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THE GLOBAL COMMERCIAL SPACE LAUNCH INDUSTRY: JAPAN IN COMPARATIVE PERSPECTIVE

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Introduction

Japan has been seriously attempting to break into the commercial space launch vehicles industry since at least the mid 1970s. Yet very little is known about this story, and about the politics and perceptions that are continuing to drive Japanese efforts despite many outright failures in the indigenization of the industry. This story, therefore, is important not just because of the widespread economic and technological merits of the space launch vehicles sector which are considerable. It is also important because it speaks directly to the ongoing debates about the Japanese developmental state and, contrary to the new wisdom in light of Japan's recession, the continuation of its high technology policy as a whole. Perhaps most important of all, the ongoing saga of the space launch sector fits in nicely with the Japanese government's historical emphasis on technology, wealth, and power.

Technology policy has been at the center of Japan's development efforts since the late 19th century. According to key postwar studies of Japan's industrial development, the Japanese government self-consciously selected sectors based on the perceived potential for economic growth and technological change.[1] In fact, any industry favored for promotion had to be of seminal importance to Japan's technological development and national economic welfare.[2] The focus, in short, was on the acquisition of key industries and technologies that could be crucial for national defense, especially those characterized by high growth and high knowledge intensity, as well as widespread extensiveness of uses and economic benefits.[3] Behind these assertions about the Japanese emphasis on technological acquisition and indigenization lie specific historical beliefs and ideologies about technology as a whole. Japanese elites arguably have a distinct set of historical beliefs about the development of technology and national security in the long run, and these continue to permeate the economic institutions even today.[4]

Some of these beliefs can be captured in the formal ideological slogan of the Meiji era -- *fukoku kyohei* ("rich country, strong army") -- that has consistently underpinned efforts to develop technology and industry. Since 1868, Japan has displayed a concern with relative gains and standing in industrial manufacturing, which was seen as the source of national strength, wealth, power and security. In this respect not much has changed since the Meiji era, and the continued attention given by the Japanese government today to the commercial space launch vehicles sector should be seen through this historical prism. Playing "catch-up," with the more advanced West, the Japanese have tended to identify strategic sectors as those that were crucial sources of technology, regardless of military or civilian applications. While high rents (especially high value-added) were also an important criterion as in steel, the more important one appears to be potential for technological change and extensiveness of uses of the sector as in the naval shipyards or aerospace industries. Here the Japanese "technonational" ideology led to an emphasis on promoting industries on the basis of nonproduction benefits, especially learning and diffusion. In distinguishing between competing paradigms of how military and commercial technologies are related -- that is, through spin-off, spin-away and spin-on -- the argument for supporting strategic sectors is based on the critical concept of spillovers that affect not just the sector of concern but many others in its industrial wake.

The central theme of technological externalities, widespread benefits, extensiveness of uses or, put simply, spillovers, that comes across in the Japanese case also has a strong counterpart in the more formal strategic trade policy literature. While this literature has fallen out of favor even with its pioneers because of the difficulties in ensuring implementation and actual economic gains, one of its core propositions is that some sectors are strategic because of certain economic characteristics, namely rents and especially external economies.[5] Rents refers to the idea that capital and labor in a sector earn exceptional returns compared to sectors of equal risk, meaning that there are higher levels of growth, as well as supernormal profits, value-added, and wages. External economies refers to the idea that some sectors will higher returns because they confer benefits not just to capital and labor employed within their own confines but also to other sectors in the economy.

This concept of external economies, or more generally positive externalities or spillovers as discussed in the Japanese case, is considered *the* pivotal element in distinguishing strategic sectors from others.[6] It is this element that is especially important in the context of Japan's technology policy, and serves as a key perceptual factor in garnering support for the acquisition of high-tech sectors like space launch vehicles.[7] In fact, the widespread perception, both among Japanese economists and relevant government officials, is that industries with dynamic economies of scale and externalities can flourish with government support, a process that can have far-reaching and beneficial effects on the industrial structure.[8]

This emphasis on spillovers or technological externalities, which constitutes the essence of the technonationalist ideology, unites the case of space launch vehicles with other historical cases involving high-tech industries in Japan's past. As the brief review above makes clear, the tenacity with which the Japanese government remains committed to the space launch vehicles today can only be understood through this vibrant historical optic, and Japan's competitors ignore this angle at their peril.[9] The goal of the remainder of this paper is to assess Japan's activities in comparison with the other more established players in the US and Europe, and from there to evaluate the future prospects for Japan's entry into the global space launch vehicles industry.

The paper is organized as follows. The first part focuses on the realities of global competition in the commercial space launch industry. It lays out the key developments in the industry, as well as the competitive realities among the dominant players in the US and Europe. Against this global backdrop, the second part then examines the activities of both the Japanese government and the private sector chronologically. It also provides an overview of the main stages of Japanese rocket generations, and how they have fared in terms of breaking into the global commercial launch vehicles market. Finally, in keeping with the technonationalist ideology, the third part highlights the reasons why, despite failures, setbacks, competitive global realities, and even private sector trepidation, the Japanese government continues its quest to indigenize space launch vehicles as an industry in Japan.

The Global Commercial Space Launch Industry[10]

The commercial space launch industry is one of the most important, yet surprisingly one of the least well-known, industries in the world. Space launch vehicles, whether expendable or reusable (or both), are designed to carry payloads into space.[11] Vehicles like rockets, for example, can transport payloads, such as either military or commercial satellites, into low, medium or geostationary earth orbits.[12] Up until the mid-1980s, launch service providers, led by the US, focused on government payloads rather than commercial ones.[13] This changed slowly over time, and by the mid-1990s although governments were still key players the ratio had begun to shift in favor of commercial payloads due largely to the boom in the global telecommunications market.[14] At that point, despite concerns about backlogs later down the line, the widespread perception was that commercial launch vehicle services would be spurred by the seemingly limitless demand for sophisticated telecommunication satellites in GEO and LEO orbits, as well as other related equipment.[15]

The high-profile $3.4 billion Iridium system led by Motorola, for example, generated a great deal of excitement about the prospects for big LEO mobile satellite systems due to go into effect near the end of the 1990s.[16] In another mobile program, estimates suggested that the US government-developed Navstar Global Positioning System (GPS) receiver sales would grow by 62% by the middle of the decade. While the commercial space sector as a whole continued to get large amounts of government R&D, private companies in the satellite business were also beginning to match government amounts of funding. Hughes, the world's leading commercial satellite maker at that point, increased its independent R&D development work by almost 50% since the early 1990s, and was actively involved in developing, among other things, key materials for the GEO mobile satellite market.[17] European Space Agency (ESA) officials, perceiving themselves to be in an unbelievably intense race with the US, also became actively involved in supporting new telecommunication technologies by private companies.[18] For all these reasons, in the early 1990s, one estimate concluded that while revenues generated by the launch industry were only one-tenth of the satellite industry, the projected growth in the demand for satellites would swiftly bring new players into the launch-vehicles game.[19]

By the end of the 1990s decade, however, the picture was a little more somber, and with important consequences for the entry of new players in the launch-vehicles game. The basic demand for more and more commercial satellites at varied orbits that were seen as driving the demand for launch vehicles took something of a hit.[20] For one thing, it was unrealistic to assume that the kind of past commercial demand in the relatively new satellite market would continue on an explosive upward trend forever. This was for the simple reason of market saturation, where the sizable portion of the demand for new satellites for both established and newcomer operators had already been established. Even if such systems needed replenishment, this would not be happening until the mid to the late 2000s.

For another thing, there was and is the "Iridium flu."[21] Iridium's spectacular bankruptcy in 1999 led to widespread negative perceptions about the commercial satellite industry as a whole in business and financial circles, and consequently there were many questions about the desirability of producing new satellite systems altogether.[22] In the US, the forecasts put out by the Federal Aviation Administration's Office of the Associate Administration for Space Transportation (AST) and the Commercial Space Transportation Advisory Committee (COMSTAC) showed a similar downward revisions of the numbers. In 1999, AST/COMSTAC projections were that an average of 51 commercial space launches would occur annually through 2010. But the estimates in 2000 show nearly a 20% reduction, with the present forecast that an average of only 41.4 commercial space launches will occur annually through 2010 in large part because of failures like Iridium.[23]

Whatever the accuracy of the predictions, it is a safe bet that the existing and more established launch service players will automatically receive a substantial portion of the market. In 1999, a total of 78 orbital launches were carried out, 36 of which were commercially designated payloads that generated about $2.2 billion in revenues.[24] And it was US and European launch service providers that dominated the market, launching 34 of the total 36 commercial payloads.[25] Who exactly are these players, and what does their dominance suggest about the viability of potential new entrants?

Arianespace: The key leader in one field of commercial launch services is Europe's Arianespace that has 50% of the market for payloads bound for geostationary transfer orbits (GTO).[26] Arianespace was created in March 1980, and consists of 41 aerospace and engineering firms from 12 European countries, 53 corporate shareholders, 11 banks, and one European Space Agency.[27] The largest single shareholder is France with about 57% of the total shares, followed by Germany at about 18% and Italy at 7%. Arianespace entered the new century in an extremely strong competitive position, with 12 consecutive successful launches in 2000 alone.[28] Its reputation for cost effectiveness, speed, and reliability have already made it an indisputable leader in the field, with many of its customers being repeat ones.

Until 1999, Arianespace's Ariane 4 was considered the most reliable launch vehicle in the world, with only 8 failures in 117 launches since 1988. With this record, this launch workhorse won the confidence of most satellite and other payload producers, and interestingly American private firms have commissioned more than half of its launches.[29] But given the increasing weight of payloads, especially satellites, the long-running Ariane 4 rocket is gradually being phased out over the next couple of years in favor of the new generation heavy-lift Ariane 5. After a shaky debut in 1996, and subsequent test flights in 1997 and 1998, the Ariane 5 became fully operational at the end of 1999, and completed its first full year of commercial service in 2000 with five successful commercial flights.[30] Overall, with the record of launches for 2000, another projected 12 for 2001, the arrival of Ariane 5, the time between mission launches an impressive average of 4 weeks, a backlog of about 49 payloads, and continued demand from both previous and new customers, Arianespace is poised to take a commanding lead in the commercial launch services market.[31]

Lockheed Martin: Arianespace's main competitors are basically from the United States, with both Lockheed Martin and Boeing at the top of the list. Lockheed Martin is one of the largest space and defense companies in the world, and has a long tradition of being active in the government launch business.[32] Since the mid 1980s, the company has worked closely with both the US Air Force and later NASA to develop and launch vehicles for military and government payloads. In this sphere, its' series have included the Titan, Athena, and Atlas rockets. The Titan series is not available for commercial purposes. The Athena series, while operational, has had relatively little commercial demand. As discussed below, it is the Atlas series that has moved definitively forward in the commercial launch arena, with a heavy-lift Atlas V currently in development.

