Japan’s Space Development: Past, Present, and Future

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Abstract

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This report is an effort to present an overall perspective of Japan's space development activities for the past three decades, along with exploring one possible prospect for Japan in the near future. Even now, Japan labors to continually revise its domestic space development policy based upon both thoughtful and practical introspection of its technical and political machineries. And as Japan's aerospace community shows clear signs of thinking beyond traditional assumptions and prejudices so defining of their international counterparts, Japan may well propel itself to the forefront of the space race. In particular, the author is interested in understanding both technical and political mechanisms that have allowed Japan's current space activities to came to fruition. Toward this objective, the author has researched extensively, though not nearly as exhaustively as the author would like, survey of Japanese literature. This paper strives to yield a window peering into our Japanese counterparts' view of themselves. More so, whenever possible, the story of Japanese space activities are squarely framed within domestic and foreign influences. Through this juxtaposition, we are able to appreciate how Japan judges its past, present, and future performances against the multihued glassworks that is space development.

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This paper has a much longer history than might be first apparent to the reader. The author would like to thank all the people these past eight years that have made this paper possible. To my host-families in Japan: Demura; Kochihara; Kitagawa; Fumuro; and, Fuwa who showed me a personal face of Japan. To my many Japanese teachers over the years who have given me the tools to discover a new world; and in particular, to M. Tsutsui and M. Kato who are mentors in the truest sense of the word. To all my many conversation partners who have all become the dearest of friends: Y. Kitane; N. Shiomi; Y. Nozaki; K. Noguchi; I. Yamada; Y. Mori; M. Ishida; H. Ishikawa; and, S. Akiyama. Finally, to my father whose stories of his time in Okinawa coupled with his deep respect of Japan helped plant the seed that has grown to be my adulthood obsession.

DEDICATION

To Japan: its peoples; its culture; its language; its simple sincerity.

Chapter 1
INTRODUCTION

Even today, when we think of the words “super powers”, we may still define the word, and indirectly ourselves, in terms of the former Soviet Union and United States, even if the former is just that – former. At the end of the twentieth century a significant shift in the balance of military and political power occurred. Once traditional centers of influence have, in part, been diffused throughout the world, coalescing into multiple, competing centers of influence, both large and small. Furthermore, it was not merely the military might of nations that either shifted or eroded, but uncountable secondary and tertiary influencers, too. We have had to reexamine how we conduct ourselves, and even reevaluate where to draw lines in the sand. More pointedly, and more germane to the topic at hand, our sense of “space power” must be equally redefined to reflect this new age at the turn of the century.

Since the race to outer space began shortly after the end of World War II, the United States has had a considerable lead against all other efforts barring the former Soviet Union. As a country, we have dominated both aeronautical and aerospace sectors with a sustained effort from private, business, and government alike. However, with a downturn in government funds available for NASA, along with cutbacks in military budgets that indirectly affect both NASA and the aerospace market domestically, and coupled with an upturn in competition from overseas, the United States has been forced, as a nation, to reassess how it does business.

At the start of 1985, when then president R. Regan announced the call for a space station, it was envisioned as a permanent, American presence in space – a scientific and engineering platform that would enable us to catch up with our then rival’s Mir space station. However, as the Cold War cooled significantly, as did related budgets, the space station seemed doomed to never see the light of day, let alone outer space. Nevertheless, in the years that followed, NASA, with its tightened budget, saw a means to gain expertise from the former Soviet Union's space program while at the same garnering both financial and political support from outside itself. By leveraging it's old rival's technology while building an international community that would later span four continents and sixteen nations, the International Space Station, as we presently know it, was born. Furthermore, with the cost of developing, deploying, and maintaining the multi-billion dollar project distributed among sixteen countries, NASA knew that the United States Congress would be far more likely to cast the votes necessary for its budget.

Internationalism, as it were, has gained increasing coinage during the last decade of this century. In large part, the impetus for this shift from "built here" attitude that hallmarked the 1980's, and exampled by the many "Made in U.S.A." tags found on everything from T-shirts to spoons, is the economic advantages gained by pooling limited resources irrespective of national and political borders. Moreover, this phenomenon is exceedingly congruent with the popular pluralism movement within the United States; thereby, the former ideology is merely a more generalized form of the later.

However, how does this all fit in with Japan's space activities and development? In large part, it does not; at least not initially in the 1970s with the start of a nationalized space development program. That is to say, both in practical and philosophical terms, Japan's view of space development was at the outset provincial at best. It was not till a shift in national policy [44] a decade later, in the early 1980s, that Japan itself decided that international cooperation, even international stewardship, was naturally aligned with its domestic objectives. More precisely, its domestic objectives became aligned with more fundamental, humanistic conditions, and therefore international cooperation evolved as a natural response to this condition.

It is then, and only then, that we truly see internationalism come into the Japanese lexicon. This is not to imply that Japan is adverse to cooperative efforts – many political leaders are convinced that internationalism is neither contrived nor incompatible with Japan's national and racial character. Indeed, many in Japan envision their nation as natural leaders of this recent trend of consolidating intellectual and financial resources across borders and politics. However, many, even some Japanese, see such statements as simple hubris. Furthermore, Japan has had to wrestle with a sense of community identity that, once traditionally was racially derived, is now becoming increasingly infused with foreign ideologies. As a consequence, both the traditional and modern senses of how Japanese perceive themselves are juxtaposed – at one point seeming fundamentally didactic, and at another point irrevocably intertwined.

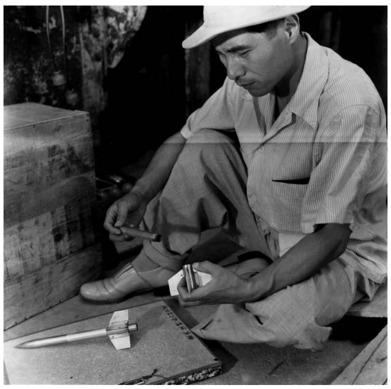
And so, as much as internationalism can bridge economic, scientific, and even political chasms for the greater common good, it still is considered heresy to examine the deconstruction of sovereignty – in that every nation must retain its sense of identity while involved in international activities. And therefore, it should be natural to expect that there are multiple agendas, both seen and unseen, when these types of relationships develop. Regardless, it should come to no surprise for the reader that Japan has for a long time aimed to become a dominant player in the space race – more importantly, we will see that Japan is attempting to do so as a cooperative member of an international community without necessarily losing its identity in the process.

As we take this one piece, namely internationalization of Japan's space development, and stitch it into a worldwide fabric of ongoing histories, peoples, and changes in the political and military balances of influence and power, we will come to foresee the arrival of Japan as a dominant influencer of international space development.

In this report we will explore in Chapter 4 how Japan understands what tools are necessary to leverage this opportunity to its advantage, and discover that Japan is poised ready to open the skies so that everyday people will ultimately be the engine, and not Japan's advanced LE-5 rocket engine, launching Japan to the forefront of the space race. However, before we can get to this point we must put Japan's space development into historical context. In Chapter 2 we examine the infancy of Japan's national space policy first envisioned in 1969. The proper historical framework is constructed, thereby enabling the reader to fully understand the many forces, both domestic and foreign, shaping Japan's space development into what it is today. Next, in Chapter 3 we will focus our attention on three of Japan's current efforts: H-II rocket and its derivatives; Japanese Experiment Module (Kibou) that will represent a substantial part of the International Space Station capabilities; and, an experimental, unmanned cargo shuttle launched atop its H-II rocket (HOPE-X).

Finally, the author would like to emphasize that this paper is based on his own efforts to unravel Japan's motives and objectives with a purely academic approach; namely, an extensive survey of literature written by leaders in Japan's aerospace industry with his own language skills to help foster his comprehension of their ideas and attitudes. Furthermore, the author does not want to merely regurgitate in monotone precision what he has so laboriously digested, but also provide, when feasible, insight that positions events in a framework that the reader can better appreciate. Nonetheless, it is difficult to make any emphatic statements about the true motives of the many participants in this tapestry of histories that the paper attempts to reconstruct. This is due largely to the author himself. As an outsider, both in terms of having never worked in Japan's aerospace sector nor lived through the many meetings and talks that sewed together our story, the author is forced to replace his aerospace engineer's skullcap in place of a historian's. And he, quite possibly unduly, has relied upon his sense of Japan, integrated through by his own experiences living and working in Japan, to help sift through the facts to reconstruct a more humanistic story.

Chapter 2
THE PAST



The title of "father of rocketry" in Japan is rightly bestowed upon Hideo ITOKAWA, who launched a pencil rocket in 1955, heralding in Japan's space development [42]. It is not merely his accomplishments, but his unbridled enthusiasm and child-like passion that qualify him for this title. He is quoted as once saying,

> *"In the United States, they have already entered into the rocket age. Let us, too, build rockets. So that, different than jet engines, we may fly out to the heavens on our rockets."*

However, we would not see anything more significant until the launch of OOSUMI satellite launched atop Japan's L-4S rocket on February 11, 1970 [43][44][54]. Lofted into an elliptical low-Earth orbit, the satellite's objective was to demonstrate Japan's rocket capabilities and investigate engineering issues related to satellites. In the following year, two more satellites where launched, both atop M-4 rockets. However, Japan was not satisfied with merely proving that all systems were go. With its satellite, SHINSEI, carrying a scientific payload for observation of ionization, space radiation, and solar phenomenon, Japan proved to the world and itself that it was capable of far, far more than lofting dead weight into space. It also set a strong precedence in Japan of basic research objectives with its satellites that to this day remains. By the end of 1998, Japan had launched a total of 67[1,2] man-made satellites [77].

In this chapter we will examine the maturation of Japan's bureaucratic structures established on both the principles of its engineers and visionaries as much as a reflection of the times that these events were born to.

JAPAN'S FIRST BRIGHT STAR

Before we get too far ahead of ourselves, let us return to the dawn of Japan's space development. H. ITOKAWA of Tokyo University Production Engineering Research Center heralded in start of the space race in Japan on April 14, 1955 when and his rocket club conducted their first firing of their pencil rocket. Eleven years thereafter in April of 1965, Tokyo University Aeronautics Research Center evolved from ITOKAWA's rocket club to form what would later become in 1981 the Ministry of Education's Institute of Space and Aerospace Sciences (ISAS). It was at this time that the organization announced its plans to develop a 3-stage rocket named LAMDA, (*see Table 5 for further details.*)

It is important to put this event in context, though. Japan, in October of the same year, opened Tokaido, its first high-speed shinkansen. In addition, the country saw a significant penetration of color televisions into Japanese homes as its people anticipated the broadcast of the Olympic Games to be held later that year in Tokyo. In short, Japan was riding a sense of

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[1] This is only second to the United States and the Soviet Union [77].

[2] Additionally, according to the same sources, namely [54] – [77], only a total of 36 satellites were launched on domestic rockets. Another 7 satellite launches can be added if we include US rockets and US space shuttle, thereby bringing the total to 43 launches. In addition, Reference [42] suggests another 10 satellites were manufactured by foreign countries but launched on Japanese rockets. Nevertheless, there is a discrepancy of 14 satellites that the author cannot account for.

euphoria. Its citizens saw themselves entering a period of technology-based, high-level growth; especially poignant when we consider Japan's state at the end of the 1940s some fifteen years prior.

