'Mission,' the development of a particular missile, was made paramount, everything else (organization, procedures, personnel, finances, etc.) was made subservient. Obvious as this approach might seem, in practice it was nothing short of revolutionary. Bureaucratic procedure for the first time took a back seat. Results [were] what counted. Review teams for every missile met once a month to not only review progress but also to take on spot decisions without need to refer to any higher body.[58]

IGMDP produced five missiles. Two surface-to-air missiles (the short-range *Trishul* and medium-range *Akash*) and one anti-tank missile (the *Nag*) met with mixed success. Then, in 1988, IGMDP tested the *Prithvi* single state tactical missile. Capable of sending a 500 kg warhead 250 km, it was deployed in the early- to mid-1990s. "Western analysts have commented very favorably on the *Prithvi*'s design and operational flexibility."[59] In 1994, it was reported that the *Prithvi* used only 5–10 percent imported components, and that this percentage was steadily shrinking.[60] India has also developed a 350-km variant for deployment on surface vessels, the *Dhanush*.[61]

In 1989, 1992, and 1994 India successfully tested the *Agni*, a relatively advanced and capable missile. Dr. Abdul Kalam and his top colleagues had derived *Agni* from India's SLV-3 space launch vehicle.[62] The group was moved from the Indian Space Research Organisation (ISRO) to the Defense Research and Development Laboratory for the purpose,[63] in part to avoid the possibility that ISRO might be sanctioned for developing missiles.[64] While the *Agni* was officially called a "technology demonstrator,"[65] its reported 1,500-km range apparently makes it capable of delivering a nuclear warhead anywhere in Pakistan or in southwestern China.[66] In the words of *India Today*, *Agni* "blossomed into a chariot of fire that propelled India into an exclusive club dominated by the world's technological and military giants."[67] Tests were subsequently suspended given their success and U.S. pressure.[68] India's Pokhran II nuclear tests in 1998 and the Kargil War with Pakistan in 1999 led to increased emphasis on developing India's nuclear deterrent, however. Following a series of flight tests that began in 1999, India's *Agni-II* medium-range ballistic missile has reached initial deployment in limited numbers. The road- and rail-mobile missile has a range of approximately 2,000–3,500 km.[69] The *Agni-II* 's imported content was reportedly less than 6 percent.[70] India's *Agni-III* intermediate-range ballistic missile is in initial operational deployment following flight tests in 2006, 2007, 2008, and 2010. While the first failed to reach its target, the next three were successful. With a range of 3,000–5,000 km, *Agni-III* is capable of striking targets anywhere in China. In addition, the *Agni-IV* has been flight-tested; and the 5,000+km-range *Agni-V* was reportedly flight-tested for the first time in April 2012.[71]

Like that of its missiles, India's space launch vehicle development started much more slowly than did China's. India spent the 1960s and early 1970s establishing a basic space infrastructure. In the late 1970s and early 1980s, India began to construct and operate satellites and launchers. Starting in the mid-1980s, India would focus "on larger, more powerful and mission-specific systems."[72] In 1962, Dr. Vikram Sarabhai, chairman of the Indian National Committee for Space Research, established the Thumba Equatorial Rocket Launching Station, India's first space facility, for meteorological sounding rockets.[73] That same year, New Delhi and Moscow signed their first space agreement, which gave Moscow access to this rocket range.[74] India began by producing and launching U.S. and French-derived sounding rockets, but launched its first indigenous version, *Rohini* 75, in 1967. Starting in 1969, India would rely on indigenous propellants.[75]

In 1966, Sarabhai became chairman of India's Atomic Energy Commission and Secretary of its Department of Atomic Energy. He used this position, with its substantial responsibility for space development, to draft India's first plan thereof. On 25 May 1970, Sarabhai codified his vision in a detailed, ambitious plan for atomic and space research over the next decade that has become known as the Sarabhai Profile.[76] Sarabhai envisioned a practical mission for India's space program, assisted by substantial cooperation with developed nations:[77]

> There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the Moon or the planets or manned space flight. But we are convinced that if we are to play a meaningful role nationally and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society which we find in our country. The application of sophisticated technologies and methods of analysis of our problems is not to be confused with embarking on grandiose schemes whose primary impact is for show rather than for progress measured in hard economic and social terms.[78]

India's space program therefore avoided piloted spaceflight and elaborate scientific experiments. It focused instead on developing mass communications to connect remote areas and remote sensing to better map and manage national resources as well as cope with natural disasters. Though his ambitions were not completely fulfilled, Sarabhai's emphasis on practical results did enable him to obtain increased space program funding in the late 1960s, despite tightening national budgets.[79] In 1969, the ISRO had been established as part of the Department of Atomic Energy.[80] In 1972, following Sarabhai's death on 30 December of the previous year, his successor Homi Sethna would establish a Department of Space outside the Atomic Energy Commission to avoid political controversy.[81]