Overall, Lockheed Martin approached the commercial launch market in two distinct ways, one through a long-term and costly partnership with NASA and the other through multinational ventures with other companies.[33] On the government side, NASA began to put forward the idea of the Reusable Launch Vehicle Technology (RLV) Program in the mid 1990s in an effort to remain competitive in the commercial launch business. Using a partnership with the US Air Force and private industry, the goal was to develop experimental flight vehicles – X-33 and X-34 – that could potentially provide revolutionary and cheap access to space.[34] In 1996, NASA awarded Lockheed Martin about $900 million to build the half-scale prototype X-33 as the fundamental technology driving next-generation reusable launch systems that incorporated single-stage-to-orbit (SSTO) characteristics. The company put up an estimated $200 million of its own money into the prototype, while also planning to funnel as much as $5 billion into the private development of the actual full-scale VentureStar.[35]

While the X-33 was to have first flown in March 1999, its estimated date of flight was later changed to 2003.[36] Lockheed Martin, and its team of subcontractors, was unable to complete the X-33 satisfactorily under the $912 million NASA commitment that ended December 2000. The program was then stretched out to March 2001 with an additional $68 million from NASA in order to keep the X-33 team involved in the project.[37] But in March 2001 NASA eventually terminated the X-33 and X-34 project in the face of mounting criticisms, budget limitations, and project uncertainties.[38] In its place, NASA focused attention on the Space Launch Initiative (SLI) that would support entrepreneurial space launch companies like Kistler and Kelly Aerospace, and eventually lead to a Fiscal 2005 decision on full-scale development of a reusable launch vehicle.[39]

Since the primary purpose of the X-33 joint project was to give a solid sense of how a full-scale prototype would perform under actual circumstances, the real payoff would have been in the "VentureStar" that would ideally replace the present government-owned Space Shuttle. A VentureStar fleet, built entirely by Lockheed Martin, would have become essential not just for the commercial satellite market but also for NASA's interest in using it for ferrying crew and supplies to the International Space Station. The SLI initiative differs from the VentureStar in that it focuses primarily on getting humans and cargo to orbit for NASA rather than simply launching payloads for NASA.[40] NASA began to announce contracts for this "second-generation" reusable launch vehicle effort by the middle of May 2001.[41] It is important to know that the VentureStar effort is not yet over, as Lockheed Martin has turned to the US Air Force to seek funding for its stalled X-33 program. The selling point, supported by some and questioned by others, is that the service needs a reusable spaceplane or space maneuvering vehicle for military purposes. Contingent on whether the Pentagon actually makes a decision to fund the projects at the cost of several hundred million dollars for at least two years, the VentureStar may well become a reality.[42] There is little doubt that the VentureStar remains a huge technology leap and, if successful, will revolutionize cheap access to space in the long-term and secure Lockheed Martin's place among the dominant players in the global industry.

In the more medium-term, however, Lockheed Martin has also attempted to enter the commercial launch services market more directly through joint ventures and mergers. In 1993, Lockheed Martin established the Lockheed Khrunichev Energia International joint venture in order to exclusively market the Russian Proton launch vehicle. In 1995, it then merged this joint venture with Martin Marietta that had purchased the General Dynamics Space Systems Division and its Commercial Launch Services subsidiary responsible for marketing the Atlas launch vehicles.

International Launch Services, a joint venture stock company, was the direct result of the Lockheed and Martin Marietta merger announced on 10 June 1995. With the formal original organizational structure of these two entities intact, ILS continues to operate as the main contracting entity for Proton and Atlas launches.[43] In July 1999, ILS also received the exclusive right to market the Angara class of launch vehicles, currently in development almost entirely domestically by Khrunichev of Russia and capable of handling payloads ranging from small-to-medium LEO satellites to medium-and-heavy LEO or GTO spacecrafts.[44] In 2000, ILS became a serious and established player in the competitive commercial launch market with 6 Proton and 8 Atlas launches of almost perfect operational reliability, two dedicated launch sites in Florida and Kazhakstan capable of simultaneous and independent launches, over $1 billion worth of contracts for launches altogether, and a backlog of about $3 billion representing launch contracts for 40 launches.

Boeing: The other serious player on the US side is The Boeing Company. With the merger of Boeing and McDonnell-Douglas in August 1997 – a move that shunted aside the seismic importance even of the merger between Lockheed Martin and Martin Marietta -- Boeing became the single largest aerospace company in the world.[45] Like Lockheed Martin, Boeing has had long-standing experience with space transportation systems, including NASA's Space Shuttle, the world's first reusable space launch system since the early 1980s. Here, Boeing, in a joint venture established with Lockheed Martin in the form of United Space Alliance (USA) since 1996, has been the single primary contractor for NASA's Space Shuttle programs.[46]

On its own, Boeing's main series has included the historic Delta rockets, the mainstay of NASA's and the US Air Force's missions and payloads into space. Although the Delta rockets production halted in 1981 due to the advent of the Space Shuttle, the Delta launch vehicles were resurrected in 1986 with the executive announcement that the Shuttle would not be carrying commercial payloads. Although the Delta II series that emerged after that was used primarily for US Air Force payloads, the Delta III series was driven primarily by a desire on Boeing's part to enter the lucrative commercial launch market for GTO payloads that were too heavy for the original series.[47]

But Delta III has had a shaky debut, and its future is not entirely certain. In 1998, the inaugural Delta III rocket exploded after it took off, destroying the satellite it was carrying. The second mission in 1999 also ended up with an engine failure, and the payload ended up in useless orbit.[48] Finally, in August 2000, to prove the rocket's safety, reliability, and long-term viability in the commercial launch market, Boeing decided to absorb the $85 million cost of flying the Delta III since it could not secure a customer. Fortunately, the third mission was successful with a simulated payload, and Boeing now has 18 Delta IIIs worth about $1.5 billion in order but there are few payloads assigned to those slots. Even with the successful mission, the estimated projection is now about 4-6 commercial missions starting in about 2002.[49]

The success of the third Delta III mission is also crucial for the reason that it is the transition vehicle for the ongoing development of the Delta IV Evolved Expendable Launch Vehicle (EELV) for medium-to-heavy payloads.[50] Once Delta IV becomes operational in the commercial arena, Boeing will phase out the Delta III. What is important, above all, is Boeing's commitment to the commercial launch business, with the top executive at Boeing pointedly stating that space projects, rather than commercial aircraft, represent the greatest opportunity for near-term growth at Boeing.[51] On this front, Boeing more recently made another aggressive move designed to cash in on the potentially lucrative commercial satellite industry to complement the launch side of its operations.

In January 2000, Boeing announced the acquisition of the space and communications businesses of Hughes Electronics Corporation, the world's largest satellite maker, for $3.75 billion in cash – a move some analysts dubbed a match made in heaven despite Hughes' problems.[52] According to Boeing, this acquisition, cleared by US and European regulators in October 2000, is expected to boost its annual space and communication revenues by more than a third for a total of about $10 billion, and allow it to gain a leading position in the global space and communication market that is itself expected to grow from its current annual figure of $40 billion to $120 billion by 2010.

Like Lockheed Martin, Boeing also remains committed to a presence in the commercial launch business indirectly through a multinational joint venture enterprise established in April 1995. The group is Sea Launch, with Boeing owning 40%, Russia's RSC-Energia owning 25%, Anglo-Norwegian Kvaerner Group of Oslo owning 20%, and Ukraine's SDO Yuzhnoye/PO Yuzhmash owning 15%.[53] Each partner is responsible for different operational contributions, and Boeing provides overall analytical and physical systems integration and missions operation. Since all launch sites in the US are owned and controlled by the government, private launch providers face uncertain costs and unlimited liabilities, as well as the possibility of commercial launches being preempted by government ones.[54] In order to mitigate some of these concerns, the truly novel idea behind Sea Launch is the use of a modified oil rig in the Pacific ocean, approximately 2200 kilometers Southeast of Hawaii, for commercial launches.[55] By launching from the Earth's equator, rockets can use the Earth's rotation to give additional boost, payloads have shorter distances to travel to their orbital locations, use less fuel, and cost less.[56]

The Zenit 3SL rocket, manufactured by Ukraine in tandem with Russia, was designed exclusively for Sea Launch operations for delivering large payloads to GTO. After payload processing and launch vehicle integration in the home port in Long Beach, California, the Zenit 3SL is then loaded onto a converted oil-drilling platform that sails to the equator where the rocket is positioned, fueled, and launched. The company now boasts a 50-day turnaround between launches from its floating platform, with the possibility of even using the command ship to fetch a second rocket and payload leaving the platform at sea. The inaugural flight for Sea Launch, with a demonstration payload on the Zenith, took place successfully in March 1999. This was also followed successfully with the launch of a real satellite in October 1999. With a two-for-two record, Sea Launch looked poised to butt heads with the established players in the commercial arena. But then disaster struck in the form of a pre-launch sequence glitch in March 2000, and the Zenit failed to deliver the satellite for a crucial customer into space.[57] But despite this failure, and strong criticisms by competitors about Sea Launch's lapses in production, overall market confidence in the Sea Launch venture remained strong, and with justification.

Sea Launch rebounded quickly, establishing its presence with two faultless back-to-back launches. In fact, the fourth mission was crucial not just for restoring confidence in the viability of heavy-lift launches by Sea Launch as a multinational venture but rather, more importantly, for securing additional customers since many of them required a minimum of three successful launches before a trusting a new booster like the Zenit 3SL in the market.[58] In July, Sea Launch successfully placed a satellite into GTO. And in October 2000, it launched the world's heaviest commercial communications satellite for a telecommunication company based in the United Arab Emirates, with the additional promise of the next satellite in line for the same company.[59] Thus far, all three of the successfully launched satellites have been built by Boeing Satellite Systems, or its predecessor Hughes Space and Communications – confirming Sea Launch's, and especially Boeing's, intention of moving forward in an integrated and aggressive fashion in both the satellite and launch business. With a success rate of 80% thus far, and a launch backlog of about 17 payloads, operational capability for processing and launching at least 8 launches annually, it is safe to say that Sea Launch is going to be one of the premier launch suppliers for the heavy-lift launch capabilities.[60] In June 2001, Sea Launch also began to seek US government launch contracts such as through NASA, though at this stage it seeks to stay away from competing for military payloads.[61]

Overall there can be no question that Arianespace, Lockheed Martin, and Boeing remain the dominant players in the commercial launch arena. And in this arena, launch costs are crucial since they can serve as potential deterrents to hopeful entrants.[62] Here, everything depends on the payload weight and orbit required, and thus the launch-vehicle itself. For Arianespace, launch costs run from $65-$125 million for the Ariane 4, and about $150-$180 million for the Ariane 5. For Lockheed Martin and ILS, the Proton launches cost from $90-$112 million and the Atlas launches run the gamut from $75-$170 million. For Boeing and Sea Launch, the Zenit launches are estimated to go from about $35-95 million.