In September of 1966, the new organization launched its L-4S no. 1 from Tanegashima Island during the height of the war between the United States and North Vietnam. We will return to this fact later as we explore Japan's attempts for peaceful use of space. However, on that day the second and third stage fail to separate resulting in an unsuccessful launch. Only three months later in November of the same year, L-4S no. 2 is launched. The rocket itself operates correctly, however the fourth stage (satellite) fails to ignite resulting in no orbital insertion. Five months hence in April of 1967 L4-S no. 3 is launched. During this interim a considerable amount of improvements are made to the basic design. It is expected that this launch, the third attempt, will place Japan on the map. Unfortunately, the third stage's fuel fails to ignite, and the rocket tumbles out of the sky and into another failure. This time, instead of racing to another launch, they retrench themselves, continuing with basic research and further development. After a protracted period, L-4S no. 4 is launched on September of 1969. The entire launch appears to be textbook perfect. All four stages separate and fire. However, the satellite again misses its intended insertion orbit and re-enters the atmosphere. It is later discovered through inspection that the culprit is stage three, which fails to cut off thrust during separation from stage four. The result is that stage three slams into stage four with the end result being failure. During all of these four failed launches Japan's researchers never lose their resolve. Only five months later on February 11, 1970 L-4S no. 5 launches OOSUMI satellite into outer space.

In the span of a day Japan is thrown into jubilation at its achievement. Newspapers laud the satellite as the star of Japan, and televisions the country over televise the launch of Japan's first successful rocket launch. Overnight, Japan is launched into the space race; joining only three other countries with this distinction.

However, what did this really mean in context to the rest of the world? At that time Japan was the fourth country to launch a satellite, led only by the then Soviet Union, United States of America, and France. Both Italy and Australia had launched satellites before Japan, however they did not do so using their own rockets. To be more precise, Japan had the distinction of being the fourth country to "launch a satellite under its own rocket power." To further illustrate this achievement, in the same year there were 127 satellites launched into space globally. Furthermore, by 1970 a total of 1,073 satellites had been launched. In other words, Japan's OOSUMI was on order of the world's 1,100th satellite to be launched. On top of this, the United States had landed on the Moon the year before.

Was this truly a remarkable accomplishment worthy of comment? Quite simply the answer is yes – at least for Japan. OOSUMI satellite sparked a fire in the imaginations of the people who launched it, heralding in a golden age of rocketry in Japan.

ROCKETS ARE JUST MISSILES

United States documents, declassified in March of 1996, reveal that sometime around September of 1965, the United States wrote the following of Japan,

> *"Japan, should it obtain solid rocket capabilities, will be able to develop in less than three (3) years a ballistic missile of its own."* [43]

But why would the United States connect solid rockets with Japan, let alone ballistic missiles? Recall that Japan was still twelve months away from launching its first rocket, L-4S no. 1, albeit unsuccessfully. As we will presently show, the statement reflects far more about the United States than any reality of Japan. Japan-U.S. relations were at an all-time high. In 1965, the United States has been involved for over a year in the Vietnam War. During all this, Japan has supported the United State's policy, providing cooperation and strategic launching points from Japan itself. Therefore, it seems absurd that the United States should see Japan as anything as its partner, both militarily and politically.

Japan had never shown itself or its motives to be anything other than, quite literally, academic. To the engineers and researchers in Japan, the LAMDA series was purely for advancing research and development of key technologies. However, the United States was evaluating Japan more on experiences in Europe with England, France, and Germany than anything that can be attributed to Japan. These three countries and others in Europe were caught between a tête-à-tête with the then Soviet Union and United States.

In 1962, various European nations came together to form two organizations. European Space Research Organization (ESRO) and European Launched Development Organization (ELDO) became these countries' proverbial legs, which were to launch them into outer space. Ironically, these organizations' mandate was to further technologies for the economic, and not military, benefit for its member nations. In their goals they planned to build EUROPA-I. Even further irony, as we will shortly see, is that much of the technological basis for EUROPA-I would come from missile advancements from the three main member nations, including the United States.

The three stages of the rocket were being designed and built by England, France, and Germany, respectively. While both England and France had already established space development programs of their own by this time, the purpose of these two organizations was to provide its members with collective resources for the development of basic technologies and infrastructure. Nevertheless, even though the motive may have been rather unquestionable, the technology that each of the three main members brought to the bargaining table was not.

For Germany, its team relied heavily on research done on the V-2 rocket that so psychologically devastated England's morale toward the end of the Second World War. For France's part, it utilized DAEMON technology that it had developed for its own ballistic missile research conducted since the end of the war. Finally, England's contribution was its Blue Streak, its domestically produced long-range ballistic missile that had adopted fuel tank technology from the United State's General Dynamic's ATLAS rocket.

Even to a casual observer using Europe's EUROPA-I as a center point, during the 1960s there was a strong correlation between rockets and missiles. It was the United States experiences that rockets were by-products of missile technologies. In both the United States and former Soviet Union, the domination of outer space was seen an eminent domain necessary to ensure the survival of each respective government ideologies. In short, the United States analysis of Japan was not one done using Japan's own metric stick; instead, the United States showed its own bias on how it viewed these technologies; completely disregarding the true motives of Japan – the development of rocket technology for the benefit of its society.

PEACEFUL IS NOT ALWAYS PEACEFUL

During the first unsuccessful launches of L-4S series, Japan as a political engine was already thinking toward the future. In the middle of 1969, a minimum of three different political institutions drafted terms for the use of space by Japan. The following three resolutions are presented as examples[1] of the Japanese mindset at the close of the 1960s.

> *"Resolutions for foundation of our country's utilization and development of outer space*
>
> *May 9, 1969*
>
> *Lower House of Parliament*
>
> *The development and utilization of objects launched into the outer space that exceeds the limits of our atmosphere over this Earth and of rockets used to launch said objects will be for, as best as possible, peaceful intentions for the progress of science, betterment of our citizens' lives, and enrichment of mankind's societies through industrial development and use."*

> *"Proposed resolution regarding National Space Development Agency (NASDA) legislation (excerpt)*
>
> *June 13, 1969*
>
> *House of Councilors Special Committee for Science and Technology Policy*
>
> *As for the many activities of development and utilization of outer space by our country, as best as possible toward peaceful means, will be conducted on the principles of independence, democracy, openness, and international cooperation."*

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[1] See Reference [43] pp. 30 – 31 for original Japanese texts. English translations are by the author of this report.

"National Space Development Agency (NASDA) legislation (excerpt)

June 23, 1969

Legislation no. 50

Condition 1: The National Space Development Agency is founded with the objective as is best possible toward peaceful means of promoting the utilization and development of outer space through the effective and strategic synthesis of pursuing man-made satellites and rocket development"

In all three of these translations we see the use of one particular term used repeatedly. Namely, "heiwa no mokuteki ni kagiri." Roughly translated it means "as best as possible peaceful intentions" or, "to the limit of peaceful objectives." Many who read those words believe that Japan's aspirations may have military underpinnings; ergo, hoping to develop a stronger military presence with ballistic missiles. However, this is far from the truth. Again, we need to place Japan in context with the affairs of state during that period.

In 1966, Japan saw a wave of demonstrations and protests wash across its cities as people fought against environmental pollution, industrial corruption, and concerns over the future direction of their country. In April of that year in China the Cultural Revolution began, reminding everyone how much times had changed in a short period of time. The year before, the United States had become embroiled in Vietnam; its forces were transported from military bases in Japan and Japan's government stood behind the United States international policies in the region including Vietnam. In the following year, 1967, demonstrations became nation-wide just as they did world over. And in 1968, the U.S. inaugurated its first nuclear-powered aircraft carrier "Enterprise" which the Japanese protested when it drew into port in Japan. We also saw, as mentioned previously, a worsening of relations between the then Soviet Union and United

States. One consequence was a heated space race; the Soviet's launched astronaut Yuri Gagarin, and soon thereafter Kennedy said to a special joint session of Congress, "…the nation should commit itself to achieving the goal…of landing a man on the Moon…." Both General Dynamics and McDonnell Douglas worked on development of their intercontinental ballistic missiles, leading to their ATLAS and DELTA rockets, respectively. Similar to rationales described in the prior section, the world at this time did not distinguish between rockets and missiles, the former was simply a more benign version of the later.

It should not too surprising then to the reader that Japan would capture the essence of its future space objectives in terms that seem to lead to a potential contradiction in its true intentions – peaceful development of outer space. In other words, the use of the word "ni kagiri" in Japanese leaves some margin for maneuvering of its political body, leaving doubt both in Japan and abroad if Japan intended to develop minimally a defensive space presence with its technology. Furthermore, and to the chagrin of many Japanese, this loophole has yet to be rectified in the intervening years.

Case in point is the LE-5 engine developed for use with the H-I rocket. It is a world-class liquid fuel rocket with the unique capability of re-firing. When plans for H-II were devised, this same engine was dramatically improved and renamed LE-5A. The capabilities of the engine were not lost on powers outside of the Japan, either. In the late 1980s when both McDonnell Douglas and General Dynamics where planning their next generation rockets, DELTA-III and ATLAS-II, respectively, they petitioned the Japanese government for licensing of the LE-5A technology for use in their own rockets.

In Japan and abroad this move was seen as the step that would finally truly legitimize Japan's space development efforts. Namely, United States, who was arguably the world leader in the space race, was looking to license Japanese technology to make its domestic rockets more effective. For the United States who had for a long time looked at “made in Japan” as a sign of inferior quality products, the irony, for some, must have been heavy enough to choke on. In both cases the rocket engine would extend the rockets’ abilities to place larger payloads into the very lucrative geosynchronous orbit and reduce the cost of launches. However, both companies’ rocket has traditionally had three major customers, or government, industry, and military. It was decided, based upon the wording of Japan’s directives for outer space use, that licensing of technologies to these companies would be against the spirit of these documents. Furthermore, the words, “through industrial development and use,” stipulated in the Lower Parliament’s resolution clearly indicates that Japan’s technology could not be used for military applications. Consequently, both instances of licensing were, in the end, denied.

This decision was both a great loss and even greater victory for Japan. From the perspective of short-term objectives it is obvious that these licensing agreements would have greatly influenced the near-term direction and funding of Japan’s space development program. However, it is questionable what the effects would have been in the long-term. Authorities in Japan do not argue against the licensing of its technologies – quite the opposite – however many such as F. NAKANO [43] argue that Japan needs to set a stronger precedence. Namely, based on these experiences of the potential misuse of Japanese technology, Japan should change the wording of its resolutions from “peaceful objectives as much as possible” to “peaceful utilization”, leaving no ambiguity to its people and the world what the true motives of Japan are.

TOWARD A BETTER FUTURE

We will now examine the direction of Japan’s space development from its engineers and scientists. In particular, it is illuminating to examine the policies and suggestions brought forth by its industry every few years. While Japan has a single-year budgetary system where it is not uncommon for modifications to occur to its space program on a yearly basis, the Space Activities Commission has met in 1978, 1984, 1989, and most recently in 1993 to help provide long-term direction, and more importantly, vision to its industry. The committee's suggestions in no way carry any legal significance; however, it does provide us with many insights into how, as an industry as a whole, Japan's technocrats envision their industry.

The typical mechanism for revision of these plans includes numerous special committees and polling of its members to develop a consensus on any given topic.

In the beginning of the 1970s ISAS and NASDA vision only extended to the immediate future. By 1975 its CS, BS, and GMS had been launched on Japan's N-I series rockets. It was seen by the members that they had an obligation to provide long-term vision to the industry to ensure its viability and integrity.

At the very start they created the Operations Group, headed by Shigebumi SAITO, to help assist with management of these mechanisms. The group's objective is simple. Ensure that the will of the commission's members are clearly voiced.