China's orbiting of a satellite in 1970, following its initial nuclear test of 1964, "rais[ed] the specter of a significant Chinese ballistic missile capability to launch nuclear warheads at distant targets." The Indian Institute of Public Opinion stated, ". . .we felt humbled for having lost a race we never chose to enter."[82] Following the 1971 India–Pakistan war and New Delhi's resulting concern about the formation of a "Sino–Pak–U.S. axis" to limit India's strategic options, New Delhi's space program expanded significantly, assisted in part by the return of overseas Indians. India created a Department of Space in 1972.[83] That same year, agreement with Moscow paved the way for the latter to launch India's first satellite, the 160-kg *Aryabhatta*, on 19 April 1975.[84] *Bhaskara I*, India's first low Earth orbit observation satellite, which carried out remote sensing experiments, followed on 7 June 1979.[85] *Bhaskara II*, a more sophisticated mapping satellite, would be launched by Moscow on 20 November 1981.[86]

In the 1980s and 1990s, Moscow and Washington would help India to launch two series of satellites: Indian Remote Sensing Satellites (IRS) and the Indian Satellite System (INSAT). Imaging and other data provided by IRS has been credited with reclaiming arable land[87] as well as with improving Indian mining, fishing, urban planning and road construction, well drilling, and environmental protection and management.[88] INSATs have handled communications and meteorology (for example, cyclone warnings) from 24-hour synchronous geostationary orbit. Indian launchers were initially incapable of providing this orbit, so in 1981 the National Aeronautics and Space Administration (NASA) launched INSAT-1 using the Space Shuttle.[89] INSAT-1 was constructed by Ford Aerospace, but subsequent versions were indigenously produced.[90] Like the IRS satellites, the INSATs served clear societal purposes:

> . . . INSAT-1B extended television coverage to over 75 percent of India's population and subsequent INSATs brought most of India under television coverage. The INSAT-2 satellites provide telephone links to remote areas; data transmission for such organizations as the National Stock Exchange; mobile satellite service communications for private operators, railways, and road transporters; and broadcast satellite services used by India's state-owned television agency and commercial television channels.[91]

In recent years, HAL has cooperated with Israel in satellite development.

Despite these successes, India was determined to develop autonomous space launch capabilities. During the 1970s, Germany's space agency had transferred relevant technology.[92] On 18 July 1980, on its second attempt, India launched its 35-kg *Rohini* satellite using an indigenous SLV-3,[93] becoming only the seventh nation to accomplish such a feat.[94] Eighty-five percent of SLV-3's components were developed indigenously.[95] A second, similar *Rohini* satellite was launched in May 1981, but the rocket failed to deliver it to the correct orbit. *Rohini 3*, launched the following year, was far more successful. SLV-3 was only capable of placing satellites into low Earth orbit, however, and in order to support other satellite applications, India needed a more powerful launcher to place payloads into the versatile geostationary orbit.[96] In 1986 and 1989, the SLV-4 was tested.[97]

A further impetus to Indian autonomy in space launch vehicles occurred in 1992. Because of the aforementioned problems concerning power and reliability, in 1991 the ISRO had arranged to purchase three powerful KVD-1 cryogenic rocket engines from the Soviet firm Glavkosmos to facilitate the launching of larger satellites at a price of $250 million.[98] On 11 May 1992, U.S. President George H. W. Bush, fearing that sensitive Russian technologies would soon become widely available,[99] declared the sale in violation of the Missile Technology Control Regime (MTCR).[100] Bush imposed two years of sanctions on the companies involved.[101] Former Indian foreign secretary S. K. Singh captured the resulting Indian indignation: "Who . . . are the Americans to say they will have missiles and nobody else will?"[102] In 1994, President Bill Clinton allowed the sale of the engines but not production technology.[103] The Glavkosmos contract was modified accordingly.[104] In 1998, India received the first of seven engines.