There is an additional factor, complicating the cost structure and the viability of new entrants. Since dual-manifesting is now feasible with launch vehicles able to launch with two satellites at one go, it is estimated that roughly half of the forecasted satellites will be launched simultaneously especially with the heavy-lift launchers. The size of the market, perhaps more now than ever before, matters for any new entrants into the commercial launch vehicles game. At present there are 40-45 launch vehicle programs that are or plan to be operational in the near future. The New Ariane, Delta, and Atlas boosters, as well as the Proton and Zenit are already well ahead in the game, especially as the commercial satellites continue to become heavier.[63] But, given the existing dominant players who will no doubt automatically receive a substantial portion of the market no matter which way it is headed, it is difficult to see how all these newer entrants will remain viable as commercial ventures.[64]

China and India: Yet these concerns have not stopped many other nations from wanting to enter the commercial launch arena. In fact, Japan is not unique in its desire to break into the space league of the dominant players. Despite severe setbacks for two years that almost made its Long March launch vehicles virtually uninsurable until 1996, the state-owned China Great Wall Industry Corporation, for example, continues onwards with upgrading its booster for both light and heavy launches.[65] With the simultaneous deployment of three satellites to LEO orbits by the Polar Satellite Launch Vehicle (PSLV) in May 1999, the Indian government too heralded its own arrival into a specific niche of the commercial launch market.[66] Like China, it too has been aggressively upgrading the PSLV for both LEO and GTO capacity.[67] In April 2001, India successfully launched its most advanced rocket, the Geosynchronous Satellite Launch Vehicle (GSLV-D1), capable of deploying heavy payloads into space.[68] Even if operational capability is not fully viable for all launches, both China and India are able to secure manifests simply because of global launch backlogs and, more importantly, the cost factor that many analysts deem key to long-term survival and success in the industry. Again, depending on the weight and orbit required, China's Long March launches can cost as little as $20 million for LEO and $75 million for GTO-bound payloads. The estimates for India's present and upgraded boosters suggest a similar range from $15-$45 million.[69]

Thus, despite justified concerns about the slowdown in the commercial launch arena, the costs as well as the uncertainties, the question is still not whether governments are interested in favoring the launch vehicles sector.[70] They clearly are. With the increased impetus given to reusable launch vehicles, governments in the US, Europe, and Japan, are all moving towards greater roles in the process of forging ahead. In fact, there is a widespread sense that these projects cannot be driven by the market, but may very well have to be driven by governments.[71] The harder question is why governments continue to persist in their favoritism. Based on the emphasis on technology and security developed at the start of this paper, I will provide one answer by examining the Japanese case more closely.

The Japanese Commercial Space Launch Industry

The commercial launch vehicles sector has formed one of the two main pillars of the Japanese space program, the other being satellites.[72] From a commercial point of view, space industry activities are dominated by space vehicles -- launch vehicles, space shuttles, and satellites -- followed by ground facilities, software development and data processing and analysis.[73] But it is still small compared to other industries, and all of these segments combined to produce a turnover of about $3.7 billion, exports of about $0.24 billion, and employees at an estimated 11,000 figure well into the close of the 1990s.[74]

The financial picture aside, there is also a historical and institutional trajectory of development in this industry that deserves careful attention. This section first sets out the main public and private players involved in Japan's space program more broadly. It then focuses on the main rocket generations in Japan, from the Lambda series that launched Japan's first satellite in space to the ongoing development of the next generation H-IIA. Finally, in keeping with the main theme, it assesses the criteria for selection, both economic and political, that are potentially driving the Japanese government's continued interest in this industry.

The Players

From the beginning, Japan's rocket research and development was subject to the intrusion of not one, but rather several, major government institutions.[75] The actual launch vehicles research began principally at Tokyo University in the mid-1950s, with a small group of intensely committed engineers and scientists. From there, it eventually led to the establishment of the Institute of Space and Aeronautical Science in 1964 at the University of Tokyo that functioned as a university-based research institute, and which was responsible for more systematic efforts at rocket development. In 1981, this institute was reorganized and taken over by what was then the Ministry of Education, and is presently known as the Institute for Space and Astronautical Sciences (ISAS). Because of the amalgamations planned under the Japanese administrative reforms, the Ministry of Education transformed into the Ministry of Education, Culture, Sports, Science and Technology (MEXT) effective 6 January 2001.[76] Continuing with its emphasis on core research and development, even today ISAS remains the main inter-university locus of activities and research in both space sciences and technology under MEXT as well.

The Space Activities Commission (SAC), established in 1968, is an independent senior advisory body under the Prime Minister's office, and has been responsible for formulating the fundamental policies of Japan's space program. It has also been responsible for interacting with the Science and Technology Agency (STA), the other main player in the space program. Until recently, this was an agency under the jurisdiction of the Prime Minister's Office, which had the status of a ministry and whose head had the status of a Minister of State for Science and Technology. Again, however, because of the administrative merges in January 2001, MEXT's minister is serving concurrently as the science and technology and ministry of education minister, and STA is now subsumed under MEXT. Both the National Aerospace Laboratory (NAL) and the National Space Development Agency (NASDA) were until recently under STA's jurisdiction, and are similarly now part of MEXT. With respect to launch vehicles, the focus in the early stages was the development of small-scale, solid fuel rockets that could launch scientific satellites, the first of which was launched in 1970. It was the general emphasis on getting into space as a whole that led to the creation of NASDA on 1 October 1969. NASDA was able to rely on the technology transfer provisions in the1969 US-Japan Space Technology Agreement to specifically produce rockets for launch application satellites.

One of the major criticisms of the Japanese space programs until recently, was its split jurisdiction, specifically between NASDA and ISAS, as well as the relations of the government agencies with the private sector.[77] Typically, at the head of Japan's space program as a whole, NASDA has conducted both engineering and hardware development, and is still the primary agency responsible for developing the next-generation H-IIA launcher series. ISAS has concentrated on basic scientific space research, and still takes the lead in all science and planetary programs. Although they have teamed up and done research and development together with respect to launch vehicles, culminating in the ongoing J rocket series, there were issues of jurisdictional rivalries between the two agencies.

NASDA has also been the bigger of the two agencies, in terms of personnel and budgets. As of 2000, NASDA had a staff of about 1000 personnel, whereas ISAS had one of only about 300. Similarly, NASDA's overall budget of about $1.7 billion dollars is far greater than ISAS's average of about $200 million.[78] Some international perspective is necessary here in terms of budgets, however. In the United States, NASA spends an average of about $13 billion a year for its space project. In comparison, Japan's combined official budget for space programs comes to around a total of $2 billion that leaves very little room for operational and developmental mistakes. As it is, a succession of failures in both satellites and launch vehicles has led to widespread domestic criticisms of the Japanese space program, its jurisdictional splits, and its ineffectiveness in establishing Japan's credibility as a player in the global commercial space arena. While consolidated under MEXT and waving the cooperation flag, ISAS and NASDA have not really merged in any real sense, with their various fields of competence still intact.[79]

Other, but far less pivotal, government players also have ambitions in the space sector. The Ministry of Posts and Telecommunications – now transformed into the Ministry of Public Management, Home Affairs, Posts and Telecommunications -- has had an interest in space activities related to radio waves, and it oversees other interested players like the Communications Research Laboratory (CRL), Nippon Telegraph and Telephone (NTT), Kokusai Denshin Denwa (KDD), and the Japan Broadcasting Corporation (NHK). The Ministry of Transport – now known as the Ministry of Land, Infrastructure and Transport -- has long been investigating the establishment of a multipurpose satellite system that would essentially cover the telecommunication needs of the ministry as a whole.

At the beginning of July 1997, two separate divisions at MITI, aircraft and space, both under the Machinery and Information Industries Bureau, formally merged into the Aircraft, Ordnance and Space Division. This division continues to exist under the ministry's new designation as the Ministry of Economy, Trade and Industry. While no formal reason was given for this merge, the idea continues to be that this focus on aerospace as a whole was the same as those found in other countries like the US and EU, with a bigger emphasis on space activities.[80] But in comparison to the talent, resources, and budget, MITI has been neither the most important nor the biggest player that is helping to shape this sector's prospects. Its main activities in the field are focused on the promotion of industrial utilization of space with a specific focus on remote sensing and uses of micro-gravity.[81] Even under its newly-minted description as the Ministry of Economy, Trade, and Industry (METI) in 2001, however, the ministry retains its interest in the space sector largely through its connections to the main firms involved in the space business, specifically those comprising the Rocket System Corporation (RSC).

No discussion of the central players in the Japanese commercial space enterprises would be complete without reference to the private firms with a vested stake in the business. The Rocket System Corporation, a Tokyo-based consortium funded by over 70 Japanese companies, was established in 1990.[82] Formed out of the long-running efforts of Mitsubishi, it was modeled after Arianespace, the European launch service provider, to specifically offer commercial launch services using the H-II and J-I family of launch vehicles.[83] Some of the main participating firms include Mitsubishi Heavy Industries, Ishikawajima Harima Heavy Industries, Kawasaki Heavy Industries, NEC, Mitsubishi Corporation, and Nissan Motors which sold its entire aerospace and defense unit for about $374 million to Ishikawajima Harima in February 2000.[84] Mitsubishi is the main leader in the group, and although its leadership has been resented it has thus far been successful in keeping RSC focused on the potential for launch service profitability in the future even when it appeared murky to the other members of the consortium. It has also been the systems integrator for all of the main rocket series in Japan discussed below, with Ishikawajima-Harima and Nissan as the key subcontractors.

The impetus for the formation of the RSC was partly to ensure successful commercialization of the H-II launchers though a deliberate and concerted effort to reduce costs. But that is not the only reason suggested for its formation. On 15 June 1990, a US-Japan Agreement on the Policies and Procedures for the Procurement of Non-R&D Satellites was concluded between the two governments, bringing to an end a "Super 301" investigation by the United States Trade Representative. On the Japanese side, many of the key firms involved in the space business, and especially the production of the H-II launcher series such as Mitsubishi, felt that the agreement represented a total concession by the Japanese government to American trade pressures.[85] From their point of view, the dire implication was that the H-II would get fewer satellite launches since interested parties would go for cheaper launches from abroad in competitive procurement situations. The emphasis on commercialization also galvanized the firms to seek support from both NASDA and MITI, in the form of securing foreign procurements in order to fill the now-vacant slots on the H-II's schedule.

But, typically, from the budget of the space program as a whole to the direct involvement and support of the government, little has been forthcoming. In terms of actual government support shown to this sector, favorable trade and industrial policies are modest. Unlike the past, there is no push to have a specific space industry law because trade partners, like the US, may take this as yet another sign of specific industry targeting. The legal basis for action is therefore provided under the Basic Law on Science and Technology enacted in November 1995, which stresses the general importance of promoting any related industries.[86] Total budget allocations for space development as a percentage of GDP hit a postwar high of 0.05% in the mid 1970s, and have since then fluctuated between 0.03% to 0.04% of GDP.[87] Budget increases have also been characteristically low, with the Ministry of Finance granting nominal increases of about 2% per year more recently, and a mere 5-7% in the past. Nor is government procurement alone enough to guarantee survival in the launch vehicle market alone.

While both the STA and NASDA have been involved on the research and development side, MITI is characteristically concerned with the business potential and welfare impact of the space industry. This, according to its officials, is its main concern through the RSC. For a variety of reasons, unlike other industries in the past the space industry cannot just be picked up for promotion through all kinds of tangible TIPs. So from the early 1980s, the idea has been to sell the potential of space-related businesses (such as in the no-gravity field) to the firms in term of how it affected their profits and sales.[88] Firms have been reluctant to move in given the nature of international competition and their backward status that has, as in so many other previous industries, galvanized government support. Within the present division at MITI, therefore, there continues to be innovative thinking about the kinds of institutional and infrastructural suport that would both encourage firms to move into this sector more wholeheartedly. With respect to launch vehicles more specifically, the goal is to make RSC more competitive in world markets vis-a-vis rivals in the US, Europe, Russia, China, and India. Industry officials suggest that ISHII interview.

The key idea from a commercial point of view is "cost-consciousness," that is making sure that products, such as rockets or satellites, have comparatively lower costs while still maintaining excellent quality. In addition, the idea is to shorten the time in terms of a product's delivery date. Both of these aims are consistent with the emphasis on deselection, rather than selection, made perhaps even more important by virtue of the hawkishness with which the US, and to a certain extent Europe, monitors Japanese developments in this sector. [89] To this end, allowing the importation of cheaper parts or giving tax breaks are under immediate consideration, because this would be the fastest way to encourage the domestic firms – though none of this can be guaranteed in the ongoing flux of administrative and budgetary changes in Japan today.