In February 1975, twenty-five representatives from government along with members of the commission converged on a conference to help discuss the long-term vision of Japan's space development. It was not until July of 1977 that a final report was submitted, nearly two and a half years from the original conference. Representative of the type of questions posed by its members is exemplified by the following quote from the then head of Tokyo University Space Research Center, professor Toshi ODA who asked,

> *"(The question is not only) what can we accomplish in outer space; but also, what* should *we accomplish in outer space."*

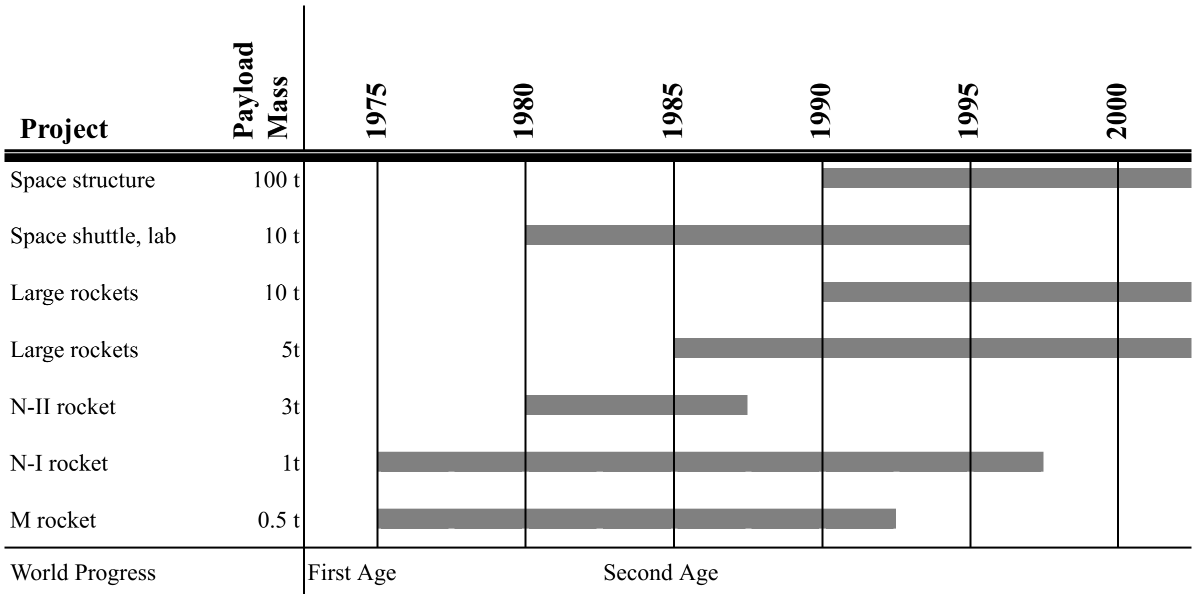
The imperative was not to drive technology for the sake of technology, but to see outer space and its related technologies as an opportunity to exact positive change on Japan as a whole.

Interestingly, there was great debate about the speed that Japan was taking with its space development. As mentioned previously, while Japan was the fourth nation to go to outer space under its own power, its first satellite was in all actuality one of over a thousand that had been launched by mankind up to that time. In short, there were those who were impatient with Japan's present status, and wanted to see progress accelerated. On the other side of the argument, there where those who took a more protracted view, seeing the need to go slowly but surely through its growth into maturity.

As a contrast with other space developing nations, while Japan launched TAIYOU satellite in February of 1975 and its Experimental Technology Satellite (ETS) in September of the same year, the United States and western European nations were in the post-Apollo era, already planning reusable launch systems such as the United States Space Shuttle introduced in the 1980s and large-scale space structures to be introduced in the 1990s. For many in Japan, as evidenced by their projected timetable, Japan needed to hasten progress; otherwise, risk the chance of being left behind in the space race.

Table 1 is a generalized chart presented in reference [43] on page 286. What is interesting to note from this table is the truly accelerated pace of development that its members hoped for. For example, the commission hoped to introduce a space shuttle similar to the United States by the 1980s when they had only successfully launched their first satellite, OOSUMI, in 1970. In comparison, the United States had been launching successfully for nearly 20 years by that time. And more to point, the United States, which had decades more experience and significantly larger budget, was going to introduce its version of a space shuttle around the same time as Japan. It should have been obvious to even the most optimistic member that they were doomed to miss the mark. However, the sense of urgency was so great that an accelerated approach would succeed.

Table 1 – Projected rocket development for Japan presented at Special Conference of Japan Space Development held in July of 1977



We must not forget the 1970s for Japan was dominated by themes set forth by the many ministries in the Japanese government. It was in this decade that the government called for “research and development of the electric automobile”, “research and development of jet aircraft engines”, and even “research and development of pattern processing systems.” So it must have seemed natural to the commission’s members for it to create a mantra of “yesterday today” as a call for rapid development of Japan’s space development program.

There seems to be a note of pride in the directives issued by the commission. They saw the future fast approaching, and they did not want to be left behind. However, as it always the case, scientists and engineers are phenomenally adept at seeing future technologies and their application, however they are equally notorious for over-optimistically predicting the pace that these technologies will go from laboratory curiosities to mature applications ready for society's consumption.

Table 2 – Projected satellite missions for Japan presented at Special Conference of Japan Space Development held in July of 1977

Objective	1975	1980	1985	1990	1995	2000
Space Beacon		earth physics, positioning, hazard warning				
Space Communications						
• Transmission	BS/CS/ECS	multi/moving communications, Earth/space broadcasting				
• Control		aircraft/ship control, spacecraft control				
• Surveillance		broad-area surveillance				
Space Observation	small-scale		multiple obj.	synthesized		
• Astronomy, near-Earth		large-scale (orbital astronomy, lunar, planetary)				
• Atmospheric	near earth	Ocean	multiple obj.	synthesized		
• Earth	meteorology	Land	multiple obj.	synthesized		
Space-based Experiments						
Space-based Materials		SEPAC (sci. eng. experiments)		large orb. lab		
Space Biology	small rockets	med. rockets	pilot plant	factory		
Space Colonization						
Planetary			lunar → inner → outer			

space station

By the time of the issuance of the report, the N-II rocket was complete. The next evolutionary step in rocket development would come in 1985 with the investigation of the H-I liquid-fuel rocket. The project was to be split into two derivatives. The first was the 550-kg class of geosynchronous satellites, and the second, H-IB, was for 800-kg class satellite. They also had plans for the further future, envisioning a need to place 10 to 15 ton satellites into low-orbit. The rocket developed to do this would later become the H-II rocket, daughter to the H-I project. Shortly thereafter, Japan would be able to enter space with a permanent presence using space shuttles and orbital space structures.

Table 2 is another interesting case in point. The bold vertical line shown for around 1997 indicates the belief that many of these mission objectives would be integrated into an orbital space platform, or space station. Coupled with the proposed rapid development of rocket capabilities shown in Table 1, Japan was indeed very ambitious with its proposals in 1977; only some twenty hence they anticipated a fully developed orbital infrastructure.

It would be negligent to not mention that many at the conference in 1977 were against the plans for the same reasons the author has already mentioned – a far too ambitious plan without little or no concrete evidence of its feasibility. Nonetheless, those supporting the plan acknowledged that the development of an orbital platform would require significant amounts of international cooperation for its completion; however, many opponents did not know how to place this cooperation in sight of the fact that Japan sought to remain autonomous from other world space agencies. It would be another five years before they would collectively come to understand how international cooperation would be both mutually beneficial and complimentary to their program agenda.

Further to point, if we examine the current progress of the H-I and H-II rockets, we see that the schedule shown in Table 1 is only 1 to 2 years ahead of present-day reality. Furthermore, the prediction of platform-"ification", that is to say the convergence of multiple technologies and mission objectives in one satellite bus became reality when SFU and the Earth observation technology satellite, ADEOS, became operational. However, the greatest stumbling block has been the development of reliable space shuttle technology.

Even with all the controversy surrounding the conference, this did not stop it members from looking continuously forward to improve both their vision and the mechanisms to develop that vision. One significant result of this conference, besides the report, was the creation of the Exploratory Regulation Committee, which held its first conference in October of the same year, 1977.

The committee took the conference report as its central component, expanding upon its vision to include the more mundane, but necessary issues of administration and budget. In short, its mandate was to develop a set of cohesive, workable regulations and guidelines pursuant to the goals stipulated in the conference report. In addition, the exploratory committee had to have some vision, too, in order to make the impossible possible.

It was necessary to try to predict the future budgetary environment, and therefore Japan's space development budget, which would in turn solidify its expenditures. A report was published a year later in January of 1978. In the report the committee had broken down the conference report into three main categories. Namely, 1) what should Japan accomplish in the next 15 years; 2) What might Japan accomplish 15 to 30 years from now; and, 3) What might Japan consider accomplishing 30 years and beyond. Two months later in March the members of Japan's Space Activities Commission voted on the guidelines. Of the guidelines, the most important clauses are its most fundamental clauses[1].

(1) *Harmony* with *needs* of society and *vitality* of Japan

(2) *Maintain* Japan's *autonomy*

(3) *Accord* with *international* activities and norms

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[1] Italicized portions are this author's own, for purposes of emphasis.

The second clause would prove contentious in later years. However, before we discuss this let us jump five years to the summer of 1982 when NTT needed to launch 2 – 4-ton satellites into geosynchronous orbit. Per the schedule of rocket development shown in Table 1, Japan needed to revise its regulations in order for Japan to remain competitive in the market. The significant portions of revisions at that time were borne from surveys with customers from the communications sector such as KDD, NTT, and NHK. In contrast to the first conference with its varied and, to some degree, overly ambitious agenda, the second round of revisions concentrated on practical, achievable results in the next 5 years. Among the revisions was the cancellation of development for the 800-kg class H-IB rocket. In its stead, priority was given to the 2-ton to GEO class H-II rocket and other large-scale satellite development.

It was also evident that maintaining Japan's autonomy was proving onerous, and might indeed prove to be an impediment to Japan's success. However, cooperative efforts had developed between the United States. Though the only formal relation was the development of materials used on the space shuttle, there were numerous other cooperative, yet informal relations, between the two agencies during this period.

A year later in July of 1983 the commission's members came together to understand the suggested revisions, which in turned resulted in further revisions by the members themselves. These revisions were presented on February 23, 1984. The single largest change, at least fundamentally, was altering fundamental clause (1) from "harmony with needs of society and vitality of Japan" to "harmony between technology development and utilization."

No One Is An Island Unto Itself – Even Japan

While fundamental clause (2) of the Japan's Space Activities Commission called for Japan's autonomy, the rest of the world thought otherwise. In January of 1985 then president R. Regan of the United States, echoing the sentiment of president J. F. Kennedy's speech that sent mankind to the Moon, presented plans for an international space station. Also at the this time, the chief of NASA asked the prime minister of Japan himself for Japan to join the United States in this ambitious plan.

However, the real turning point for Japan had came three years prior to this in August of 1982 when the second United Nations International Space Activities Conference (UNISPAC) was held in Australia. It was here that use of outer space was seen as a powerful observational tool for the preservation of the Earth's environment – air, land, and water. As a result there was a request to the attending community to develop an Earth observing satellite platform for this purpose. It was this that would catalyze Japan, transforming its once provincial view of outer space into one that was more mature, more community oriented. It was becoming rapidly apparent that Japan could have a significant role and impact on the international community by contributing to Earth observing satellites capable of natural resource surveillance, preservation of the environment, and so forth.

It is at this time that we begin to see the rapid change within the Japanese technical community for a need to better address issues facing the world. The fundamental clause (2) calling for Japan's autonomy, while still important to Japan's identity as an industrialized nation is slowly being evolving into a balance between self-identity and international cooperation. In part, Japan's sense of autonomy helped to nurture a sense of leadership for Japan within the international community; setting a tone and example for everyone else. Around this time, the head of the Domestic and Foreign Policy Research Center, Takeo OOKITA, remarked,

> *"There is large desire from the rest of the world for Japan to contribute to the international community. It is necessary that our primary consideration be the crucial*

planning of earth observation satellites. The Space and Technology Bureau should exert more effort to contribute to the world, as a whole, through the cooperative utilization of outer space." [44]

As we will see in the next section, Japan's present-day efforts have indeed followed the challenge called forth by T. OOKITA. Even with an expenditure one tenth of the Untied States in 1990, Japan's contributions are significant. Of the difficulties to arise in the late 1980s and 1990s will be a shifting of ideology between the two agencies; namely, Japan will see its space development as key to industry, and conversely the key to its industries is space development.