Having determined to develop cryogenic engines indigenously, India recorded its first success with the intermediate launcher, Advanced Satellite Launch Vehicle (ASLV), in May 1992.[105] This was part of a larger pattern in which "ISRO and Indian industry indigenously developed many space and missile technologies after being denied their import."[106] India is currently developing two more advanced launchers, the Polar Satellite Launch Vehicle (PSLV) and the cryogenic Geo-Synchronous Satellite Launch Vehicle (GSLV).[107] The first PSLV, launched in September 1993, failed.[108] On 15 October 1994, however, a PSLV successfully orbited the IRS-P2 satellite.[109] A PSLV launcher orbited IRS-P3 in March 1996, though a subsequent launch in September 1997 failed to deliver IRS-1D to the correct orbit.[110] Despite international sanctions in response to India's nuclear testing the previous year, another PSLV launched 1,050 kg *Oceansat-1*, its "first dedicated ocean observation satellite" on 25 May 1999.[111] The GSLV, first launched in 2001, arguably has propelled India into "the ranks of the world's five most advanced space agencies" with its geostationary orbit capabilities.[112] Still, India's program has had to address persistent failures—as of 2001, "only five out of eight (62 percent) SLV-3 and ASLV launches were successful, while four out of five (80 percent) of PSLV launches have been successful."[113] Following its initial failure, partial failure, which bracketed two successful launches, the PSLV has achieved an unbroken record of seventeen successful launches. These have included orbiting microsatellite payloads and small satellites for a wide range of international customers."[114] The GSLV has been less reliable thus far. Of its seven launches between April 2001 and December 2010, there have been two successes, one partial failure, and four complete failures.[115]

Today "India has one of the fastest-growing space budgets in the world and its space industry . . . employs 17,000 people."[116] It has, however, continued to adhere to Sarabhai's vision. It has produced a variety of spin-offs, and "can claim to be one of the most cost-effective in the world. It has been careful to limit and focus its ambitions and not indulge in prestigious projects. . . . Indian space spending has been small compared to its neighbor China. The space program has never been politically controversial, having obtained the support of all prime ministers from Nehru onward, and has rarely been criticized in Parliament."[117]

A future driver of Indian aerospace capabilities will be its nuclear weapons program. On 17 August 1999, India issued a tentative "Draft Report of [the] National Security Board on Indian Nuclear Doctrine."[118] The report, while probably India's "single most coherent statement on nuclear doctrine" to date, "still suffers from some internal tensions and, more important, from continuing ambiguity with respect to its status as a policy document."[119] It called for minimum deterrence with a full triad and space-based platforms for "early warning, communications, [and] damage/detonation assessment."[120] It also championed global disarmament, and called for "no first use" against other nuclear states and "no use" against non-nuclear states.[121]

Indian nuclear weapons delivery systems could include "Jaguar, Su-30, and Mirage-2000 aircraft as well as medium-range missiles. . . ."[122] Chinese strategic targets remain elusive.[123] India has long lacked a fully-operational ballistic missile with a demonstrated range of greater than 5,500 km, the commonly-accepted threshold for status as an intercontinental ballistic missile (ICBM). Its SLVs are "handicapped by their enormous weight, excessive diameter (often on account of their strap-on boosters), and extremely high weight-to-payload ratios."[124] There have long been reports of a *Surya* ICBM being in development. Even if the *Agni*-V proves to be a true ICBM in terms of range, it is likely to require four or more additional flight tests before being declared fully operational, a process that is unlikely to be completed before 2015.[125] India has not deployed a submarine launched ballistic missile (SLBM).[126] In 2001, Ashley Tellis projected that

> New Delhi's deterrent posture will center for a long time on a limited, monadic delivery system: short-range strike aircraft. At least another decade will elapse before a dyadic posture involving aircraft and land-based ballistic missiles becomes fully ready and operational, and it is unlikely that India will have a credible triad of any size, effectiveness, or flexibility for a least another decade or two.[127]

Civilian space spin-offs have already been particularly useful for India's military space programs.[128] New Delhi lacks continuous satellite coverage of Pakistan,[129] but reportedly has "experimented with IRS [Indian Remote Sensing satellite] images for reconnaissance purposes" and may be able to select Pakistani targets in this fashion.[130]

## India's Bifurcated Aircraft Achievement

India's aircraft development is really a tale of two aircraft industries, licensed and indigenous, which—in sharp contrast to India's missile and space industry—seem not to have communicated sufficiently with each other, let alone with the private sector.[131] Industrial Policy Resolutions of 6 April 1948 and 1956 made India's arms industry, including its aircraft manufacturing subcomponent, a state monopoly,[132] with few if any links to the private sector. Because of the dominant Congress Party's Gandhian principles and concern about the military's prior links to colonialism,[133] moreover, the arms industry was further isolated within the state sector.