Although there is developmental funding provided through NASDA, direct subsidies are also not considered an option because of the limited budget and US pressures on a level playing field. In addition, there are now multilateral trade considerations at the WTO – which is all the more reason to emphasize bringing down the costs. Nor are R&D subsidies considered the overarching option, with the basic technology already in place, and with potentially little meaning again for the cost angle.[90] Overall, therefore, the private sector, whether through the RSC or not, is having to deal directly with the vagaries of foreign competition. Government agencies, whether ISAS, NASDA, or MITI, both in their old and newly transformed states, continue to emphasize the importance of thinking in explicitly commercial terms, discouraging direct government support or pointing to its limited nature particularly in comparison to that found in the US and Europe.

The RSC, composed of Japan's heavyweight aerospace firms, can well be thought of as a functional parallel to a government-sponsored procurement agency, much like the Japan Electronic Computer Company.[91] Its main procurement activities, however, go beyond government or national contracts to foreign ones in order to establish a foothold in the global launch services market. But irrespective of the budgetary and technical problems with government support as a whole, there is little doubt that the Japanese actors and players, especially on the government side, have not backed off from the development of a competitive space launch vehicle. Although slow to realize its initial potential, the emphasis given to indigenization comes across from the earliest postwar rocket series to the present development of the H-IIA that now stands at the heart of Japan's entire commercial launch ambitions in the future.

Main Rocket Generations

With respect to launch vehicles, Japan's rocket effort began in the 1920s, reached very modest success based on German rocket designs during world war II projects under Mitsubishi, and were stymied because of the SCAP ban on the production of aircraft and rockets in the postwar era.[92] It was not until after the Korean war, and the American exit from Japan that rocket production began to take shape. Here it was a private individual – "Dr. Rocket" – rather than the government that eventually paved the way for rocket development. Under the almost single-handed determination of Hideo Itokawa, best described as the Japanese Robert Goddard, Japan's independent launch ambitions began with the "Pencil" rocket, designed and launched 29 times by Itokawa and his associates. In 1955, public demonstrations of the Pencil were given in Tokyo, though the scientific community was not always convinced of their utility. From there, as Table I lays out, Japan's rocket series have moved in stages, showing a country clearly in quest of an indigenous and independent launch service capability.[93]

After the Pencil, the next rockets were the Lambda and Mu series whose development by Nissan Motor Company in conjunction with the Institute of Space and Aeronautical Sciences at the Tokyo university became key to launching satellites independent of foreigners.[94] In February 1970, Japan became the fourth nation in the world to put a satellite, albeit a test one, into space using the upgraded Lambda series. By August 1972, Japan had successfully placed three scientific satellites in orbit. Although the Mu series culminated in the present sixth-generation M-V that can launch astronomy satellites and planetary missions for the Japanese government, Japan also moved solidly in the direction of more powerful rockets that could be used in the commercial arena.[95]

By the mid 1970s, Mitsubishi had begun development of the N-1 series based on the use of licensed American technology rather than indigenous technology. The N-I series not only carried the first engineering test satellite for the budding telecommunication field, but also allowed Japan to be only the third country in the world to reach GEO orbit in 1977. In all, N-1 placed 7 satellites in orbit between 1975 and 1982 that were concerned with testing out telecommunication technologies. While Japan also continued to use the American Delta launcher for actual telecommunication satellites, it began to think about upgrading to the N-II series that could handle heavier payloads and reduce reliance on foreign launches. Again Mitsubishi was key to the enterprise, and again also it developed the N-II based on licensed American technology. In all, between 1981 and 1987, the N-II launcher placed 8 test, communication, and weather satellites in orbit.

Japan's ultimate ambition was the creation of an operational and competitive rocket. Since none of the fifteen N or nine H-1 missions was ever lost through launch failures, and this boosted Japanese confidence that Japan could break into the competitive commercial launch market.[96] The H-1 series represented a leap in indigenous technological advancement, since it meant using cryogenic propellants and an inertial guidance system made in Japan.[97] Since about 84% of the H-1 was made with equipment designed and built in Japan, it was a vital step in establishing independent launch capability in a country trying to catch up with the more established vehicles in both the US and Europe.[98] On its maiden launch in 1986, the H-1 successfully took three payloads into orbit thereby establishing its ability to handle heavier missions. Between 1987 and 1992, the H-1 took an additional 8 satellites successfully into orbit.

In the same month that the H-1 was making its debut as a launch vehicle, NASDA also sanctioned the development of the H-II. The H-II was constructed with the twin goals of technological autonomy and commercial service entry.[99] It succeeded in terms of the first goal. From start to finish the H-II was designed, developed, and launched by the Japanese using the lessons learnt during the earlier rocket series. It was capable of handling primary missions for intermediate GTO and LEO bound payloads. Although the H-II had a troubled development history, many observers believed that its maiden flight in February 1994 laid all qualms about its launching viability to rest.

Trouble began with its very next flight in August that started off with ignition problems and was eventually a partial failure, since it did not deliver its payload, the *Kiku 6* satellite, into GEO orbit.[100] Between 1995 to 1998, the H-II managed however to dispel those doubts by successfully placing 4 more payloads into space. And in fact the H-II was hailed as one of the most advanced rocket system in the world in terms of its integration of modern materials, electronics, computers and propulsion.[101] But its costs at around $165-$170 million per launch were prohibitive for commercial purposes, and the H-II remained captive to Japanese government payloads.[102] More important in terms of reliability assessments, the H-II had consecutive failures that tarnished it fatally. In February 1998, it had a partial failure when it was unable to deliver its payload to the correct orbit.[103] And its death toll came with an outright launch failure in November 1999, where both the rocket and the payload had to be destroyed minutes into the flight since the rocket began to veer off course.[104]

The H-II failure at the end of 1999 had wide-ranging repercussions, the most important of which was that it cast the indigenous development of a launch vehicle in a very poor technical and commercial light. Japanese officials cited it as the "most painful experience" in domestic launch

Table I
Timeline – Japanese Space Program and Launch Vehicles[105]

1945		Allied Powers ban Japanese armaments completely – aircraft research is prohibited. Academics move to closely related fields.
1952		San Francisco Peace Treaty: jet-planes research attracts former aeronautical engineers
1953	Dec.	Prof. Hideo Itokawa and others form the Avionics and Supersonic Aerodynamics Group (AVSA) are geared towards rocket development in Japan.
1954	Feb.	AVSA has its first official meeting. AVSA is given ¥600,000 as an annual budget for rocket development. Ministry of Education also gives the University of Tokyo ¥400,000 and ¥2,300,000 to the Fuji Seimitsu Company (now Nissan). These funds help develop PENCIL.
1955	Apr.	Institute of Industrial Science, University of Tokyo, conducts an experiment to launch the 23-cm long **PENCIL** rocket. 29 satisfactory test flights in 10 days launched horizontally from a 1.5m-long launcher. Based on these tests, a 300 mm long PENCIL, a two-stage PENCIL and a tailfin-less PENCIL are tested in a lab attached to the University of Tokyo in Chiba City. Following PENCIL, the 120-cm BABY Series is developed, consisting of the BABY-S, BABY-T and BABY-R.
1957-1958		International Geophysical Year (IGY) – Japan's participation is a success based on observations of the upper atmosphere and cosmic rays from the newly developed K-6 rockets (60km altitude). This success instigates further rocket improvement and the development of a K-8 type rocket.
1962		Kagoshima Space center established and opened as full-scale launch site. This new launch site on the Pacific Coast was a better launch site for the improved rockets than the narrow Japan Sea.
		NASDA's predecessor begins launches for applicational use, and encounters protests from fishermen, who lodge complaints with the Japanese government.
1964		**Institute of Space and Aeronautical Science**, University of Tokyo (the predecessor of ISAS) established upon the recommendation of the Science Council of Japan. This institute develops many sounding rockets: S-210, S-310, S-520, K-9M and L-3H (L-series).
1965	Jan.	**L (Lambda) SERIES** L-3-2 makes a successful flight, reaching the Van Allen belt, beyond 1000-km altitude.
1966	Jul.	L-3H-2 clears 1800 km summit altitude.
1967-1968		ISAS does not launch any rockets due to the "Fishermen's Problem". Since then, launches of sounding rockets from Kagoshima and Tanegashima have been limited to two 45-day periods, January-February and August-September.
1968		**Space Activities Commission (SAC) established.**
1969	Oct.	61st Session of the National Diet approves establishing National Space Development Agency of Japan (NASDA).
	Oct.	**NASDA established**. NASDA headquarters in Tanegashima, with branches in Kodaira and Mitaka, and tracking stations in Katsuura and Okinawa.
1970	Feb.	Japan's first satellite, *OHSUMI*, launched by the L-4S rocket, developed after trial and error experiments with the M-4S rocket, in development since 1966.
	Oct.	Development of N-II launch vehicle starts.
1971	Feb.	M-4S rocket's first launch, based on the success of L-4S. *Tansei*, a technological test satellite is put into orbit. This marks the beginning of the **M (Mu) SERIES** rockets.
	Sep.	Japan's first full-fledged scientific satellite, *Shinsei*, launched on a M-4S.

1972	Jun.	Tsukuba Space Center established.
	Aug.	Another M-4S launches *Denpa*, a full-fledged scientific satellite.
1974	Feb.	M-3C (2nd generation Mu with improved orbit injection) rocket No.1 launches the satellite *Tansei 2*.
1975	Feb.	M-3C rocket No.2 launches *Taiyo*.
	Sep.	**N-I SERIES** launch No.1, carrying *Kiku-1* Engineering Test Satellite – developed by the transfer of technologies used for the US Delta-Thor rockets.
1976	Feb.	N-I rocket No.2 launches *Ume* (Ionosphere sounding satellite).
	Sep.	Development of N-II launch vehicle starts.
1977	Feb.	M-3H (3rd generation Mu with greater payload capability) rocket No.1 launches *Tansei 3*.
	Feb.	N-I rocket No.3 launches *Kiku-2* (Japan's first geostationary satellite).
	Jul.	Delta 2914 (US) launches Geostationary Meteorological Satellite (GMS) *Himawari*.
	Dec.	Delta 2914 (US) launches Communications Satellite (CS) *Sakura*.
1978	Feb.	M-3H rocket No.2 launches *Kyokko* into orbit.
	Feb.	N-I rocket No.4 launches *Ume-2*.
	Apr.	Delta 2914 (US) launches Broadcasting Satellite (BS) *Yuri*.
	Sep.	M-3H rocket No.3 launches *Jiliken*.
1979	Feb.	N-I rocket No.5 launches Experimental Communications Satellite (ECS) *Ayame*.
	Feb.	M-3C rocket No.3 launches *Hakucho*.
1980	Feb.	N-I rocket No.6 launches *Ayame*-2.
	Feb.	M-3S (4th generation Mu with improved launch accuracy) rocket No.1 launches *Tansei 4*.
1981		Institute of Space and Aeronautical Science, University of Tokyo reorganized to become the **Institute of Space and Astronautical Science (ISAS)**, under direct control of the Ministry of Education.
	Feb.	**N-II SERIES** No.1 launches *Kiku-3*.
	Feb.	M-3S rocket No.2 launches *Hinotori*.
	Feb.	Development of H-I launch vehicle starts.
	Aug.	N-II rocket No.2 launches *Himawari-2*.
1982	Sep.	N-I rocket No.7 launches *Kiku-4*. Completion of N-I launch vehicle operations (7 satellites launched).
	Sep.	H-I launching facility built at Tanegashima.
1983	Feb.	N-II rocket No.3 launches *Sakura-2a*.
	Feb.	M-3S rocket No.3 launches *Tenma*.
	Aug.	N-II rocket No.4 launches *Sakura-2b*.
1984	Jan.	N-II rocket No.5 launches *Yuri-2a*.
	Feb.	M-3S rocket No.4 launches *Ohzora*.
	Aug.	N-II rocket No.6 launches *Himawari-3*.
1985	Jan.	The first **M-3S-II** rocket – still under development – successfully launches the *Sagikake* probe to Halley's comet, a success for ISAS.