COMING OF AGE

On July 26, 1993, Japan's Space Activities Commission met for the fourth time to discuss and revise its long-term vision for its industry. During the conference, matters ranging from a definition of space development to its implications to details for future launch systems and objectives were discussed. Whereas we have previously focused on the fundamental nature of these conferences, in this section will examine in detail the many objectives, policies, and long-term goals set forth by the Japan Space Activities Commission during this conference[1].

To begin, we will examine how its members perceive the development of outer space within

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[1] The author has translated a variety of text found in reference [11]. In many instances the words "we will" and "our" have been added to the translation to help make them more natural for the reader. Nonetheless, the reader should read the translations in the spirit the original author intended, and not be overly concerned about the legal scope of certain (grammatical) articles, and so forth. It should be assumed that the commission's own policies and opinions are meant as guiding principles for its own members, and does not necessarily reflect the beliefs or attitudes of legislative bodies in Japan. Indeed, as mentioned previously, the commission's four conferences provide an insightful barometer of Japan's *technocrats*, not their bureaucrats.

an international and globally inclusive framework. Congruent with other world nations, the commission defined the development of outer space as,

> *"In order to contribute to the continual prosperity of life on Earth, we should strive to effectively maximize the utilization of the limitless possibilities of unknown outer space through mankind's shared assets."* [11]

Implicit in this definition, and what should be apparent to the reader, is Japan's support for international cooperation based on a sense of commonality with others as members of humankind. The following five (5) interpretations show how the commission views the development of outer space, per the above purpose.

1) Through the inquiry into unknown outer space, we will contribute to the creation of new cultures, expansion of humankind's information frontier, and so forth.
2) Contribute to the preservation of humankind and expansion of our domain of activity. (Earth environment observation, realizing enriched lives, et cetera)
3) Through the development of cutting-edge space technologies, we will contribute to the creation of the future's new technologies and industries.
4) By deepening an international, mutual understanding and reliance, we will contribute to development and stability of an international society.
5) Contribute to the development of the next generation of skilled people who will support the world's societies.

At the conference, it is understood that it is imperative that Japan develop a set of cohesive space development policies that are both better appreciated and supported by the citizens of Japan. This viewpoint, the author believes, is in part a result of public relations problems stemming from a recent spat of launch failures with Japan's most advanced rocket, H-IIA. From the conference its members support the following three policy objectives.

1) The challenge of getting to outer space, and ever advancement of understanding of Earth should include, in a positive manner, universal issues regarding the basic development of humankind.
2) The objective of expanding the range of humankind's activities in outer space should include, in a positive manner, development of space technologies that support future needs.
3) Sharing with the world a vision and purpose of development of outer space, and while working cooperatively, endeavor to expand upon space activities.

From these three basic policy objectives, the conference also developed a set of seven corollary policies that are designed to support the above policy objectives.

1) Propel creative aspects of research and development, and widen both the breadth and depth of international, state-of-the-art technologies.
2) Advance, in a positive manner, international cooperation.
3) The fruits of technology development are intimately interconnected to those who seek to utilize them and with space development organizations that seek to further expand the social usefulness of these results. As such, we should advance the development of technologies by accurately reflecting these demands.
4) In order to achieve the establishment of a variety of space activities as a component of everyday life within a broad society, we will advance development that seeks to realize more efficient and economical utilization of outer space.
5) Hereafter, after having developed unmanned systems with a high level of

capability and reliability, we will endeavor to bring to fruition manned systems as well as orbital platforms such as a space station.

6) Be concerned about the preservation of the Earth's environment.
7) The Japan Space Activities Commission, while judiciously evaluating the progress of a project will continue the project in a flexible and systematic manner.

From these seven concrete policies it should be apparent to the reader that the commission's members indeed take international cooperation and stewardship as central to their mandate. Further to point, a reoccurring theme in these policies is a very paternal attitude toward the development of technologies that accurately reflect the demands and needs of society. Indeed, Japan's technocrats show a very humanistic approach to their technology development.

The commission envisions that there will be four major areas of development. These are: complete Earth observation system; support of sophisticated space science projects; an orbital research platform; and, implement development of a new space infrastructure.

For the first, an observation system for all of Earth will require around the 2010 somewhere between 20 and 30 satellites to complete. Of these, Japan plans on providing one-quarter of the total number of satellites, or 5 to 8 satellites. For the second cornerstone, both the M-V rocket and H-II rocket are designed to lift to orbit and beyond medium-size and large-size payloads, respectively. The M-V rocket is appropriate for survey missions to the Moon, Mars, and asteroids within the orbit of Jupiter. As for the H-II rocket, it is appropriate for lifting heaving payloads requiring extended range such as survey missions to Jupiter and beyond. In consideration of developing orbital platforms, Japan is presently in the midst of contributing its Japan Experiment Module (JEM) as a member of the sixteen-nation International Space Station project. However, while the members do not call out definite plans, it is apparent that Japan will not rest comfortably with just JEM. Finally, the last component to Japan's next fifteen years will be developing a new space infrastructure. This objective includes a doubling of the payload capacity presently available with H-II rockets. Also, continued development of HOPE and other unmanned transport systems is required. In 2010 it is expected that a significant reduction in launch costs will be achieved in comparison to present-day launch systems. Moreover, research and development of in-orbit robots, real-time data acquisition satellites, and orbital, unmanned experiment platforms will be conducted for improving the advancement of space environment experiments.

In order to achieve all the above-mentioned objectives, policies, and long-term goals the commission understands that it needs to cultivate a new generation of scientists and engineers capable of working in this newly emerging environment of international cooperation. This will require more inclusion of young researchers at universities, support of international exchanges, and creation of an environment conducive to promotion of ideas pursuant with developing outer space in a cooperative, international manner. What is most encouraging is the clear desire by the commission to become more actively involved with other developing nations in Asia and the pacific-rim region. While there are many arguments, both positive and pejorative, the author remains optimistic that Japan's space development technocrats sincerely see themselves as natural leaders for international cooperative efforts.

Finally, the commission shows a strong support of its domestic industries as a means of substantiating its goals to support society-centric technologies. That is to say, industry is equal to society as being both catalyst and benefactor of Japan's space development aspirations and long-term vision. This is not wholly unlike the environment in the United States, where NASA burdens the cost of development of cutting-edge technologies in areas where industry refuses to enter due to the level of risk. However, whereas the United States see this symbiotic relation as tenuous at best, the author is of the impression that this relation in Japan is very well developed, indeed.

Chapter 3
THE PRESENT

We have seen how, since the first successful launch in 1970, that Japan's space development ideology has matured to reflect the realities of technology readiness and societal needs. However, we have not, as of yet, discussed many of fruits of these endeavors. Presently the author sees three projects of significant importance both as proof of Japan's ability to produce world-class space technology, and also as litmus of how far Japan can advance in the future. Namely, we will examine the H-IIA rocket, Japanese Experiment Module (JEM), now christened as KIBOU, and H-II Orbital space plane Experimental (HOPE-X), formally known simply as HOPE[1]. However, it is entirely unreasonable to provide examples of technology without first placing it in the proper context. Specifically, we will provide a comparative analysis between the United States' and Japan's space development and budget economy of scale.

APPLES TO ORANGES

It is instructive to compare the scope of Japan's space development with that of the United States, thereby emphasizing how effective Japan's programs truly are. Furthermore, understanding that Japan's NASDA is neither equivalent in mandate or scope, nor in scale nor size to the United States' NASA is important for the reader to realize. Otherwise, unfair comparisons are made and incorrect analysis conducted when we look to Japan's efforts in a

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[1] As a humorous aside, the author predicts that Japan may run amuck with foreigners who might be tempted to translate Japanese christen names in English. Case in point, JEM's christen name is KIBOU which means "hope" in English. Many a person, not familiar with Japan's space program, will have a hard time

framework both domestically and internationally.

The major nine agencies of NASA employ some 24,000 employees. Another 2,500 employees work at Jet Propulsion Laboratory (JPL). That is total of 30,000 employees, enabling NASA to develop aeronautical and aerospace technologies for the American peoples. Japan, on the other hand, has fewer than 1,000 employees at its largest agency, NASDA. This is twice the number of employees at NAL, and three times the employees at ISAS. In other words, Japan only employs approximately 1,700 employees, or 6% of NASA. It simple terms, JPL with 2,500 employees and responsible only for unmanned missions such as planetary probes, is nearly one and a half times larger than all three major agencies of Japan.

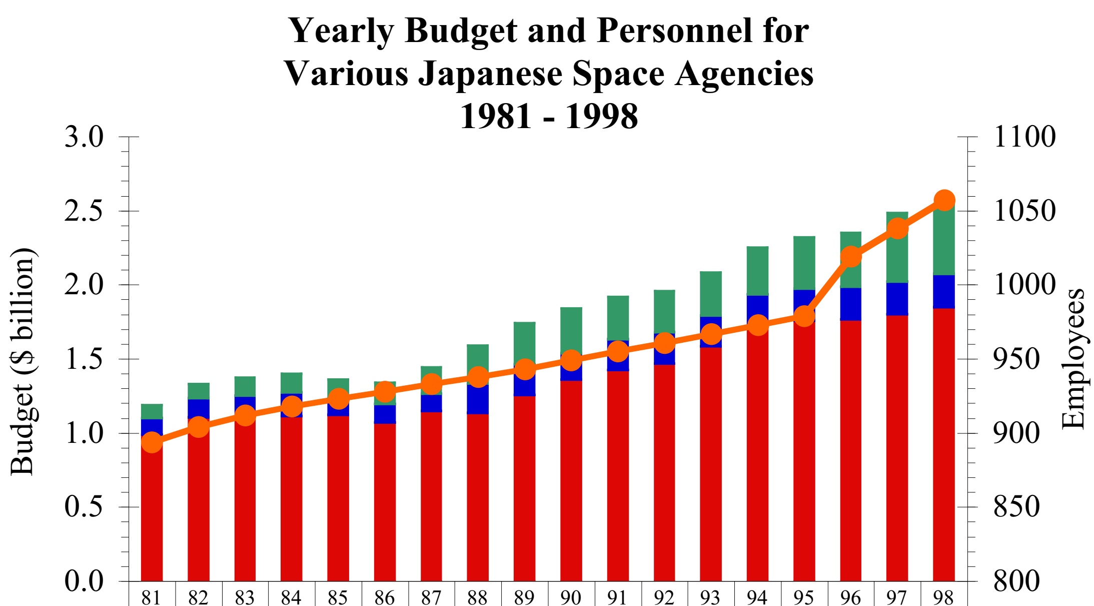
Table 3 – Comparison between United States NASA and Japan NASDA budget in 1990

Category	**United States NASA ($ billion)**	**Japan NASDA ($ billion)**	**Difference (%)**
Space Transportation	5.0	0.5	10000
Research, Development	7.0	0.4	1750
Other	2.0	0.3	6500
Total	*14*	*1.2*	*1167*

The United States annually appropriates approximately 1% of its budget for NASA, or $14 billion in 2000. Over $7 billion is spent on research and development of space probes, space station, and space sciences. Space transportation accounts for another $5 billion. The remaining $2 billion is needed for facilities, and research and program management. The $14 billion for NASA does not include another $20 billion appropriated to the Department of Defense that invests heavily in aeronautical and space sciences. In comparison, Japan, in 1993, set aside annually $1.22 billion for its space development agencies. NASDA by far receives a lion's share

determining if the speaker is referring to JEM or HOPE, the unmanned, orbital space plane.

of $1.2 billion. The H-II rocket development program requires approximately $500 million annually, support of the space station another $400 million, and the remaining budget is used for management, Earth observation, and basic research and development. Both NAL and ISAS receive significantly less; approximately $92 and $170 million annually, respectively. Even if we do not included Department of Defense budget, this still equates to the United States spending 11.5 times more annually on its domestic space program than Japan.