Licensed aircraft production became relatively capable. By 1994, HAL had already built over 2,400 aircraft, most under license.[134] India produced the *Vampire* turbojet in the 1950s, the *Jaguar* in the 1970s, the MiG-21 in the 1960s and 1970s, the MiG-27 in the 1990s, and is currently producing the Su-30 MKI. Using a classic less developed country method, that of the "ladder of production," India would start assembling kits of British, and later Russian, aircraft, and then develop a viable production line. The *Vampire* turbojet "served first as a frontline fighter and then as a trainer and reserve combat aircraft for two decades."[135] In 1956, India purchased 25 *Gnat* fighters, and 25 kits, from Britain's Folland Corporation. "By 1962, HAL announced that the entire engine was manufactured indigenously. India acquired most of the technology when Folland folded in the late 1960s, and as a result HAL eventually produced over 85 percent of the airframe and 60 percent of the engine. The *Gnat* performed very capably in InAF service for over thirty years."[136] India decided to produce the MiG-21 in 1962.

> Later deliveries provided an improved variant, and local participation and production was given a higher priority after the 1965 war with Pakistan. . . . HAL produced the MiG-21FL, MiG-21M, and MiG-21bis, and modified the designs of the latter two aircraft to fit Indian needs and industrial capabilities. . . . While the MiG-21 initially cost more to produce in India than to import, a production run of close to twenty years and over 500 aircraft eventually saved considerable foreign exchange.[137]

It must be emphasized that, at least in terms of aircraft, "the bulk of India's defense production has previously been substantially more sophisticated than that of China, due primarily to India's continued willingness to utilize licensed production."[138] China, with its technological isolation and emphasis on indigenization, did not possess aircraft comparable to the MiG-21 or -27 when India was successfully producing them via license. In another contrast to Chinese failure through autarchy, licensed helicopter production was similarly successful:

> HAL produced two French helicopters under license, the Aerospatiale SA 315B Lama (known as the Cheetah in Indian service) and the SA 316B Alouette II (known as the Chetak). The Chetak is one of the few complete systems manufactured at HAL to be exported to a "developed" country. Unfortunately, it was exported to the Soviet Union, which raised some concerns about the safety of Western technology in Indian hands. Negotiations for the Chetak began in early 1962, and by 1966 the French were buying

> spares from HAL to take advantage of the low labor costs in India. . . . Both these aircraft remain in Indian service today.[139]

The major drawback of licensed production is that it has not helped India to completely fulfill its goal of technological and armament autonomy. Licensing from Moscow has rendered India vulnerable to interruption in parts supply and restrictions on technology transfer and re-export.[140] Moscow has attempted to undercut Indian defense production in order to boost its own sales.[141] Some Soviet equipment, such as aircraft engines, has developed problems.[142] Some aircraft were not a perfect fit for India's Air Force. For example, the first shipments of MiGs reportedly lacked air conditioning.[143] An absence of supply diversity has paradoxically given India a multiplicity of aircraft types. Licensing has been comparatively affordable, but may not have given India's Air Force the platforms or performance that it most needs.[144]

India's indigenous aircraft production has not matched its licensed production. In 1950, HAL began development of a basic trainer. In 1956, it began a two decades long, ultimately unsuccessful effort to produce the developing world's first modern supersonic fighter. India spent the years between 1956 and 1979 developing the HF-24 *Marut*, only to have it enter service already obsolete.[145] A mere 145 of a planned 214 units were produced.[146] Indeed, according to one U.S. scholar,

> India's first attempt at indigenous design and production of a modern fighter aircraft was a disaster. . . . At the time the Marut program was begun, India only barely possessed the capability to design and develop elementary piston-engined trainers like the HT-2, much less state-of-the-art supersonic fighters. HAL lacked the experienced design teams necessary to carry out the design and development of such a program, so expertise was imported from abroad in the form of Dr. Kurt Tank [who] had been director of development at Focke-Wulf in Nazi Germany. . . . The plane was designed around a British Orpheus 12 engine. . . . Unfortunately for India, the Orpheus 12 project, linked with a European collective aerospace effort, was cancelled. . . . As a result, when the first Marut was test-flown, it used Orpheus 703 engines and was substantially underpowered. India then sought engines from other sources. . . . By 1964, it was clear that this effort was also a failure, and production had fallen severely behind schedule. The first ten Marut MK 1 aircraft were obsolete when they entered service in 1964, relied heavily on imported parts and cost more than a comparable or superior aircraft imported from abroad. . . . Production of the Marut ceased in 1975, almost twenty years after the decision was made to begin development.[147]

The Light Combat Aircraft (LCA), the development of which began in 1983, has been officially named "Tejas," approved for Indian Air Force pilots' use in 2011, and may finally become operational as early as 2013.[148] It might be equivalent to an F-16, a *Mirage* 2000, or a Swedish *Grimpen* in performance capabilities. But, thus far, while development has progressed far more smoothly than that of the ill-fated *Marut*, the program is still expensive and inefficient.[149] In 1993, India has sought foreign partners with which to develop the aircraft,[150] but challenges remain. The Indian Air Force, unwilling to bet on the LCA, has ordered a variety of foreign aircraft in recent years.