Aug. Another M-3S-II rocket launches *Suisei*, which along with *Sagikake* succeeded in observing the comet, as part of the "Halley Armada" of spacecraft from the US, the USSR, Europe and Japan.

Aug. 3 Japanese payload specialists are selected for US Space Shuttle.

Sep. H-II launching facility construction begins at Tanegashima.

1986 Feb. N-II rocket No.7 launches *Yuri-2b*.

Aug. Development of H-II launch vehicle starts.

Aug. **H-I SERIES** No.1 launches

- Experimental Geodetic Satellite (EGS) *Ajisai*.
- Japan Amateur Satellite (JAS-1) *Fuji*.
- Magnetic Bearing Flywheel Experimental System (MABES).

1987 Feb. M-3S-II rocket launches *Ginga*, the X-ray astronomy satellite. *Ginga* later reentered the atmosphere.

Feb. N-II rocket No.8 launches Marine Observation Satellite (MOS-1) *Momo*. Completion of N-II launch vehicle operations (8 satellites launched).

Aug. H-I rocket No.2 launches *Kiku-5*.

1988 Feb. H-I rocket No.3 launches *Sakura-3a*.

Sep. H-I rocket No.4 launches *Sakura-3b*.

Sep. Intergovernmental Agreement (IGA) signed by Japan, US, European countries, and Canada, as a framework for the Space Station.

Sep. Completion of firing for the H-II rockets, test facility, the LE-7 engine at Tanegashima.

Sep. **TR-I SERIES** : TR-I-1 rocket launched – technical data acquisition for H-II development.

1989 Jan. TR-I-2 rocket launched – serves as basis for technical data acquisition for H-II development.

Feb. M-3S-II rocket launches *Akebono*, a scientific satellite for observation of the northern lights.

Jun. National Diet approves Intergovernmental Agreement (IGA).

Aug. TR-I-3 rocket launched – technical data acquisition for H-II development.

Sep. H-I rocket No. 5 launches *Himawari-4*.

1990 Jan. M-3S-II rocket launches *Hiten*, to conduct lunar swingbys. *Hiten* later ends up falling onto the moon.

Feb. H-I rocket No.6 launches

- *Momo-1b*.
- JAS-1b *Fuji-2*.
- Deployable Boom and Umbrella Test (DEBUT) *Orizuru*.

Jul. RSC established.

Aug. H-I rocket No.7 launches *Yuri-3a*.

1991 Mar. RSC – Orders awarded for H-II Launch Vehicle No.3 and spare vehicle, as well as TR-IA Rocket No.2.

Aug. H-I rocket No.8 launches *Yuri-3b*.

Aug. M-3S-II rocket launches *Yohkoh*, for solar observation.

Sep. **TR-IA SERIES**: TR-IA-1 – microgravity experiments.

1992	Feb.	H-I rocket No.9 launches Japan Earth Resources Satellite (JERS-1) *Fuyo*. Completion of H-I launch vehicle series (9 satellites launched).
	Mar.	RSC – Orders awarded for H-II Launch Vehicle No.4 and spare vehicle, and TR-IA Rocket No.3.
	Jul.	Delta 6925 (US) launches *GEOTAIL*, a Japan-US cooperation for the study of the solar-terrestrial system.
	Aug.	TR-IA-2 – microgravity experiments.
1993	Feb.	M-3S-II rocket launches *ASCA*, an X-ray astronomy satellite.
	Apr.	RSC – Order awarded for Tanegashima launch site facilities maintenance services.
	Apr.	Development of J-1 rocket starts.
	Sep.	TR-IA-3 – microgravity experiments.
	Oct.	RSC – Nagoya Branch Office established.
1994	Feb.	**H-II SERIES** rocket No.1 launches ▪ Orbital Reentry Experiment (ORBEX) *Ryusei*. ▪ Vehicle Evaluation Payload (VEP) *Myojo*.
	Mar.	RSC – Orders awarded for H-II Launch Vehicle No.5 and TR-IA Rocket No.4.
	Jul.	RSC – Tanegashima Branch Office established.
	Aug.	H-II rocket No.2 launches *Kiku-6*. Failure to inject satellite into orbit.
1995	Jan.	M-3S-II's final act, the launch of the *EXPRESS* satellite ends in failure.
	Mar.	RSC – Orders awarded for H-II Launch Vehicle No.6 and TR-IA Rocket No.5.
	Mar.	H-II rocket No.3 launches Space Flyer Unit (SFU) and *Himawari-5*.
	Aug.	TR-IA-4 – microgravity experiments.
	Nov.	RSC – Order awarded for H-II Launch Vehicle No.8.
1996	Feb.	**J-I SERIES** rocket No.1 launches Hypersonic Flight Experiment (HYFLEX).
	Mar.	H-II Launch Vehicle No.7 and TR-IA Rocket No.6.
	Apr.	SAC 12-member task force deems J-1 rocket to be "slightly inferior." [106]
	May	NASDA announces its intention to scrap the J-1 launch rocket.
	Jul.-Aug.	Automatic Landing Flight Experiment (ALFLEX) conducted 13 times.
	Aug.	H-II rocket No.4 launches Advanced Earth Observing Satellite (ADEOS) *Midori*, and JAS-2 *Fuji-3*.
	Sep.	TR-IA-5 – microgravity experiments.
	Nov.	RSC – Contracts concluded with Hughes Space & Communications International, Inc. and Space Systems / Loral, Inc. for commercial satellite launch services using H-IIA launch vehicles.[107]
1997	Feb.	**M-V SERIES** makes its debut as the first M-V launches *HALCA*, the world's first space VLBI satellite.
	Sep.	TR-IA-6 – microgravity experiments.
	Nov.	H-II launch vehicle No.6 launches ETS-VII *Orihime Hikoboshi* and Tropical Rainfall Measuring Mission (TRMM).

1998	Feb.	H-II rocket No.5 launches *COMETS* Satellite– fails to put satellite into high enough orbit.[108]
	Mar.	RSC – Order awarded for the Test Vehicle No.1 of the H-IIA Launch Vehicle.
	Jul.	M-V rocket No.2 launches *Nozomi*, Japan's first Mars explorer.
	Nov.	TR-IA-7 Experimental Space Rocket successfully launched from Tanegashima.[109]
1999	Nov.	H-II Launch Vehicle No.8 fails.[110]
	Dec.	Space Activities Commission (SAC) decides to scrap H-II program in favor of developing **H-IIA launch vehicle**, based on H-II's failure in November.[111] Other relevant recommendations: ▪ Cancel H-II Launch scheduled for FY 2000. ▪ Addition of another H-IIA flight demo to the existing one (Scheduled FY 2000 and FY 2001). ▪ Start of H-II Orbiting Plane Experimental (HOPE-X) to be passed over and project to be reconsidered anew.[112]
2000	Jan.	NASDA and the Japan Marine Science and Technology Center (JAMSTEC) publicize the retrieval of H-II No.8's lost engine[113]
	Jan.	NASDA and France's Centre National d'Etudes Spatiales (CNES) sign an agreement on the High-Speed Flight Demonstration (HSFD), covering managerial and operational cooperation on the HOPE-X, which NASDA and the National Aeronautics Lab (NAL, under STA) hope to launch in FY 2004.[114]
	Feb.	M-V rocket No.3 launches *ASTRO E* – failure.
		NASDA concludes a 20-year agreement with the Republic of Kiribati concerning the use of Christmas Island for constructing a landing site for HOPE-X, with the agreement to be reviewed at 7, 12, and 16 years.[115]
	Jun.	H-IIA first-stage captive test successful. Next test projected for July 2000.

vehicle development.[116] By the end of 1999, NASDA had to scrap the H-II program altogether, and cancelled the subsequent flight of an almost fully developed H-II (Number 7), last in its series, that was to have launched experimental and communications satellites.[117] The after effects of the failures also reverberated in the future course and development of the J-1 launch vehicles. Designed as a combination of both the H-II and M-3SII rockets, the J-1 series were to specifically carry small LEO payloads with estimated commercial launch prices running from $30-45 million. The J-1's one and only flight in February 1996 can best be termed a partial success, since the launch was perfect but the payload, the prototype HYFLEX shuttle, sank after it splashed down and could not be recovered.[118] From a jurisdictional perspective, this was a blow, since the J-1 was designed and developed using the expertise of both ISAS and NASDA – a move that was surely partially designed to showcase the potential of inter-agency cooperation for Japan's space program as a whole. In the follow up, a task force of the SAC labeled the J-1 rocket "slightly inferior" both in terms of quality and cost since it price averaged in at more than twice the global average.[119] Although research for the J-1 Upgrade Launch Vehicle started in November 2000, an evaluation report of the Subcommittee for Space Transportation suggested postponing any actual development plans of the small rocket program while still encouraging the ongoing research.[120]

In the place of both the H-II and the J-1, the production focus of the Japanese launch ambitions is henceforth on the H-IIA launch vehicle family with at least five distinct versions.[121] The target launch costs were estimated to be around $75-$95 million for intermediate GTO and LEO payloads that could compete directly with those offered by US and European launch service providers. These cost reductions were thought possible both because of a more streamlined rocket and also foreign procurements, especially from the private sector. In 1996, buoyed by the then successes of the H-II, Hughes Space and Communications signed an estimated $1 billion deal with RSC, with 10 launches commissioned on the H-IIA beginning in 2000.[122] This historic deal was crucial to establishing the credibility of RSC as a viable entrant in the global competition. A unit of Loral Space and Communications, Space Systems/Loral, had also signed on an additional 10 flights on the H-II, again contributing to establishing the Japanese as significant players in the commercial launch arena.

Since the H-II served as the basis for Japan's future launch vehicle technology, such as the H-IIA, its performance had strong implications for whatever would follow in its wake. At the moment, market perceptions of Japan's launch vehicles are hardly positive given the H-II's back-to-back failures and the as yet untested potential for the H-IIA itself.[123] And unfortunately, at the start of 2001, business for the H-IIA does not look promising. For one thing, NASDA has already announced launch delays, with the prototype launch pushed to late 2001 and the maiden flight of the H-IIA not even projected to occur until some point in 2002.[124] These delays can be crucial for the very survival of Japan's rocket program because the US Air Force-subsidized EELV, a commercial rocket that will eventually replace the existing US Delta III, Atlas, and Titan boosters, is set to become operational in 2002. This would be at about the same time, if all goes well, that the H-IIA will be making its debut. In a head-to-head competition, delays of even a year or two could have severe competitive implications for which launch provider gets the most satellite customers.[125]

The overall developmental goal for the H-IIA class vehicles remains not only to increase operational launch capability with double the payload capacity but also to make sure, more significantly for survival in the commercial market, that launch costs are reduced significantly. And here is another key problem. Much to the consternation of RSC, Hughes, now part of Boeing, cancelled the 10 firm launch orders in May 2000 citing the unreliability of the Japanese launch vehicles thus far.[126] Space systems/Loral, the other major RSC client, has not cancelled its contract but has requested and received its prepaid portion.[127] But overall, despite official reprimands, H-II failures, H-IIA production delays, high costs, falling budgets, as well as fleeing business opportunities, Japanese space-related government agencies have not lessened their commitment to entering the commercial launch service arena. Why? What is so important about this particular industry that it must be indigenized?