	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
Other Bud.	0.08	0.09	0.12	0.13	0.13	0.14	0.17	0.25	0.27	0.3	0.29	0.28	0.29	0.32	0.35	0.36	0.46	0.47
ISAS Bud.	0.11	0.13	0.15	0.16	0.11	0.12	0.12	0.2	0.21	0.18	0.21	0.21	0.21	0.21	0.21	0.22	0.22	0.22
NASDA Bud.	0.99	1.11	1.1	1.11	1.12	1.07	1.15	1.14	1.26	1.36	1.43	1.47	1.59	1.72	1.76	1.77	1.8	1.85
Total Bud.	1.19	1.33	1.38	1.4	1.36	1.34	1.44	1.59	1.74	1.84	1.92	1.96	2.08	2.25	2.32	2.35	2.48	2.55
NASDA Emp.	894	904	912	918	923	928	933	938	943	949	955	961	967	973	979	1019	1038	1057

Figure 1 – Japan's two (2) major space agencies, NASDA and ISAS, and minor agencies (other) annual budgets from 1981 to 1998. In addition, NASDA number of employees is shown for the same period. The aggregate annual budget is tabulated below the chart. Budget is in billion of dollars, with a conversion from yen at $1 per ¥100.

However, what has this meant for Japan? That is to ask, how does an economy of scale some ten times smaller than that of the United States mean to the bottom line – space development? In Japan, a typical wind tunnel capable of supersonic flow at Mach 4 has a 50-centimeter test section. By way of comparison, NASA Langley has a large, high-speed wind tunnel with a 20 by 30 meter test section. The difference in budget means, quite obviously, that Japan is not fiscally capable of building facilities on the scale or sophistication of the United States. And we will show this has the effect of consolidating Japan's efforts on technologies viewed as vital to the continuation of autonomous space activities.

Figure 1 is equally revealing, showing Japan's annual budget[1] for its major centers, namely NASDA and ISAS, along with other minor agencies from 1981 to 1998. In addition, we note that the employment rate over this same period matched the rate of budget increase. However, since 1996 this is a marked increase in the hire rate at NASDA; though, the author is unable to offer a concrete reason for this. Speculation includes an increase in part-time workers, or other institutional reforms such as facility costs savings allowing increased hiring without reduction in projects.

Finally, Table 4 helps provide numerical evidence of the shift between Japan's past space activities and the present. Namely, the table shows a shift from purely scientific science objectives to developing a robust space infrastructure. In a single year, even with a 13% decrease in total budget, the space shuttle program is significantly increased by nearly a factor of 20,

[1] The author found discrepancies between different sources of information, namely references [51] and [53], regarding yearly budgets for agencies. In all cases, it is assumed that an agency's published budget is the correct budget value, and is used for purposes of Figure 1.

showing Japan's decision to commit itself to orbital vehicle technologies. We also see favorable increase in space structures. With a downgrade in satellites, Japan seems ready to position itself as the means of getting to, and staying in outer space. Also, the decrease in satellite expenditures may be in relation to NASDA's continued efforts at more extensive international cooperation, ergo increase cooperative projects with the European Space Agency (ESA) and NASA that have significantly more funding for this type of expenditure. Additionally, we see an increase in NASDA investment of data processing and acquisition technologies, which may be in response to more complicated satellite objectives that included platforms with multiple missions such as ADEOS.

Table 4 – Breakdown of NASDA Yearly Expenditures in 1990 and 1991. Cost shown in $1 million increments, and with a $1 to 100¥ exchange. [39]

		1991		1990		1990 to 1991
Category		Cost ($)	Percent (%)	Cost ($)	Percent (%)	Percent Change (%)
Hard	Rocket	502.64	29.2	607.64	30.8	82.7
	Space Shuttle	24.55	1.4	1.33	0.1	1845.9
	Satellites	483.04	28.1	505.97	25.6	95.4
	Space Structures	51.41	3.0	37.54	1.9	136.9
	Sub Total	*1061.64*	*61.7*	*1152.48*	*58.4*	*92.1*
Earth Facilities		510.32	29.7	744.21	37.7	68.6
Soft	Software Development	70.12	4.1	42.29	2.1	165.8
	Data Processing/analysis	76.52	4.5	36.28	1.8	210.9
	Sub Total	*146.64*	*8.6*	*78.57*	*3.9*	*186.6*
	Grand Total	*1718.6*	*100*	*1975.26*	*100*	*87.0*

In conclusion, Japan has a significantly smaller annual budget than the United States. However, Japan is no less intent on developing world-class space technologies, nor is it content to remain a mere follower in the wake of larger foreign agencies. However, it would appear that Japan is maximizing its international relations to ensure that Japan remains a significant contributor to basic science missions while lowering its overall financial burden in these endeavors; and instead, it is targeting precious capital to develop long-term, domestic infrastructure that will pave the way for other self-sustaining ventures such as orbital factories and laboratories, and even tourism.

ITS MASS, NOT SIZE, THAT MATTERS

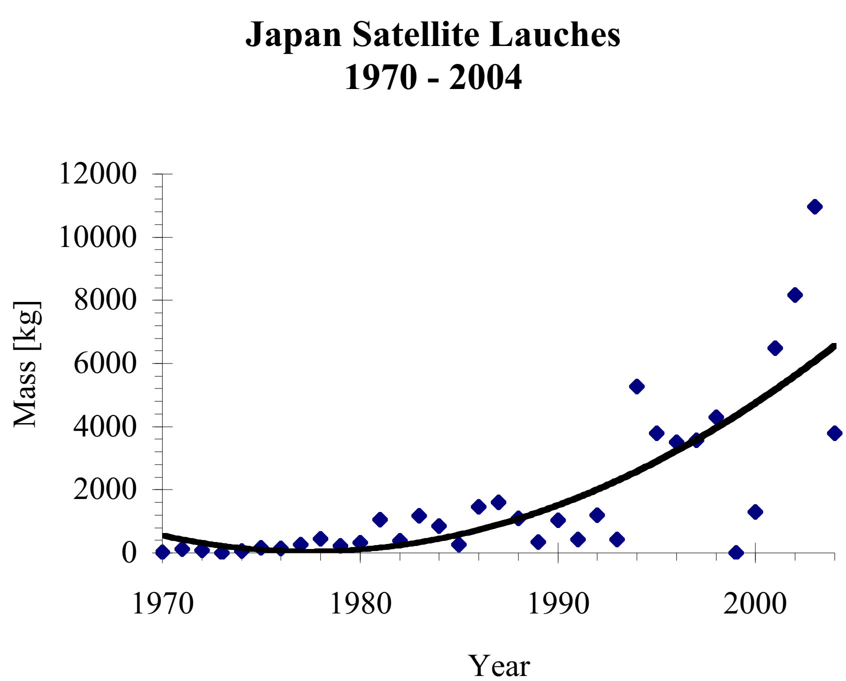


Figure 2 – Total mass [kg] launched annually (actual and projected) from 1970 to 2004 by Japan. Launches other than by domestic rockets are not included. [54] – [77]

It is possible to read the literature detailing the specifications of Japan's rocket from the LAMDA series to the H-IIA and its derivatives. However, this does not adequately frame the true accomplishment of Japan thus far. It is extremely educational to examine how Japan's space capabilities have developed from 1970 into a projected 2004. Using information gathered from references [54] – [77], both Figure 2 and Figure 3 help assist in this discussion. The first figure shows the total payload mass launched successfully into orbit annually. The second figure shows the number of successful launches conducted annually. As will be shown, when we consider these two sets of data together, a truly remarkable opinion of Japan develops.

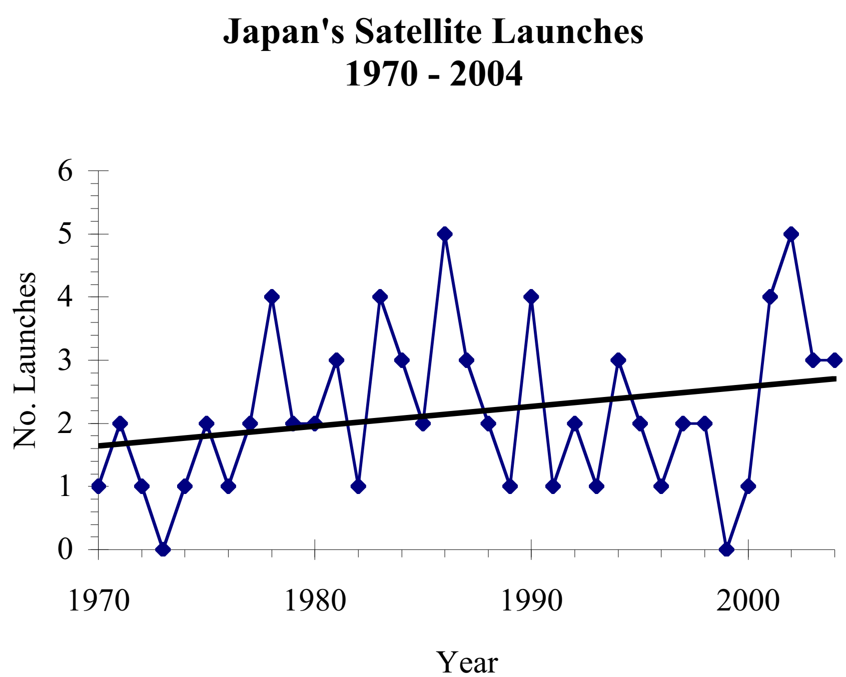


Figure 3 – Number of satellite launches (actual and projected) from 1970 to 2004 by Japan. Launches other than by domestic rockets are not included. [54] – [77]

In recent years, due to fiscal problems resulting from a decade-long recession, we have seen projects scaled-back as in the case of HOPE, or anticipated launch dates moved into the future. However, this is not to say that Japan is losing momentum garnered from its “golden” 1970s and 1980s. Indeed, Figure 2 and Figure 3 show a steady increase in both launched mass and number of launches, respectively.In the first figure there is a clear indication that Japan’s rockets are becoming more powerful; that is to say there appears to be exponential growth in its launch systems since 1970. Furthermore, this result is even more remarkable when we consider the implications presented in Figure 3.

We see over the same period (1970 to 2004) the number of launches, on average, have increased from a little under 2 a year in 1970 to nearly 3 a year in 2004. Of course there is variation around this average, but the important issue is that the number of launches per year grows linearly. In short, in order to put more payload mass into orbit Japan's has had to make each new generation launch systems (rocket) far more powerful than its predecessor.

H-IIA Rocket

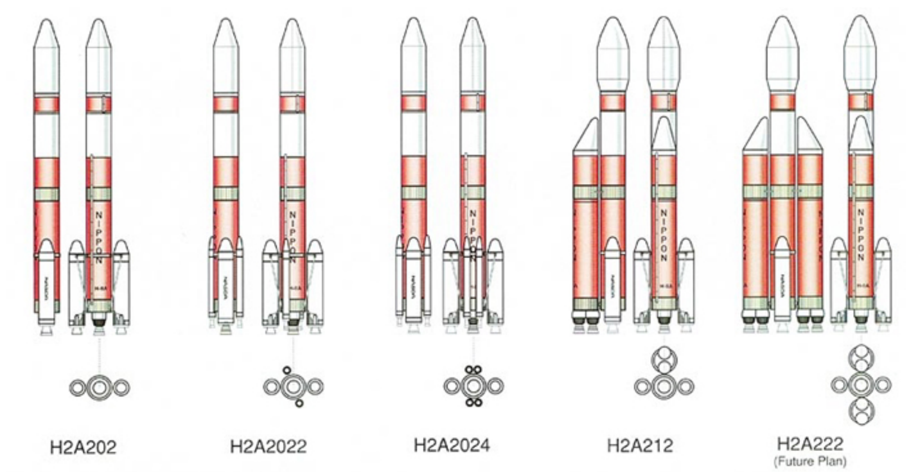


Figure 4 – Five major configurations of the H-IIA rocket are shown. Capabilities scale from 2-ton to geosynchronous orbit to 4-ton to geosynchronous orbit and beyond, along with ability to meet other types of mission objectives.