The LCA appears to suffer from problems that have plagued India's aerospace industry as a whole: ". . . changing requirements in mid-program; the constant threat of external purchase; and the long delays in research, development, and production."[151] In 1987, S. R. Valluri resigned as director of the National Aeronautical Laboratory in Bangalore, which was developing the LCA. In a November 1987 lecture at the National Physical Laboratory in New Delhi, Valluri decried the lack of coordination between licensed and indigenous aircraft production: "The gulf that separated R&D and production in industry was so wide that those from the industry dealing with license negotiations rarely involved R&D and design staff. . . . In that environment, no effort seems to have been made in negotiations to bear in mind problems related to acquiring the technology base . . . and plan for its absorption in a systematic manner." Valluri continued: "We cannot improve upon the proverbial wheel if it is produced under license, and if we do not understand how the wheel is designed."[152]

India's indigenous aircraft development challenges stem from limited resources and prioritization, institutional obstacles, and problems with worker productivity. The Indian aircraft industry has been assessed as being less efficient economically than that of Germany and France, and perhaps only 10 percent that of Israel. In 1999, for instance, Israel aircraft industries' 14,000 workers generated $2 billion in sales, whereas Hindustan aircraft industries' 50,000 generated only $500 million.[153] Whereas India's civilian space program has greatly complemented its missile program,[154] influential strategist K. Subrahmanyam has argued that India's failure to develop "an adequate civil aeronautical industry" to complement its military aircraft industry inhibited

> aggregated and economical demands for aircraft, alloys, instruments, various accessories, and hydraulic systems. . . [and] did not provide an adequately broad base to develop R&D for various subsystems and materials, with the result that the defense aircraft industry had to depend on a certain amount of imported components. . . . [In addition,] delays in forcing indigenous equipment developments through to the production stage also affected the industry's ability to satisfy the needs of the armed forces.[155]

Both Air India and Indian Airlines have epitomized the inefficiency associated with India's Cold War, state-led economy. Air India was founded in 1932 as Tata Airlines by India's then second-largest industrialist J. R. D. Tata. It achieved early milestones as India's "first international airline" and, after becoming state-run Air India, as "the world's first all-jet airline in the 1960s."[156] It even assisted such nations as Singapore and Malaysia in establishing their own flag carriers. Lack of competitive business practices and the removal of the Tatas from management, however, reportedly led to its possession of "the largest ratio of employees to aircraft of any airline in the world" and an inability "to compete with the very airlines it had helped establish, let alone the major carriers of Europe and America."[157] Indian Airlines, New Delhi's monopoly domestic carrier until the early 1990s, ". . . was even less efficient than Air India. It is still subject to the whim of government bureaucrats and politicians in the matter of routes, schedules, safety, and the purchase of equipment. It was and remains too small, with its fares kept artificially low despite widespread demand at a higher price point."[158]

In recent years, however, India's domestic air transportation industry has been growing with unprecedented rapidity, and there is increasing evidence that many of the historical problems are being addressed. Clearly this is an important and dynamic economic sector for India, one that promises to contribute substantially to the development of nation's infrastructure and economy.

## Explaining India's Differential Aerospace Development

Table 20–1 shows possible explanations for India's uneven aerospace development. Based on the material presented above, it is argued that limitations in national capacity have been primarily responsible for this variation.

| Explanation | Actual Result? |
|---|---|
| 1. Market Based | No |
| 2. Sector-Sequence | No |
| 3. Domestic Politics | No |
| 4. Comprehensive National Power | Yes |

**Table 20–1:** Alternative Explanations for India's Differential Aerospace Development.

The market-based model does not correspond to India's pattern of aerospace development. As a matter of policy, India constantly strove to develop indigenous aerospace capabilities at considerable expense, even when cheaper products were available on the international market. The sector-sequence model also fails to explain India's aerospace development: "India has consistently violated this theoretical ladder, skipping or ignoring steps in pursuit of symbolic goals. It has regularly rejected the possibility of incremental improvements to existing arms based on local R&D, preferring instead to purchase or develop entire new systems."[159] The political model is also inadequate, as it cannot explain why India's indigenous aircraft production failed, despite being emphasized repeatedly as a means of giving India security and technological independence.