Spillovers, Defense, and National Economic Security

No matter what their differences or specialization, the official reasons for focusing on this sector are the same across the board in the government agencies, whether in actual documents or in interviews. SAC, which has been formulating the fundamental policies on Japan's space activities since 1978, sets the tone for the entire enterprise on civilian use of future space activities. Pointing to the fact that space technology is a highly sophisticated generic technology which integrates various fields of science, SAC's vision is that it will not only lead to new technologies but may well give rise to entire new industries in materials, computers, robotics, electronics, communications and information processing.[128]

The STA points to the importance of space development for providing solutions to global environmental problems, increasing communication in the society at large, and potentially creating new technologies and industries in materials and electronics.[129] From the perspective of the whole Japanese economy, it is clearly the criteria of growth and spillovers in this technology and knowledge intensive industry that is driving concerns about its place in the Japanese economy.[130] NASDA too points to the immeasurable impact of the industry on other fields both in the past and the future.[131] Along the same lines, MITI too considers space to be a high growth and high value-added sector with great potential for technological spillovers that will go on to affect the future industrial destiny of Japan.[132] In short, the widespread perception in the Japanese space-related governmental institutions is that this leading industry of the 21st century will spur transformations in existing technologies, underwrite the future of the information society, and expand the frontiers of humankind.[133] On behalf of the industry firms, SJAC points to the potential profits to be made in an industry that promises to spill over into many different activities in the future.[134] It is difficult to appreciate the importance attached by Japanese official to positive technological spillovers, and the role these play in industrial advancement, without reference to the perceptions and beliefs of Japanese government officials. The following comment by an official is particularly apt, since it comes from someone who was heavily involved in the process of initiating and coordinating space efforts in the public institutions.

> It wasn't that it was a huge industry that we could have completely, but the idea was to promote some high-tech systems… like engines… The fact that the space industry was a very linked industry helped the interest in other industries, and it could pull them along. The main criterion that was important was this idea of spillovers… and the idea is that other ordinary sectors could also be helped. That is why the merit of the space industry is

> that it is R&D intensive and so new, it is a new way, it uses up a lot of existing industries technology like telecommunications or satellites, it is a fast new flow. Essentially the idea is to promote the technological spillovers. Well, the whole thing is in terms of potential anyway... and there is a dream of space, and that is why it is supported by bureaucrats and also politicians…[135]

But the focus on spillovers and external economies in the economic sphere alone, as this official went on to explain, is unsatisfactory, since there is a specific defense and military angle to consider as well. This is what links the launch vehicles sector vitally to perceptions about national economic security. While there has always been some concern that space launch vehicles could be used for military purposes, such as the conversion of the H-II series into intercontinental ballistic missiles, the more immediate issue is one of national launch capability for reconnaissance satellites. This is an aspect that most officials are not willing to discuss openly. This is largely because, as many observers have noted, the Japanese public or private actors involved in technology matters consciously choose to avoid association with defense production.[136] However, it is a public fact that since May 1993 when North Korea test-launched a Nodong-1 missile that landed in the Sea of Japan, Japanese defense and space-related agencies have considered launching spy satellites.

These domestic debates came to a head in August 1998, when North Korea launched a multistage Taepodong-1 missile whose nose cone flew over Honshu and landed in the Pacific Ocean. Directly in response to this North Korean threat, there was a flurry of domestic political rhetoric and activity over the necessity of launching spy satellites at all. Even strict adherents of Japan's defense-only security policy concurred with the necessity of better intelligence and information in order to safeguard Japan's territorial integrity. Whereas it had considered buying them from the US, by early April 1999, Japan had formally announced that it would be developing and launching four spy satellites by 2002, and subsequently 2003, on its own.[137] More important, but less obscure from the high profile public debates, was the basic necessity of how Japan would get those satellites up into orbit. This is exactly where space launch vehicles become crucial in the defense arena. As it turns out, if all goes well, the four reconnaissance satellites will be launched using the H-IIA – making Japan far more independent in terms of its intelligence gathering capabilities and thereby also strengthening its defense resources at a basic level.

While the national defense capabilities argument can be used by the government space-related institutions to galvanize more support for the domestic industry from the politicians, it is also one that can be used effectively by the private sector firms to garner more direct developmental funds from the government. This can done either individually by heavyweight firms like Mitsubishi through NASDA, or in the impressively combined lobbying power of either the SJAC and RSC through politicians or other government agencies.[138] The focus of such efforts, given the emphasis on commercialization as well as the vigilance of Japan's trade partners in this particular sector, means government support for securing procurement whether at home or abroad in the active manner of Arianespace.

Although criticisms of the space program as a whole abound in Japan these days, the launch vehicle sector, both for reasons of technological externalities and defense, is shielded from the influence and interest of politicians.[139] While there is some electoral impact because the sector comprises the concentrated firepower of Japan's heavyweight aerospace firms, it is hard to make the argument for unilateral influence from politicians to bureaucrats if the firms want more favorable policies. For one thing, the firms, whether individually or through their combined platforms, are more likely to approach the government space agencies directly, often bypassing politicians altogether. After all, it is the government space agencies that are far more interested in the fate of the launch vehicles sector, and what it ultimately means for Japan's long-term economic and security policy. What made the job of industry influence problematic was also the bifurcated nature of Japan's space agencies that limited effective cooperation and support for the industry. The recent amalgamation of both ISAS and STA may have important implications for the overall political backing and sanctioning of further developments in this sector.

Moreover, given the succession of failures in the Japanese space programs as a whole, the real challenge is to worry less about political pressures and more about how to keep the private firms even interested in the potential profitability of the space sector as a whole, and the launch vehicles business in particular. As it is the aerospace business in total comprises a mere 10%-20% of the total business even in the big firms, with space-specific activities even lower. There can be little question, however, that in a very general sense both the politicians and the public do ultimately have national pride in Japan's space program as much as the bureaucratic agencies. In my judgement, despite all manners of problems, there continues to be a strong consensus in both the public and private sphere that Japan's goal should be the development of an indigenous launch vehicle, with the present hopes pinned largely on the H-IIA.

The Future of Japan's Space Launch Vehicles Industry

Given these realities – the limited nature of government support, the skittishness of business firms, the recent setbacks, but still the very real consensus on indigenization – it would be helpful to end by discussing where Japan's launch vehicles program is headed. First of all, it is important to remember that setbacks and disasters are not just unique to Japan. Some of the presently dominant global players have also been similarly plagued. Boeing's Delta III, for example, has had a rocky and uncertain ride until very recently. To prove its worth the third time around to potential customers, Boeing had to swallow the cost of sending the rocket up. Japan's H-IIA program may well have to go the same route, since it has already lost potential customers and desperately needs to attract them back in order to remain viable in the commercial launch arena at the global level. One or two successive launches by the H-IIA, with the Japanese government absorbing the cost of at least one, could very well bring Japan back definitively into the commercial game since perceptions as well as technical reliability matter in the long run.

Second, short-term agreements, partnerships, and joint ventures may be key to Japan's ultimate quest for indigenization. Again the Delta III, one of the largest and most powerful privately funded launch vehicles ever developed, is equipped with hardware from contractors like Mitsubishi.[140] This kind of know-how is crucial for Japan's launch vehicles ambitions as a whole because Mitsubishi has played the pivotal role of system integrator for all the major rocket series in Japan, including the H series. But the focus on expendable boosters is not the only way to go. Arianespace also now has an agreement with NASDA to expand the commonality of technical components between the Ariane 5 and the H-IIA. Since, according to this agreement, the H-IIA will be equipped with satellite mounts compatible with the Ariane 5, Arianespace clients that run into launch troubles or failures will have the option of an emergency back up service through the Japanese. This will allow Arianespace, and to some extent the Japanese as well, to compete directly with established competitors like Boeing and Lockheed Martin in the US.[141] On 31 January 2000, NASDA also signed an interim agreement with Centre National d'Etude Spatiales (CNES), the French Space Agency, in order to develop cooperation in the field of reusable launch vehicles. The goal is to pool services and exchange equipment and resources with a view to designing spaceplanes that constitute an important step towards developing technologies for next generation of reusable launch vehicles.[142] These technologies may well end up butting heads directly with similar efforts in the US, such as the possibility of continued public-private cooperation in the X-33 and X-34 projects, and the new directions under NASA's Space Launch Initiative (SLI) that focuses on reusable launch vehicles.

To conclude, given the flux in the present administrative, political, and business spheres, whether the Japanese space agencies can actually support the launch vehicles industry, or space sector as whole, as much as they would like is unclear. But what is clear is the logic that motivates them: technological linkages and externalities, as well as the very real defense and military implications. Even when political pressures exist for more favorable government support however, these realities determine the limited nature of government selection, and to some extent, force Japanese firms to deal with the vagaries of economic competition from the start.

The buzzword is "commercialization," where the emphasis continues to be on assuring the ability of Japanese industry to get up on its own merits and compete in the global space launch arena.[143] In this respect Japan is not unlike Europe which has long sought to surpass the US space industry. Perhaps the commercialization of the Japanese industry has a long way to go to catch up with the more established competitors in Europe and the US, and perhaps it will get there only in fits and starts at the global level. The point is not that the Japanese are less than successful in the global launch vehicles industry. The point is that they remain in the game for the widespread benefits, perceived and tangible, that are then conferred upon the whole Japanese industrial base and that affect Japan's national economic security in the long-run. In fact, Japan has not lost its emphasis on technology policy in the wake of a decade long recession. If anything, the recession has only served to show all relevant domestic participants the necessity of Japan moving onwards and upwards in the high-tech chain, space ventures included.

This thinking in Japan's space-related institutions will no doubt also receive an added impetus from the recent emphasis on the importance of outer space in strategic and military planning in the US.[144] In addition, political realities in Northeast Asia, especially with respect to China and North Korea, have already forced Japan to seek a more militarized role in space, as the continuing saga of the four projected reconnaissance satellites shows. Nor does Japan want to play a humiliating "catch-up" in launch vehicles, or in space in general, with as yet technologically backward countries like China or even India, both of whom have made important strides in establishing independent and commercially viable launch vehicle capability.

All these reasons suggest that Japan's competitors should not be too hasty in writing off either public or private Japanese efforts. Since they stand to be direct participants in the global launch markets, Japanese corporations, through the RSC, are certainly cost-conscious as this remains key to competitiveness in the global commercial launch market. But despite tangible setbacks they also remain interested and, through subcontracts and alliances, active in the development of indigenous launch vehicle capability. What they would no doubt like to see, apart from direct financial aid for R&D, are government efforts to secure launch procurements either at home or abroad as an effective means of support in a highly competitive commercial market.[145]

Perhaps more importantly, the historically-rooted emphasis on technology as the basis for Japan's economic and political survival means that the Japanese government continues to seek an entirely indigenous launch vehicle capability. Although there is a strong emphasis on commercialization, factors such as economic uncertainties, market turbulence and unpredictability, as well as issues of cost competitiveness do not necessarily thwart this ultimate objective. It is by no means clear that Japan will become a viable player in the global commercial launch vehicle industry. But what is clear is that the Japanese government will make every effort to ensure that launch vehicles, as well as satellites that constitute the other pillar of Japan's space efforts, are indigenized in the interest of long term national security.