The H-II rocket, along with the H-IIA rocket, was developed to meet Japan's heavy-lift needs. Similar to other rockets in the world that include a certain amount of modularity, the H-IIA can be configured in a number of ways to best meet the specific mission objectives Figure 4 shows four present configurations, along with a fifth (H2A222) proposed derivative.

The rocket is capable of placing a 2.2-ton satellite into geosynchronous orbit. Coupled with Japan's advanced LE-5 engine capable of multiple firings, the rocket provides a high level of fault tolerance and mission objective deviation. The rocket and its engines are powerful enough to place a satellite into geosynchronous orbit without aid of an apogee rocket. This has the advantage of increasing satellite mission payload and/or fuel, thereby permitting expanded mission objectives, or increased mission duration, or both. Moreover, the LE-5 engine is extremely accurate. It can place a satellite to within 1 kilometer of position after traveling 6,800 kilometers, or within 50 kilometers of position after traveling 42,600 kilometers[1]. At present, the H-II will be scaled to place a 4-ton satellite in geosynchronous orbit, making it nearly as capable in payload mass to the United States Space Shuttle.

There still remain many obstacles before H-IIA rocket is considered ready for introduction to the launch system market. In particular, the cost of the system is too high from the standpoint of profitability. To date, over the past ten years, the program has cost a total of $1.9 billion, or an average of $2.50 per citizen per year. During the mid-1990s many within Japan contest that nearly $200 to $300 million can be saved by simplifying the experimentation process without unduly affecting rocket performance or overall cost. However, since the failure of three H-II rockets, this view has radically changed. Furthermore, it has been shown that a savings on the order of 30% is possible by using non-domestic parts, however, there are significant misgivings within the industry. In large part, the resistance is due to a desire by the industry to produce a "purely domestic" rocket, a result both of political and engineering posturing. And until launch

[1] Note that distance traveled from launch point to orbital insertion is not equivalent to orbit altitude. The rocket trajectory is an elongated arc, and therefore orbit altitude should be less than values provided.

costs can be reduced to levels consistent with what the international market will bear, Japan has been unable to entice many customers from abroad.

As corollary to this, NASDA and the government have positioned H-IIA as wholly Japanese built, using it to canonize a renewed belief in the country's technological dominance – not just as an adroit manufacturer, but also as an exceptional inventor. However, due to the recent string of launch failures, this symbolism has worked opposite to the original intention. Indeed, many of Japan's citizens now actively oppose further squandering of fiscal resources during a period of extended recession.

The H-IIA rocket and its derivatives is an attempt by Japan to provide efficient, economical launch systems for the world market. However, in the last couple of years the program has had numerous set backs due to fuel-pump problems, pre-firing of third stage thrusters, et cetera [9], [10], [19], [31]. These failures have led to general sentiment within Japan to reconsider the worth of its endeavors, especially in light of the cost of each mishap. Unfortunately, sensational reporting has only helped to goad the public into believing that Japan, as a nation, is incapable of becoming a world leader in the space industry.

In part, the author believes the symptom of the problem is more perception than any actual lack of competence of Japan's engineers. That is to say, Japan may have forgotten what its automotive industry went through in terms of growth in the 1960s and 1970s in order for it to come to forefront domestically and internationally. More to point, its automotive industry through strategic planning and innovative manufacturing and management techniques came to dominant market share and market drive in the United States starting in the mid 1980s. So much so that Detroit, long time leader of the industry for nearly 50 years, went to Japan to learn its secrets. However, the real secret of Japan's and the United State's success for the past 10 years has been key alliances formed between larger manufacturers. The author simply wants to stress that Japan, as a society, may have forgotten the lessons learned. Namely, that Japan may have forgotten that much of its recent prosperity was obtained through hard work and learning from its own mistakes.

However, for the technocrats within Japan, there has never been a loss of focus nor determination for its beloved H-IIA. In November of 1999, H-II no. 8 failed at launch. As a result of this incident, the third in a series of launch failures, beginning with H-II no. 6, project deadlines were extended in order to stem these humiliating losses. In May of the following year, 2000, it was determined that there had not been sufficient tests of primary components. Therefore, before the first H-IIA rocket is allowed to launch, much stricter tests and verifications were put in place. In particular, since the H-II no. 8 rocket failure was due to the first stage's LE-5 engine, extremely stringent guidelines were issued for the verification of both the LE-5A and LE-5B engines. Later on November 27 of that year, called improvement to the LE-5A resulted in an extension to the deadline. At present it is expected that the first launch of a H-IIA rocket will occur during the winter of 2001.

Consequently, on November 28 of 2000, the Japan Space Activities Commission issued the following statement.

> *"Firstly, we wish to sufficiently ensure that problems have been resolved after the recent launch failures of the H-II rocket. Many people from outside Japan have observed these failures of our newest rocket, and in addition, the string of problems that have resulted from these failures. It is therefore necessary that we confirm that normal operation of the rockets can resume. Furthermore, we should not be concerned with keeping our schedule, but instead concentrate on perfecting our launch*

capabilities." [25]

Japanese pride themselves on their ability to do to rockets what they did to automobiles – mass-produce inexpensive, reliable delivery systems. However, this overly simplified analogy may, in part, point directly to why Japan's efforts with H-II rocket are so seemingly disappointing [9][10][19][31][36][40]. However, the author believes this opinion is cultivated more by reporters and commentators, with little or no knowledge of these systems, too willing to judge the success or failure of a launch on whether it blows up or not. However, even seeming failures can be resounding successes; as such is the case with many H-II launches where autonomous back-up systems and error detection units were shown to work correctly even if an engine misfired. Japan's problem is not underestimation of the difficulties inherent in the controlled explosion that is rockets, but an over-enthusiasm that had lead to an overreach of its abilities as evidenced in the 1970s and 1980s. However, as we leave the 1990s and enter the twenty-first century, we see a Japan with adolescent overzealous to be a space power "yesterday" becoming tempered with experience, wisdom, and most importantly, patience.

Japanese Experiment Module (Kibou)

The Japan Experiment Module (JEM) is integral to the success of the International Space Station (ISS). The module allows astronauts to conduct micro-gravity experiments in a vacuum environment from within the station. This is accomplished through use of a very sophisticated root arm.

The development of the module was broken into three major steps. The first stage, from 1990 to 1993, was the basic test stage. This stage verified that process flow was achievable. That is to say, the ergonomic design of the module was necessary to ensure that human operators (astronauts) would be able to operate the experiments properly. The second step to developing JEM was the engineering model that incorporated structural and electrical design of the basic components of the module. This stage was completed in 1998. The final stage, to be completed in 2004, is the development of the "proto-flight model." Basically, the actual module for ISS is designed and built using data and experience gained from the first two stages. JEM is designed for an operational life of 10 years; however, if MIR is an indication, and disregarding catastrophic failure to space debris, the module may be in operation for much longer than this.

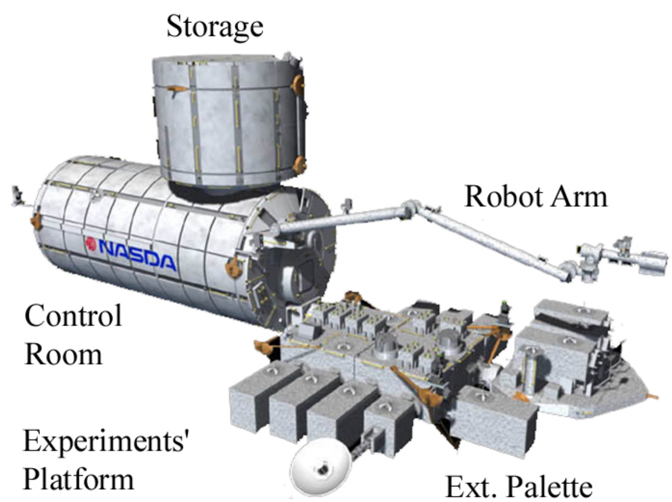


Figure 5 – Computer generated image of Japan Experiment Module (JEM). Five basic components are shown. International Space Station (ISS) crewmembers operate the robot arm from the control room. Experiments in micro-gravity, vacuum conditions can be achieved on the external palette and experiment platform in conjunction with the robot arm.

The module is composed of five (5) basic components: control room; storage area; robot arm; external palette; and, experiment platform.

The control room will house the necessary computers and other electronic equipment to operate the robot arm and conduct experiments on the experiment platform. It is 11.2 meters long, and the interior diameter is 4.2 meters with 0.2-meter thick walls. It weights nearly 16 tons. There is room for 23 racks of experiments. This component will be connected directly to the rest of the space station, enabling astronauts to move about the control room in a micro-gravity environment.

Attached to the control room is the storage area. It is only 4.2 meters long, and has the same radial dimensions at the control room. It has 8 racks for storing experiments. It will be connected directly to the control room, and will allow free access for astronauts.

The third component is the robot arm operated from within the control room. The robot arm itself is composed of two robots. The mother arm is directly attached to the control room, and allows basic rotational and transverse movement of the arm. The second robot is the child robot that can be moved with high precision. It also has the ability to use a variety of arm extensions that is chooses from the external palette to meet specific experiment needs.

The final component, and arguably, most important component, is the experiment platform. It houses the various experiments to be conducted in the micro-gravity environment. An advantage to the JEM configuration is the ability to conduct vacuum experiments along with micro-gravity experiments. The platform is 20 meters squared, and weighs a total of 4 tons. There is also an airlock connected to the exterior portion of the control room, allowing astronauts to “hand off” experiments to the robot arm.

As of August of 2000, the current timetable includes joining JEM to ISS incrementally in the start of 2004. In February of that year, the storage unit will be launched on flight 1J/A. Three months later, both the control room and robot arm will launched on flight 1J. Finally, in January of the following year both the external experiment platform and palette will be joined with the rest of the installed components.

H-II ORBITAL PLANE EXPERIMENTAL (HOPE-X)

As shown previously in Table 1 one goal of Japan is to develop a means of delivering large payloads into orbit along with assisting the nation, as a whole, to enter into lucrative space-based business ventures. Coupled with the initiative to develop orbital space platforms along with increased reliability and decreased operating costs, Japan has begun a program to develop an unmanned, hybrid spacecraft that sits atop a H-II rocket to reach outer space, returning to Earth as a glider similar to the United States Space Shuttle.