The comprehensive, national-power model seems to offer the best explanation for India's level of aerospace development. As Timothy Hoyt explains,

> Indian military-industrial policy is best described in realist terms. It is practical and cost-effective under high levels of regional or external threat, but focuses on prestigious and high-profile projects when the regional environment appears relatively benign or unthreatening. Military-industrial projects have not unduly taxed Indian society, and may even have provided some positive stimulus to national economic development despite structural barriers.[160]

Even in their "strategic enclaves," India's various subsets of aerospace development are constrained by larger national economic and technological policies.[161] Lack of qualified pilots, training, maintenance, and resources has given India's Air Force one of the world's lowest rates of utilization in the past.[162] India's overall developmental challenges have historically plagued the Air Force with problems involving poor living conditions for pilots.

Understanding India's differential aerospace development requires specific examination of five important factors: relative levels of resources, activity, technology, incentives, and institutions. Table 20–2 graphically compares these factors.

| Sector | Resources | Activity | Technology | Incentives | Institutions |
|---|---|---|---|---|---|
| **Rockets** | Medium and rising | Low but rising | High and relatively diffused | Medium to high | Small but effective |
| **Satellites** | Low but slowly rising | Lower but steady | Medium but increasing | Low to medium | Small and somewhat effective |
| **Aircraft** | High but uneven | High but uneven | High but not diffused | Low to medium | Numerous but disconnected |

**Table 20–2:** Relative Subcomponents of India's Differential Aerospace Development.

## Resources

Missile and nuclear development is not included in India's official military budget, so it is difficult to obtain reliable estimates of spending in these areas.[163] India spent $37.3 billion on its military in 2011, less than half of China's announced defense budget.[164] This places India third in Asia and ninth worldwide in total military spending, so it should not be surprising that India does not seek to compete directly with the United States, Europe, Japan, or even China in overall aerospace development. The more interesting question to ask is rather, how have resources been prioritized within Indian aerospace development? India's missile and nuclear programs in particular have "benefited both from obvious symbolic importance and also from charismatic and influential project leaders and bureaucratic stakeholders."[165] Space funding has gradually increased, to an annual average of $350–400 million dollars by 1999–2000.[166] Much of this increase has gone to PSLV and GSLV propulsion systems, sophisticated satellites, and the establishment of a second launch facility.[167] The prestige involved has made politicians consistently supportive of these endeavors.

## Activity

Over the past two decades, Indian rocket development has grown increasingly robust, both in civilian and military areas. Comparatively high rates of technological diffusion and exchange of human capital has meant that experience derived in one program often informs the other, thereby increasing India's return on its investments. India's satellite development started relatively late, but has gradually increased and diversified. India has long been engaged in substantial aircraft production. As has been demonstrated above, however, the majority of production has occurred under license, and experience and technology have not been adequately transferred to indigenous programs. This has prevented the sort of productive cross-fertilization that is essential for innovation. There has also been far less activity in indigenous aircraft production, apparently because of lack of resources and prioritization. Programs have tended to last for two decades or more without generating products that are truly useful to India's Air Force.

## Technology

Lack of proper diffusion means that Indian technology does not always help India: "Ironically, Indian soldiers who fought against the Pakistan Army in the frozen heights of Kargil were equipped with obsolete field telephones, while the Pakistanis had sophisticated satellite phones based on technology developed by Indian software engineers and programmers in the West."[168] Corruption, inadequate infrastructure, and improper incentives—all challenges common to developing democracies—have caused some of the technological difficulties in Indian aerospace. Moreover, there is an inherent tension between India's quests for technological autonomy and military capabilities.

New Delhi's 1958 Scientific Policy Resolution, 1983 Technology Policy Statement, and Science and Technology Policy 2003 have all articulated ambitious goals for technological indigenization.[169] Unfortunately, rhetoric has thus far exceeded reality. India's effort to achieve both goals to some extent has produced a sub-optimal outcome: ". . . India has consistently set the goals for its major systems projects too high, only to revise them in a manner that undermines confidence and leaves a requirement for imports as an interim measure. The indigenous project, under pressure, adopts an imitative approach that is not conducive to developing a mature technology base, while the resources necessary for fully exploiting the imported technology are taken up by the less advanced indigenous program."[170] As a result, licensed technology is rarely absorbed, particularly in the case of aircraft.[171] As Timothy Hoyt points out,

> The separation of the Indian defense sector from private industry minimizes the impact of imported defense production technology on the national economy. In the aerospace sector, sophisticated manufacturing technology imported at enormous expense has had virtually no impact on the national economy. Coordination between private and defense sectors is also uncertain. . . . Separation of the defense and private sectors was originally encouraged because quality standards in the civilian sector were often much lower than those in the defense industries. . . . As India has integrated with the global economy, however, quality in many sectors now approaches Western standards, and private industries which had previously been denied the privilege of defense production have become vastly more capable and assertive.[172]