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Endnotes

[1] Dosi, Tyson, and Zysman 1989, 4, 13.
[2] Okimoto 1989, 79.
[3] Prestowitz 1989 [1988] 248-285, 508.
[4] Samuels 1994, 14-78, 244-246, 339.

[5] Krugman 1983, 123-155; Krugman in Krugman ed. 1986, 14-17; Lawrence and Schultze 1990, 13-18; Tyson 1992, 3-5; Krugman and Smith 1994, 5-6; Grossman 1986; and Dixit and Grossman 1986.
[6] Krugman 1993, 363; Helpman and Krugman 1989, 8.
[7] Samuels 1994, 245-246. For instance, one of Samuels' key contentions is that MITI used a powerful metaphor to suggest why aerospace was a strategic industry. This metaphor -- "the industry as the trunk of a tree with roots in key basic technologies and fruits in every variety of industrial and consumer product line" -- is a powerful example of how the Japanese see linkages or extensiveness of uses as the crucial characteristic of strategic sectors such as space launch vehicles in the present study.
[8] Ithoh, Kiyono, Okuno-Fujiwara, and Suzumura 1991, 40-42, 81-82.
[9] Pekkanen 1996, 2001.
[10] Basic terminology and facts concerning the global launch vehicles industry are drawn from key publications by the American Institute of Aeronautics and Astronautics (AIAA) and the American National Standards Institute (ANSI) on space launch systems, especially from Isakowitz, Hopkins, and Hopkins 1999, ANSI/AIAAa 1999, and ANSI/AIAAb 1994. For up-to-date information extensive use is made of the official websites of all major private companies discussed here, government space agencies websites, the general online and regular features in the leading US industry trade journal *Aviation Week & Space Technology* (hereafter, *AWST*), and the excellent newssite http: //www.space.com (hereafter, *Space.com*, posted date).
[11] Launch vehicles, whose primary purpose is to deliver payloads into space, may use solid and/or liquid propellant, have different numbers of stages, and different orbital capabilities for delivery of payloads.
[12] The three major types of orbits are as follows. Low earth orbit (LEO) ranges in altitude from 200 to 1000 km. above earth, and is generally used to designate any orbital altitude below the near-Earth radiation belt. Since it takes 20 to 40 milliseconds for a signal to bounce from earth to LEO and back (latency), LEO satellites can provide services ranging from pager and cellular telephones to voice and data broadband services. LEO satellite services target three major markets, namely conventional phones especially in rural or remote areas, global mobile phones, and international broadband services. Geostationary earth orbit (GEO) refer to circular orbits over the equator at altitudes of about 36,000 km. Any payload at GEO orbit is synchronous with the earth (meaning that GEO is a particular type of geosynchronous orbit) and rotates as the same speed as the earth every twenty-four hours at a selected longitude. The latency for GEO satellites is 0.24 seconds, and because transmissions can be received through fixed antennas on greater portion of earth area, they are ideally suited for telephone services, direct TV broadcasts, digital data etc. Finally, medium earth orbit (MEO) refers to any orbital altitude between LEO and GEO, generally between 8,000 to 16,000 km. The latency for MEO satellites is 50-150 milliseconds, and they are often used in conjunction with GEO satellite systems.
[13] See specifically "Low-Cost Commercial Launch Vehicle Propulsion Technology" appearing at the Johns Hopkins University Chemical Propulsion Information Agency (CPIA) website at www.jhu.edu/~cpia/launchve.html. See also Lenorovitz 1993, 83-86; and Anselmo 1996, 87-89, who points to the trend towards commercialization fuelled by booms in satellite-buying from places like Asia. Hughes, for example, took 25 satellite orders in 1995, 22 of which were from commercial customers and only 3 from NASA. In keeping with this trend, military planners in the Pentagon also sought to take advantage of technologies developed and launched by the private sector.
[14] Asker 1995, 44-45. In terms of commercial applications, satellites are used for telecommunications, internet access, broadcasting and imaging, as well as other scientific and military applications.
[15] Velocci 1995, 66. Most private sector companies were predicting oversupply of launch capacity in the early 2000s. However, there was a great deal of disagreement over the many projected trends for market growth for launch vehicles because of the inclusion and/or exclusion of LEO, MEO, and GEO satellites.
[16] Anselmo 1996, 89. Other big LEO ventures included Loral-led Globalstar, TRW-led Odyssey, and Inmarsat-led ICO Global Communications. In all these four competing ventures represented about $12 billion worth of investments.
[17] Anselmo and Mecham 1997, 48-49.

[18] Anselmo 1997, 51-53; and Covault 1993, 83-84.
[19] Anselmo 1996, 89.
[20] The following discsussion draws on Caceres 2000b, 151-152.
[21] *Space.com*, 6 June 2001. After the original company's bankruptcy, in 2000 the Iridium system was bought out by Iridium Satellite which signed a two-year $72 million contract with the Pentagon.
[22] Dornheim 2000, 34, 51.
[23] AST/COMSTAC 1999, iii; AST/COMSTAC 2000, iii, 1. These estimates are for both the GEO, as well as LEO, MEO and elliptical (ELI) orbits. Several factors may be affecting this flattening of demand in the GEO market, such as technical problems either at the satellite or launch end, dual-manifesting, other unavoidable business, transportation, financial, or regulatory delays etc. With respect to the non-GEO market, failures like the Iridium bankruptcy are likely to affect the increased skepticism regarding non-GEO launches in the short term as a whole.
[24] Buskirk 2000.
[25] US launch service providers carried out 13 launches, with the European ones carrying out an additional 21. China and a multinational launcher carried out one each of the remaining two. Note that GTO refers to an elliptical Earth orbit that is used to transfer a payload or spacecraft from LEO or flight trajectory to a GEO orbit.
[26] See http://www.arianespace.com for some of the basic information.
[27] Since 1996, Arianespace has also been a partner in the Starsem joint venture that commercializes Russian rockets Soyuz and Molinya. The French government now permits Russian rockets to launch from its facility in Kourou, Guiana in an effort to compete head on with US Evolved Expendable Launch Vehicles (EELV) by Boeing and Lockheed Martin. See *Aerospace Daily*, 12 June 1998, 407.
[28] Part of the following draws on information on http://www.arianespace.com/news_features.htm for 7 January 2001, and 10 January 2001.
[29] Scott 1999, 36-38.
[30] In addition, several performance improvements that have been introduced in the second batch of Ariane 5s ordered in 2000 by Arianespace.
[31] There was a four-month hiatus between April 18 to August 18 2000 due to the unavailability of satellite payloads. *Space.com*, 10 January 2001, reported that the Arianespace launch consortium posted its first-ever net loss in 2000 of about $190 million due largely to its ability to operate two simultaneous launch pads but inability to launch the heaviest commercial satellites two at a time.
[32] The most recent information on the company and its launch activities is from http:// www.ils.com and also http:// www.ilslaunch.com.
[33] Lockheed Martin has also independently developed the Atlas 5 but this launcher competes head-to-head with Boeing's Delta IV that has already been contracted to launch the majority of US military satellites in the near future. For this reason, the future commercial or government viability of the Atlas 5, much less the Atlas V Heavy, is highly uncertain. See Caceres, 2001, 146.
[34] See, for example, US Government 1995, esp. 2-3. Lockheed Martin and Orbital Sciences were responsible for developing the X-33 and X-34 suborbital test vehicles respectively.
[35] Halvorson 1998. The X-33 is about one-half the size, one-ninth the weight, and one-fourth the cost of VentureStar.
[36] See *Space.com*, 26 August 1999, 27 August 1999, and 2 September 1999 for congressional criticisms and NASA's defense of the X-33 program's cost overruns at the end of 1999.
[37] Dornheim 2000, 36, 41.
[38] *Space.com*, 1 March 2001; Morring 2001a, 24.
[39] Morring 2001b, 29.
[40] *AWST*, 19 February 2001, 66. Given NASA's unsuccessful trajectory in the development of reusable launch vehicles, the birth of SLI has not been welcomed at many levels. Representative Dana Rohrbacher (R-Calif.), chair of the space subcommittee of the US House Science Committee, considers that the SLI is way off course in terms of its objectives of improving US national launch capabilities in financial and human terms.
[41] *Space.com*, 16 May 2001.
[42] *Space.com*, 16 April 2001. Orbital Sciences was seeking similar funding from the US Air Force for its equally stymied X-34 project.
[43] Legally, ILS is owned by Lockheed Martin Commercial Launch Services (LMCLS) and the Lockheed Khrunichev Energia International (LKEI) joint venture.
[44] All Angara flights are to be supervised by the Russian Aviation and Space Agency, and will give Russian military or national satellites priority over commercial ones.

[45] The most recent information on the company and its launch activities is from http:// www.boeing.com and also http:// www.sea-launch.com.
[46] Most recent information is from http://www.unitedspacealliance.com. USA was originally a joint venture between Rockwell and Lockheed Martin in 1995. However, Rockwell aerospace and defense businesses were sold in December 1996 to The Boeing Company.
[47] Boeing executives explicitly saw the heavy-lift Delta III competing directly with Lockheed Martin and foreign competitors in the "sweet spot" of the booming commercial launch market. See *Seattle Post-Intelligencer*, 21 August 1998, F1.
[48] *Seattle Post – Intelligencer*, 21 August, 19998, F1; and 27 August 1998, A1.
[49] Covault 2000d, 48-49; and Covault 2000 27-30. Hughes, as part of Boeing, has booked 11 flights, Loral has booked 5, and SkyBridge project has booked two more.
[50] In October 1998, the US Air Force announced an order for 19 Delta IV launches valued at about $1.3 billion for the EELV program. The first commercial Delta IV orders were announced in 1999, with launches planned for 2001. Note that there are two rockets, the Delta IV Medium and Medium Plus with a projected launch in 2001, and the Delta IV Heavy with a projected launch in 2003.
[51] Covault 2000a, 27. The statement is attributed to Phil Condit, Chairman and CEO, Boeing.
[52] See *Space.com*, 13 January 2000.
[53] Up-to-date information is from the official website at http:// www. seal-launch.com.
[54] Moorer 1993, 51.
[55] *The Financial Times*, 3 September 1998.
[56] Bruno 1998.
[57] Smith 2000a, 36-37.
[58] Smith 2000b, 47.
[59] Although the baseline GTO payload weight capability for the system was 5000 kg. it was increased specifically for the launch of the Thuraya-1 satellite built by Boeing Satellite Systems The stated goal of Sea Launch is to increase payload weight capacity to 6000 kg. by the end of 2002. See *AWST*, 2 October 2000, 47.
[60] See the comments by the Sea Launch vice president for marketing and sales on *Space.com*, 29 July 2000.
[61] *Space.com*, 6 June 2001; 8 June 2001.
[62] Estimated launch prices are from Isakowitz, Hopkins, and Hopkins 1999 for each series of launch vehicles.
[63] In the assessment of the geosynchronous orbit launch demand model, the AST/COMSTAC 2000 report points to the growing consensus that the weight of the commercial GEO satellites is growing.
[64] Caceres 2000a, 135-136, points out that with just about 700 satellites forecast to be launched through 2005, there is insufficient business to sustain all these newer ventures since anything less than 1000 satellite missions worldwide in the next five years represents a weak market.
[65] *AWST*, 7 February 2000, 19; and Taverna 2000a, 126-127.
[66] Taggart 1999, 50-51.
[67] Taverna 2000a, 127.
[68] *Space.com*, 18 April 2001.
[69] Launch figure estimates are from Isakowitz, Hopkins, and Hopkins 1999.
[70] Caceres 2001, 145.
[71] Taverna 2001c, 35-36; 2001d, 36.
[72] Some of the basic information is drawn from the official websites of Japan's National Aeronautics and Space Development (NASDA) at http://www.nasda.go.jp, Institute of Space and Astronautical Sciences (ISAS) of the Ministry of Education at http://www.isas.ac.jp, and the Space and Technology Agency (STA) operating out of the Prime Minister's Office at http://www.sta.go.jp.
[73] SJAC 1996a, 3.
[74] SJAC 1997, 13.
[75] Wray 1991-1992, 478-479.
[76] The planned reforms that are designed to strike at the heart of bureaucratic power and which should be completed by 2005, involve cutting 23 central government ministries and agencies to 13 and in contracting the 128 ministerial secretariats and bureaus to 96.
[77] *AWST*, 8 February 1999, 65.
[78] See both http:// yyy.tksc.nasda .go.jp and http:// www.isas.ac.jp for details.