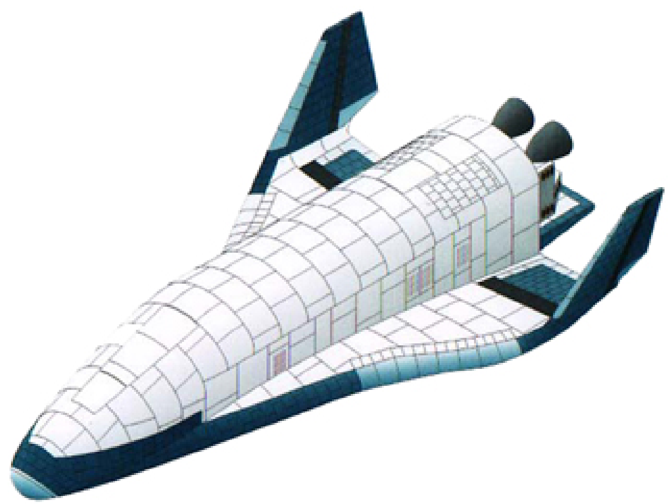


Figure 6 – Artist's concept of HOPE-X basic configuration

During the 1980s when HOPE was proposed, many failed to see any relation with its capabilities and business opportunities. In other words, there was large opposition both within and without NASDA who saw HOPE as a purely military launch vehicle. However, they have come to understand that HOPE will provide an excellent means of transporting goods into orbit for refueling orbital platforms; repairing damaged satellites; and even serving as an orbital platform itself for biological and materials science experiments.

Unfortunately, after 10 years of development Japan has yet to produce even an experimental version of the craft. Truth be told, the craft‘s original acronym was HOPE. However, sometime in the late-1990s, it was decided that, due to slower than expected progress along with reductions in NASDA’s operating budget, the project would be scaled back so that its scope was only experimental in nature. Consequently the X added to the acronym.

HOPE-X, while a viable experimental platform, it still has a variety of technological hurdles to overcome. At present it has issues with heat-resistant materials such as tiles found to be too brittle. However many advances have been made through cooperative experiences with United States development of its space shuttle. Another issue is Japan has less experience in aerodynamic, and also re-entry safety issues need to be resolved with further testing.

A typical launch cycle will proceed as follows: launch from Tanegashima Island; 30 minutes later it will reach orbit having traveled one quarter around the Earth; 48 hours later it will dock with an orbital platform such as the International Space Station; during the next 24 hours goods will be unloaded; next, it will detach itself from the platform and wait in orbit for a maximum of 24 hours while mission control determines optimal time of re-entry; once permission is received it will perform a 100 meter per second deceleration, re-entering the atmosphere; and, finally, it will land.

HOPE-X development is being validated using three main technology demonstrators. Each demonstrator is used to collect data to evaluate each flight state. As of 1994 approximately 70% of these demonstrations were completed.

The first demonstrator is the Orbital Re-entry Experiment (OREX) that resembles a “flying saucer” or “salad bowl.” This stage is also considered the most crucial toward developing HOPE. In 1994 OREX was launched atop a H-II rocket. Upon achieving an altitude of 450 kilometers in a circular orbit, it separated from the final stage of the rocket. As it traveled around the Earth it established a communications link with Tanegashima Space Center, which signaled it to fire its retro-orbit engines. Re-entry occurred some 1000 kilometers west of Christmas Island, and landed some 500 kilometers south of the island 10 minutes later. A variety of instruments on the probe allowed the indirect measurement of atmospheric heating such as electron density, temperature distribution, and so forth – a crucial component in HOPE's success.

The next demonstrator is the Hypersonic Flight Experiment, HYFLEX. On February 12, 1996, HYFLEX was launched atop a J-I rocket from Tanegashima Island. Onboard instrumentation allowed Japanese researchers to match measurements made with the OREX probe. In addition, the flight regime between Mach 3 and Mach 16 allowed data acquisition of surface pressure due to velocity over the fuselage, along with pressure distribution changes when thrusters were operated. Ultimately, HYFLEX data will be used in validating HOPE's hypersonic flight trajectory and fuselage attitude control algorithms.

The third demonstrator is the Autonomous Flight Landing Experiment, ALFLEX, which is dropped from an altitude of 110 kilometers, gliding back to terra firma. Unlike the United States approach of a manned space shuttle, HOPE is unmanned. Therefore, in order to allow it be a reusable vehicle it must be able to land autonomously upon return from orbit. From July 6th to August 15th of 1996, ALFLEX was dropped a total of 14 times from a helicopter. At is plummeted toward Earth it gained a maximum speed of 330 kilometers per hour at a 30° nose-down attitude. In less than 1 minute it autonomously landed at a speed in excess of 190 kilometers per hour. The speed is significantly higher than other aircraft, prompting the development of tires capable of handling these structural and heat loads. Onboard the craft are numerous instrumentation necessary to improve the accuracy of the glide slope, along with acquisition of in-flight position and speed data that will be used to validate landing navigation algorithms. A second stage of tests will include launching it atop a H-II rocket to an altitude of 100 kilometers where it will reach a speed of Mach 24. ALFLEX, a simplified model of the main components of HOPE will return to Earth and land some 40 minutes later.

Research continues to advance the capabilities and flexibility of HOPE-X, enabling the vehicle to have a broader range of re-entry trajectories along with increased anti-heating shielding performance and improved aerodynamics to extend the length of its re-entry trajectory. The heat-shield tiles used on HOPE are now equivalent to the United States Space Shuttle tiles in terms of performance. In addition, many advances have been made to the field of computational fluid dynamics (CFD) in pursuit of completing HOPE-X.

When HOPE, or more precisely, HOPE-X is complete it will represent the next stage in Japan's journey into outer space. It will prove essential is advancing even more ambitious plans such as permanent orbital platforms and colonizing outer space. And even as Japan advances its own causes and dreams, many in the international community look forward to seeing HOPE-X become a transport workhorse for the International Space Station.

Chapter 4
THE FUTURE

Thus far we have examined Japan's government mechanisms, technocratic attitudes, and technological fruits born from the former two for the sake of a national space agenda. However, these are bureaucratic in nature. This is not meant to denote any pejorative slant by the author toward these institutions and their activities; instead, more simply, they are orchestrations of Japan's political and technology leaders. And regardless of how democratically or well intentioned these peoples may be, it nonetheless can be strikingly different if it fails to reflect the general will of the populace. Fortunately, this is not the case in Japan. Nevertheless, many people examining Japan's space development efforts too often use metrics better suited for the United States, and therefore might erroneously conclude Japan is either misguided, or more superciliously, still in a state of maturation.

In Japan, where the line between amateur enthusiast and professional is particularly blurred, it is nearly non-existent in the field of space commercialization. Presently, there are research offices within NASDA dedicated to researching future applications of outer space outside the realm of scientific observation. Also, there are numerous self-organized research groups and investors making a concentrated effort to diverge from the traditional, rather conservative approach preferred by NASA. This has had a large impact on the political machinery within Japan itself.

All of this is particularly germane as we enter the second half of 2001. On May 6 of 2001 Daniel Tito returned from the International Space Station, not as an astronaut but as a tourist. Having paid $20 million for the opportunity, the once NASA space scientist became Russia's, and the world's, first tourist to travel to outer space. What used to be a purely academic discussion has been thrust into the political realm as a reality that will not wait until tomorrow to be resolved. More interesting, it has been NASA that has shown the greatest resistance to D. Tito's presence on the orbital research platform. In NASA's defense, its mandate from the government is not to directly develop economic opportunities, but develop cutting-edge technology for use by other companies. However, this is not the case with NASDA that has a more pragmatic set of legislation pointing it toward developing space technologies for industrial use. Consequently, NASDA has been more open to research not typically found in other world space agencies.

It is this difference that the author believes is the crucial distinction that will propel Japan past other space developing nations in the next decade. Therefore, instead of concentrating on NASDA's SELENE, a project to survey the moon, or other more ambitious plans to go to Mars or even colonize space[1], we will focus our attention on Japan's drive to develop space tourism. And ironically, this notion is not evolutionary to many in the industry outside of Japan, but indeed, truly revolutionary. However, for Japan, the idea has been around for nearly two decades. Already serious research, both business and technical, has been conducted.

SPACE TOURISM

There has been a substantial amount of research conducted in Japan regarding the marketability and economic feasibility of tourism in space. The most often cited example to substantiate the potential for this market is a survey conducted by Patrick Collins, *et al.* as a study for the Japan

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[1] While these are important programs, they are, truth be told, exceedingly passé in light that they have all been dreamt of by nearly every agency and "visionary" as far back as a century ago. Many with in the space community have a depreciating attitude toward capitalistic activities, believing that they diminish the other, more "altruistic," pure science programs.

Rocket Society. The survey asked 3,030 participants how much value they associated with a single trip to outer space. In particular, the survey asked if "three months equivalence in salary for a ticket to outer space was warranted?" There was an overwhelming response; nearly 70% of the respondents agreed.

However, it is not merely the enthusiasm but the economy of scale that this market represents. The global market for tourism, as a whole, is on average $6 billion annually[1]. Of this, the largest growing sector is "extreme" tourism, including but not limited to white-water rafting, mountaineering, and other less sedate, more dangerous alternatives. At present, this sector represents some 20% of the total revenue generated, or over $1 billion per year. In way of comparison, the entire satellite sector, which many analysts consider is nearly saturated at $1 billion per year. In other words, the bread-and-butter of the space industry is barely equal in revenues to that generated through the consumption of disposable income for vacation. And whereas the satellite sector growth is leveling out, extreme tourism is on the rise.

To better grasp what those numbers mean, let us examine the number of tourists annually within Japan. It is estimated that in 1993, 220 million Japanese traveled both domestically and abroad, or considering its population, each person traveled 1.62 times that year. Of those people, 13.5 million people traveled abroad. Even more phenomenal is that in 1964 only 130 thousand Japanese traveled abroad; 10 years later that number grew 18 times, or 2.3 million travelers abroad. And, as we have already shown, thirty years later it had grown by a factor of 100.

Still, we still need to provide numbers that substantiate the claim that space tourism is a

[1] Information gathered from an informal conversation with Joe Hopkins, market analyst of Andrews Space & Technology during the summer of 2000. The author can neither dispute nor refute these findings independently.

viable industry. If only 20% of those 13.5 million travelers were interested in “extreme” experiences, that represents 2.7 million potential people who would fit, as a first-order approximate, people interested in going to outer space. If we assume that the survey conducted in Japan is representative of the general population, that is to say 70% would be willing to pay three-months salary for a ticket, and if only half of these people actually purchase a ticket we can assume that we have a total of 900,000 people per year who would be willing to pay three-months salary for a ride into space.

However, how much could a market bear? If the cost of a ticket was on the order of $50,000[1], T. INATANI [2] shows that approximately 10,000 people would be willing to pay this price. However, further research shows that price and the number of people willing to pay this price is, quite intuitively, inversely proportional. In other words, as the price becomes cheaper, more and more people want to purchase a ticket. This data is then used to generate annual revenue as a function of ticket price, as shown below in Figure 7.

INATANI also shows that the largest amount of revenue, on the order of $1.43 billion annually, is matched by a market demand of 500,000 people willing to pay nearly $29,000 per ticket. What is most surprising is that our first-order approximation presented previously, namely 900,000 tourists within Japan alone, is on the same order is what market analysis indicates is needed for a viable industry. Expanding our analysis to international consumers willing to burden the cost of a ticket, it is indeed reasonable to argue that space tourism, at least economically, has come of age.

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[1] Considering that D. Tito paid on the order of 40 times this amount for a trip aboard a Russian Soyuz capsule, this price seems quite reasonable.