India's space program has been assessed as being 20 years behind those of the United States and the Russia, and 10–15 years behind those of Europe, China, and Japan.[173] But, thanks to its program's civilian focus, India is able to acquire more foreign space technology than China.[174] It is India's aircraft industry, however, that is the furthest behind world levels. Like China, and unlike Brazil, India engaged in technological isolationism that prevented its aviation industry from benefiting from Western technology, and has thereby missed important opportunities. According to Stephen Cohen, HAL

> . . . could have linked up with foreign aircraft manufacturing firms, but the latter were wary of the Indian government's policies on investment and foreign control. The only significant contracts with Western aerospace firms were for assembling aircraft from kits or parts, with a minimal transfer of design and manufacturing skills. By the late 1990s, when HAL was given

> greater autonomy and was offering equity in its operations, foreign companies such as Boeing and Northrop had doubts about the quality of Indian management and thought it risky to become associated with a still-inefficient operation.[175]

Indian aircraft facilities still suffer from inability to develop and integrate subsystems and armaments:

> The most notable weakness in Indian defense industry . . . is the virtual absence of a significant refit and modernization capability. . . . India's defense industry focused almost exclusively on the production of major weapons systems and platforms, and relied on imported subsystems and armaments. The result is an industrial base which can design and produce airframes, but which has difficulty installing a different radar or an improved air-to-air missile to improve performance. The Indian arms industry should be capable of far better, given the resources expended.[176]

Northrop officials have reportedly "mused that they could build an Indian light combat aircraft more cheaply and better simply by using their own Indian–American employees than by collaborating with India's Hindustan Aircraft."[177] The inability of raw talent to single-handedly transcend ineffective institutional and incentive structures is a common problem in aerospace development, however: such obstacles have driven indigenous talent from both India and China. Comparing the technological problems in China with the great achievements of its diaspora reveals similar patterns, albeit with some improvements in recent years.

## Incentives

The collapse of the Soviet Union deprived India of its major partner for economic, technological, and defense development. This collapse galvanized reformers' efforts, afoot since at least 1983, to repudiate nearly a half century of the Indian state's occupation of the "commanding heights" of the economy and consequent stifling of innovation, economic growth,[178] and cost-benefit analysis of technological investments.[179] It was a subsequent balance of payments crisis in 1991, however, that forced India to embrace economic liberalization. India's "foreign exchange reserves had bottomed out, and the Reserve Bank of India had to secretly fly gold to London to maintain the country's credit."[180] Subsequent success in the software industry, combined with Western outsourcing, has impressed India's leaders with the benefits of this course. In 1991, Defense Minister Sharad Pawar offered India's private sector access to defense laboratories "'as a way to develop new technologies and increase the quality of their products'."[181]

The impact of economic reforms on India's defense sector, however, has thus far been extremely uneven. For instance,

> Increased utilization of the private sector can already be detected in the IGMDP, which integrated private sector and academic research organizations into the military R&D process. Better utilization of India's enormous scientific establishment could substantially increase Indian military industrial competitiveness and alleviate technological shortfalls in the existing force structure. Research and development, with the exception of the IGMDP, has been sloppy and poorly supervised. HAL, with a semi-independent R&D base, maintained low-level R&D in projects that the government had no intention of purchasing, including the HF-25 and -73 aircraft in the 1970s. . . . 'There is a problematic side to the "indigenous" mystique. Indian R&D and industry is permitted to try its hand on every product with a mindlessness that is amazing. This often results in a constant endeavor to reinvent the wheel.'[182]

Half of Indian Space Research Organisation spending goes to subcontractors that include "500 public and private sector firms, national laboratories, and academic institutions."[183]

Unfortunately, similar openness has not yet been realized in India's embattled aviation sector. According to Stephen Cohen,

> The real obstacles for the development of either an indigenous aircraft industry or the maintenance of an internationally competitive airline are ideological, not economic. The Indian government defined airlines as an essential, national service and placed them under the thumb of bureaucrats instead of experts. The government officials who ran India's major aircraft manufacturer and repair facility and supervised its major airline were well-intentioned generalists who had to conform to an ideologically framed measure of success. These overmanned and inefficient entities lost money on a regular basis. Deficits were made up by the Indian taxpayer; the result was a missed opportunity. India never built up a Brazil-like capability to produce aircraft that might have earned precious foreign exchange, nor did it develop airlines—as did Singapore and Malaysia—that were consistently profitable.[184]

Even now, India faces challenges similar to China's in reforming its inefficient, welfare- and employment-providing state owned enterprises.[185]