[79] Sekigawa 2000, 123-126. The string of visible failures have included the following. In 1996, a $500 million ETS-6 (Experimental Test Satellite) was lost in orbit. Also in 1996, the HYFLEX (Hypersonic Flight Experiment) minishuttle test vehicle was lost at sea. In 1997, a solar panel collapsed and destroyed the $1 billion Adeos-1 (Advanced Earth-Observation Satellite) in 1997. In 1998, as discussed in more detail in the text later, a second-stage malfunction of the H-II launch vehicle delivered a $375 million COMETS tacking and data relay satellite in a useless orbit. In 1999, an H-II launcher had to be destroyed minutes into orbit because it was veering off course, and this also led to the destruction of a $97 million MTSAT satellite. In February 2000, an ISAS M-5 launcher failed, ruining a $108 million Astro-E X-ray satellite.

[80] Interview No. 53, Aircraft and Defense Products Division, Machinery and Information Industries Bureau, MITI, Tokyo, 1997.

[81] STA 1997, 499-505. ISAS has twice the space budget of MITI, and the Ministry of Transport has roughly the same budget as MITI.

[82] Some of the basic information is from RSC's website on http: // www.rocketsystem.co.jp.

[83] *AWST*, 9 March 1987, 132.

[84] *AWST*, 14 February 2000, 61.

[85] Wray 1991-1992, 482-484.

[86] Interview No. 87, Space Utilization Division, Research and Development Bureau, STA, Tokyo, 1997.

[87] STA1997, 499-505. Comparable figures of the American space budget stood at postwar high of 0.6% in 1967and since then about 0.2% of GDP. Space budgets in Germany, Italy, Canada and England have individually averaged around 0.04% of GDP. In the early 1980s, the French space budget began to distinguish itself from its European counterparts, rising to about 0.15% of GDP as of 1993.

[88] Interview No. 65, Aircraft, Ordinance, and Space Industry Division, Machinery and Information Industries Bureau, MITI, Tokyo, 1997.

[89] MITI 1997, 169-170.

[90] Interview No. 98, Aircraft, Ordinance, and Space Industry Division, Machinery and Information Industries Bureau, MITI, Tokyo, 1997.

[91] Wray 1991-1992, 487.

[92] The historical overview draws on Harvey 2000, 6-33, 52-78, 97-101.

[93] In the following section, specific information on the Japanese launch vehicles is from Isakowitz, Hopkins, and Hopkins 1999.

[94] Winter 1990, 102-103.

[95] The M-V was first launched in 1997 for government payloads, and continues to be commercially unavailable.

[96] Wray 1991-1992, 478-479.

[97] Harvey 2000, 29-32.

[98] Komahashi 1988, 176.

[99] According to a 1969 US-Japan Agreement, Japan was permitted access to US technology but prohibited from using that technology for launches for third parties without US consent. The autonomous development of the H-II would therefore allow Japan to throw off this legal shackle.

[100] *Nihon Keizai Shinbun*, 19 August 1994; 20 August 1994; *Yomiuri Shinbun*, 28 August 1994.

[101] Mecham 1994, 50.

[102] Estimated launch costs for the H class launch vehicles are from Isakowitz, Hopkins, and Hopkins. In large part the H-II was also expensive because few launches could be carried out due to the "fishermen's problem." An agreement with the fisherman's union means that the launch window opportunity is available only for about six-week periods in January-February and August-September. According to *Nihon Keizai Shinbun*, 17 August 1994, Japan had to get over the "high cost wall" in order to even enter the commercial launch arena. It showed how the launch costs of the H-II made the Japanese rocket a distinct outlier in comparison to other launchers in its class such as the Delta, Ariane, and Titan in Europe and the US.

[103] *Yomiuri Shinbun*, 21 February 1998.

[104] The Japanese press lambasted NASDA and even the emphasis on lowering costs as main culprits for the failure. It thereby also called into question the future of Japan's space program as a whole. See front page coverage and editorials in *Yomiuri Shinbun*, 16 November 1999, 17 November 1999; *Nihon Keizai Shinbun*, 16 November 1999; *Asahi Shinbun* 16 November 1999; and also *Financial Times*, 18 November 1999.

[105] The early (pre-1990) table is compiled almost entirely from NASDA's website (http://yyy.tskc.nasda. go.jp), ISAS's website (http://www.isas.ac.jp) and Jonathan McDowell's Launch Log (http://hea-www.harvard.edu/~jcm/space/log/launchlog.txt). The 1990s section uses Rocket Systems Corporation's webpage (http://www.rocketsystem.co.jp/e/e_kaisya.html) in addition to the above mentioned sources. Details that RSC chooses to omit are included. These are compiled from various news sources, and other websites (ISAS, STA, NASDA). Information has been checked against the Japanese space activities based on internal STA documents. Future mission schedules are taken from NASDA's webpage.

[106] *Asahi Evening News*, 26 April 1998.

[107] *The New York Times*, 27 November 1996. Hughes Electronic Corporation was the first company to sign up to launch commercial satellites using Japanese rockets through RSC. The goal was to use a new version of the H-11 rocket for 10 launches over a five-year period starting in 2000. At that point, RSC also became involved in negotiations for an additional 10 launches from Space Systems/Loral, a unit of Loral Space and communications. Both orders were estimated to be worth about $1 billion each.

[108] http://www.spaceviews.com/1998/02/21a.html; and http://www.spaceviews.com/1998/03/feature1.html. The H-II rocket, then Japan's largest and most up-date launch vehicle failed on 21 February 1998 due to premature shutdown 44 seconds into the second stage second burn. The H-II was carrying COMETS (Communication and Broadcasting Experimental Satellite), renamed *Kakehashi* satellite. Despite this failure to deliver the payload on target, however, 6 of the 7 H-II flights to date have at least reached orbit indicating that the Japanese can overcome present technical launch difficulties.

[109] *STA Today*, December 1999, http://www.sta.go.jp/sora/airospac/e9812_16.html.

[110] *STA Today*, January 2000, http://www.sta.go.jp/sora/airospac/e0001_15.html; and *Financial Times*, 18 November 1999. The launch of H-II No. 8 from the Tanegashima sight ended in failure on 15 November 1999. This constituted the second major failure to hit the Japanese launch vehicle program in a little under two years. The H-II rocket was supposed to put a weather and air traffic control satellite in orbit, but the rocket failed 4 minutes into flight due allegedly to liquid hydrogen fuel leaks from cracked pipes leading to first stage engine failure.

[111] *Yomiuri Shinbun*, 5 December 1999. NASDA announced that it would call off the production of the No. 7 H-II rocket. This was the first time in the history of the Japanese launch vehicle program that the domestic production of a major rocket was called off. NASDA also postponed the launch of the No. 1 H-IIA rocket in order to review the overall space program.

[112] *STA Today*, January 2000, http://www.sta.go.jp/sora/airospac/e0001_13.html.

[113] *STA Today*, February 2000, http://www.sta.go.jp/sora/airospac/e0002_17.html.

[114] *STA Today*, March 2000, http://www.sta.go.jp/sora/airospac/e0003_14.html.

[115] *STA Today*, April 2000, http://www.sta.go.jp/sora/airospac/e0004_13.html.

[116] Asker 2000, 127.

[117] *Yomiuri Shinbun*, 5 December 1999.

[118] *Asahi Shinbun*, 13 February 1996; *Yomiuri Shinbun*, 13 February 1996.

[119] *Asahi Evening News*, 26 April 1998.

[120] See "The 3rd Evaluation Report of Subcommittee for Space Transportation" (May 2000), appearing on http://yyy. tksc.nasda.go.jp/Home/ Press.

[121] These are identified by NASDA as H2A202, H2A2022, H2A2024, H2A212, and H2A222.

[122] *The New York Times*, 27 November 1996.

[123] *Nihon Keizai Shinbun*, 16 November 1999. Given the failed H-II flight, there were widespread concerns in the press that this would affect the development of the H-IIA as well.

[124] *Nikkei Weekly*, 4 December 2000; *Nihon Keizai Shinbun*, 12 December 1999; 23 December 1999; *Space.com*, 13 December 1999.

[125] *Space.com*, 18 November 1999.

[126] *Yomiuri Shinbun*, 25 May 2000; *Wall Street Journal*, 26 May 2000.

[127] *The Nikkei Weekly*, 7 August 2000.

[128] Space Activities Commission, 24 January 1996, 1-2.

[129] STA, 1996-1997, 18.

[130] Interview No. 87, Space Utilization Division, Research and Development Bureau, STA, Tokyo, 1997.

[131] NASDA 1997, 1.

[132] MITI 1997, 164.

[133] MITI 1996, 1, 5.

[134] SJAC 1996-1997, 11.

[135] Interview No. 65, Aircraft, Ordinance, and Space Industry Division, Machinery and Information Industries Bureau (previously Space Industry Division), MITI, Tokyo, 1997.

[136] Green 1995, 3.

[137] *Yomiuri Shinbun*, 5 November 1998; *Space.com*, 13 June, 2001. At present Japan plans to launch two satellites in February 2003, followed by another pair in July 2003.

[138] Interview No. 82, General Manager, Space Division, SJAC, Tokyo, 1997.

[139] Interview No. 65, Aircraft, Ordinance, and Space Industry Division, Machinery and Information Industries Bureau (previously Space Industry Division), MITI, Tokyo, 1997.

[140] Covault 2000d, 48. The Delta III also has hardware from France's SEP.

[141] *Nikkei Weekly*, 7 August 2000. Lockheed Martin's Atlas vehicle, for example, shares a satellite mount with Russia's Proton.

[142] http://yyy.tksc.nasda.go.jp/home/press.

[143] See the editorial in *Nihon Keizai Shinbun*, 21 December 1999, which stresses the importance of cost competitiveness and risk reduction, factors that continue to be key in Japan's attempt to gain entry in the global commercial launch market.

[144] *AWST*, 15 January 2001, 433; *AWST* 12 March 2001, 68; *New York Times*, 8 May 2001. Under Secretary of Defense, Donald Rumsfeld, military space issues are widely expected to be high up on the new Bush Administration's priority list.

[145] Interview No. 82, General Manager, Space Division, SJAC, Tokyo, 1997. There is a wide-ranging perception in Japan that the Europeans are far more effective at securing foreign procurements through their governments than the US, and that the European model therefore is the one that Japan should actively follow.