## Institutions

India's aerospace industry suffers from manifold organizational problems. The British colonial system and a history of leadership by powerful, charismatic members of the Nehru and Gandhi families are blamed for the current state of affairs, in which "decisions are excessively centralized, parliamentary consultation is weak, the talents of outsiders are rarely utilized, and coordination among differing ministries and bureaucracies is poor."[186] Consequent problems include lack of long-term planning and coordination, particularly concerning weapons acquisition and budgets:

> The Indian budget process rarely facilitates extended funding commitments. Armed service heads have extremely limited formal access to the Minister of Defense, and all defense requests are subject to very strict oversight and control by members of the Finance Ministry. The budgeting process is designed to maximize civilian oversight of defense procurement, and complicates the possibility of easily shifting funds or of maintaining consistent production rates over extended periods. Lack of a prepared national security policy or strategy severely complicates long-term planning and coordination of industrial strategy.[187]

In fact, "the armed forces play a smaller role in decisionmaking in India than in any other major state in the world"[188] and "in no other middle or great power is the military's advice so detached from political and strategic decisions."[189] The military and private sector are also excluded from research and development,[190] the former even in the case of some space research. This problem has been partially solved in the space and missile programs by moving experts between organizations.[191] Western export controls are often blamed, sometimes incorrectly, for this lack of coordination.[192]

In addition, threat assessments and planning are disconnected,[193] if pursued at all.[194] In the words of a former Indian air force official, "We don't have a National Security Council. No one knows anything. Ministers come and go, bureaucrats come and go. No one takes a long view towards strategy."[195] The absence of effective doctrine in turn leads to fluctuation in resources allocated. Lack of parliamentary oversight is also blamed for poor planning and coordination.[196] In fact, "Parliament has little voice in the routine conduct of foreign policy . . . and need not be consulted prior to or during a crisis."[197] Stephen Cohen states that a "policy of secrecy and nondisclosure [has] characterized all Indian governments since 1947."[198]

This may seem surprising, as India is a democracy whose constitution specifically mandates transparency concerning weapons procurement and military decision making. Reasons offered for this paradox include the broadening of parliament to include more representative members who lacked their predecessors' education and familiarity with parliamentary procedures and the belief of military experts that parliamentarians cannot be trusted with sensitive information. The resulting "excessive confidentiality" is blamed for

> . . . greater likelihood of corruption in arms procurement . . . inadequately analysed procurement policy [which] leads to inefficiencies and can have unhealthy consequences for national security . . . opacity in decision-making processes [which] damages public confidence in the armed forces [and subjects them] to needless controversies.[199]

Finally, India's Civil Service, which still wields great power over policy processes, is seen by some as being overly bureaucratic as well as prone to corruption and even to caste and faction-based allegiances.[200]

## Remaining Challenges for India

Shortly before its defeat in the 2004 general elections, the Bharatiya Janata Party (BJP) produced *Vision Document 2004*, which "promised to make India a developed nation and a great power by 2020, through double digit GDP growth and the creation of a multi-polar world, 'with India as one of its poles.'"[201] This vision of "India Shining" failed to resonate sufficiently with voters, and the resulting Congress Party victory and subsequent plurality in the 2009 general elections suggest that, while India has made great national progress in recent years, much economic development remains to be accomplished and problems will not be solved overnight. India's historical social hierarchy has long impeded learning and economic mobility. Though a great achievement in itself, and responsible for many of India's great strengths, democracy has not automatically promoted social change, in part because cultural and religious traditions have hampered the development of identities based on economic class. India struggles with a population that already exceeds 1.2 billion, and which is divided into "20 language groups, 50,000 castes, and 500,000 villages."[202] In perhaps the most graphic example of India's remaining underdevelopment and related challenges, the July 2012 blackout, the largest power outage in world history, affected half of India's population, including government ministers in their elite compounds.[203]

Successful technological diffusion will be critical to reducing India's increasing economic divide: between a small, potent knowledge economy,[204] and a large, backward agricultural economy.[205] This growing disparity is seen in India's complex relationship with the provisions of the World Trade Organization.[206] The Cabinet's 8 May 2001 decision to permit private armaments production as well as foreign direct investment in India's defense sector[207] is a promising start, but it remains to be seen what will be allowed in practice. The decision removed the public monopoly enacted by India's Industrial Policy Resolutions, but both production and investment are still subject to obtaining a government license, which is unlikely to be forthcoming in sensitive areas. As the world's largest democracy continues its rapid economic and societal development, therefore, it will likely continue to face the principled dilemma of how to obtain foreign technology while developing autonomous aerospace production capabilities.