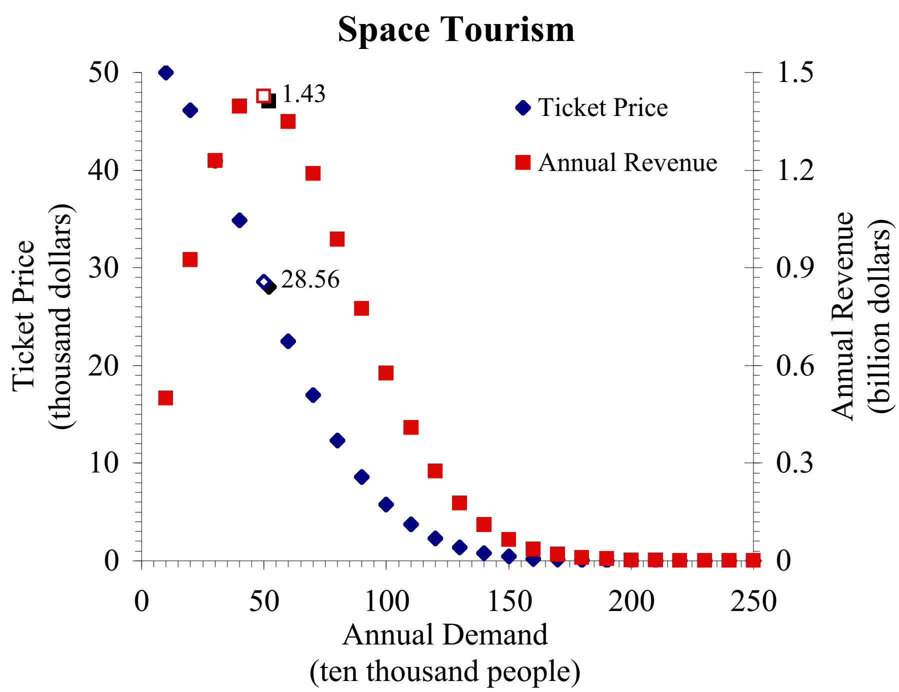

Figure 7 – Typical relationship between ticket price, annual revenue, and annual demand. See Figure 5 and Figure 6 of reference [2] for exact data.

ROADS NOT YET TAKEN

However, while researchers in Japan have shown that a market exists, there is an ocean of technical details that still need to be addressed before a viable product can be brought to market. Interestingly, it is T. GODAI, former head of NASDA, who wrote in reference [7] that both then HOPE and H-II development is crucial to dreams of lofting the citizens of Japan into space, both literally and metaphorically. This leader of Japan's aerospace technocrats envisioned a day when people would be able to look back over the plains of the Moon on the Earth, not as trained explorers and researchers of a government program, but as world citizens filled with curiosity and adventure for the unknown. It may seem be difficult to imagine this leader, who helped lionize Japan's H-II rocket program, speak with child-like fervor about a topic that to too many in the aerospace industry see as "too much dream, not enough science."

It is very well understood that space technology, as it stands today, is insufficient for the demands of a space tourism industry. To explain this, let us return to our numbers computed in the previous section. If we can build a vehicle that can handle 50 passengers, and if each vehicle is in operation on 1-day cycles ferrying people to low-Earth orbit and back year-round, we would require a fleet of 50 vehicles to accommodate 0.5 million people per year.

However, a fleet of 50 vehicles operating on 1-day cycles is not yet feasible with current technology. At present, the United States Space Shuttle takes months of preparation for a single launch, with thousands of highly trained technicians ensuring that all its complex systems are ready for launch. Any vehicle that is designed will need to be completely re-usable. In other words, whatever it launches with it, it returns with. If we use the failures of the United States X-33 and X-34 programs as litmus, we may still be two to three decades away from realizing this level of technology. Further, not only must the vehicle be re-usable, it must also be able to operated and maintained at a level consistent with airline aircraft of today. In short, fast turn-around, relatively low maintenance, and high reliability.

As for this third factor, high reliability, the world's launch capability is around 95% reliable. At first glance, this may seem quite high, but it is spectacularly low[1]. And when compared to automobiles, and even more so when compared to commercial aircraft, which both operate well in excess of 99.999% reliability, current launch technology needs to be many orders more

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[1] At a half a million people per year going to space, at that rate, 25,000 passengers will die a year.

reliable.

Another issue surrounding a fleet of 50 vehicles is both payload cost and availability of fuel. The current cost to launch 1 kilogram into orbit on the United States Space Shuttle is around \$10,000[1]. In order for transportation costs to be economical, T. INATANI suggests that payload costs need to fall to one-hundredth this level, or \$100 per kilogram. Coincidentally, this value is on the same order called for by others advocating commercialization of space technologies[2].

The other issue besides payload cost is the availability of liquid hydrogen used as one component of rocket fuel. For example, the current production rate for the United States is 200 tons per day. However, INATANI suggests that in the first year of operation, with only 4 vehicles, the venture will require production rates twice this. And the demand for production only grows linearly as vehicles are phased in over a period of 7 years. When operations are at full capacity, the production rate demand will be in excess of 3000 tons of liquid hydrogen per day, or 15 times the rate currently available in the United States.

KANKOU MARU

Regardless of the many technological shortcomings, the enthusiasm of many in Japan is astounding. The Japan Rocket Society (JRC) has designed its concept of a re-usable launcher capable of accommodating 50 passengers. The design vehicle has been called "KANKOU

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[1] How expensive is this really, though? If you filled the United States Space Shuttle with lead, launched it into space, and somehow turned all the lead into gold, the resale value of the gold would not be enough to offset the cost of launching the lead.

[2] It has been shown that there is elasticity to the entire launch market. As payload-to-orbit costs decrease, the number of launches does not particularly increase to compensate for lost revenue. However, once the threshold around \$100 per kilogram is breached, the market very quickly returns to levels comparable or better than that of the current launch market. However, there is resistance from corporate leaders who overly focus upon loss of revenue during the interim approaching this said threshold.

Maru,[1]" a reference to Japan's first steam-powered ship. The name harkens to a romantic age, and means a "ship that sails upon the light between Earth and stars that is an ocean of space."\

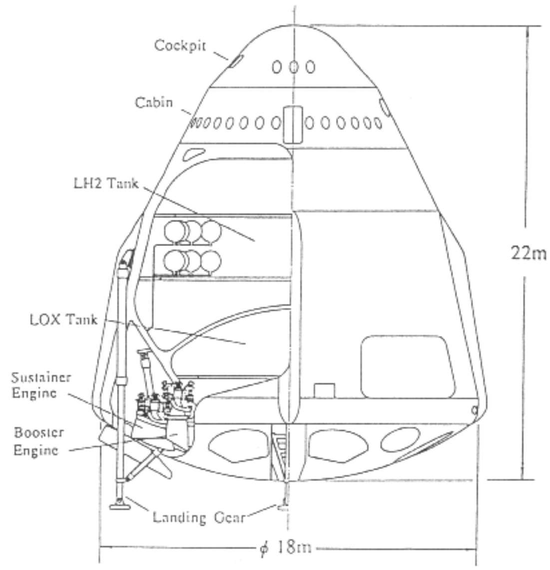

Figure 8 – Schematic with cut-away of Japan Rocket Society KANKOU Maru, its prototype for delivering 50 passengers per launch to low-Earth orbit (LEO).

Based on surveys, including the one mentioned previously, the society has designed the vehicle to be capable of two cruise types. The first is a 3-hour ride, orbiting the Earth twice before landing. The second is a 24-hour ride, orbiting the Earth 16 times before returning to Earth. Of course, the longer cruise will include 3 meals for all its passengers and crews.

Besides the overall size shown in Figure 8, the vehicle weighs 550 tons at time of launch. There are a total of 12 rocket engines on the lower portion of the vehicle. It will take off and land

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[1] 観光丸

in a vertical position[1]. It is expected to operate 270 cycles per year for its 10-year lifespan. The estimated cost per vehicle is $0.7 billion; and operating cost per flight is calculated at $1 million. At these values, the vehicle will need to operate for a little over 5 years in order to generate a return on investment. However, thereafter, each vehicle will generate $500,000 per flight.

A variety of issues have had to be considered that, while not unique to commercial airlines, is a novelty for aerospace engineers. For example, how do you entertain and accommodate 50 people for a 24-hour flight? How do you handle such personal issues as use of toilets in zero-gee environment with people who are not as extensively trained as today's astronauts? What medical screening is necessary to ensure that passengers can handle the 3-gee plus lift-off along with "space sickness," et cetera? What can you do if a person has a medical emergency requiring immediate professional attention? Other issues include being able to evacuate the vehicle during an emergency, and so forth.

Amazingly, many of these questions have been or are presently being seriously addressed within NASDA and other organizations in Japan. A search for "KANKOU Maru" on Japanese Internet search engines results in numerous hits to a variety of topics on the subject. In particular, SpaceFuture.com and SpaceTopia.com ([46] and [47], respectively), provide a wealth of information.

PIE IN THE SKY

It is difficult to defend Japan's dreams of space tourism in light of the technical hurdles facing them. However, that is not what is critical to our discussion. The reader needs to appreciate the

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[1] The Delta Clipper technology demonstrator conducted by the United States Department of Defense has already shown the feasibility of this configuration.

fact that the aerospace industry, and in particular, the development of rockets has gone at a pace set by technological advancement. As new technology is developed, engineers, scientists, and managers determine best-use situations. However, this is similar to having the horse push the cart. It is invariably slow to respond to real-world pressures, and has a tendency to reflect an attitude of "technology for the sake of technology."

Case in point is launch system developers for the satellite industry. There is a line hundreds of millions of dollars long of defunct companies that attempted to develop products without anticipating future demand. Satellite-bus technology turn-around is on the order of 18-months, whereas rocket design in on the order of 3-years, or twice this. As a consequence, many companies that started rocket companies to meet current demands for certain satellite sizes, found to their dismay that two years later the market had suddenly shifted. Their rocket design was worth less than the computer hardware it was stored on. In short, the rocket industry has yet to fully realize that it needs to develop solid business cases in order to build a rocket that the market can bear.

However, Japan has been for many years approaching its space activities with business in mind. That is to say, they have first built a very solid business-case, showing with reasonable certainty that supply is sufficiently large enough to warrant investment. Japan, as a country, is firmly putting the horse back in front of the cart; where it belongs.

By knowing what will enable its industry, as a whole, to be self-sufficient (profitable), leaders in Japan have been able to make rationale, well-founded decisions about what technology will bear the most rewards in the long-term. It is no coincidence that in 1991 Japan showed a dramatic shift toward development of orbital structures and space shuttle technology. Japan clearly understands that in 10 to 20 years, through hard work and the correct perspective, it will have the expertise necessary to make space tourism a reality.

Chapter 5
SUMMARY

This report is broken evenly into three sections exploring Japan's past, present, and future space development. However, it would be exceedingly misguided to call this report simply annals of Japan. The author has strived to weave together a portrait of a living organism, and develop for the reader a sense of how this organism has, is, and will interact with its surroundings.

Consequently, we can also equally divide the report into three sections: one, delving into reasons surrounding Japan's philosophy toward space development; second, the economic and material reasons that these philosophies are in part necessary; and three, why furthermore these philosophies are congruent with and in support of its present objectives that are solidly aimed at long-term, sustainable development.

For the sake of discussion, some of Japan's early activities, when contrasted to its current position of international cooperation, has been cast in quite a monochromatic light by the author. However, the author wishes to emphasize that, while Japan has never been antagonistic toward supporting other nations, it initially saw space activity more as a means of sustaining domestic priorities than developing international partnerships. Further to point, over the past three decades Japan has gradually grown to appreciate the fact that through assisting the international community, it is also supporting its domestic needs. That is to say, Japan sees itself in a symbiotic relationship with its international partners.

As economic necessities came to bear upon Japan's space agencies in the late 1980s and early 1990s, its leaders took a long look to its future. The author imagines them asking themselves questions of how they would fulfill their mandate – to develop a driving force for economic and spiritual growth of its people – while also doing so in a manner that is non-parasitic on society – namely, continued tax-payer investment lacking measurable return-on-investment. When this soul searching concluded, the leadership of Japan understood that, at the cost of immediate prestige evidenced by a reduction in purely scientific missions, and by focusing on key technologies such as space systems and heavy-lift, reusable vehicles, it had found a solution to its quandary.

Note that the words "economic and spiritual" are used in conjunction with "mandate". Japan is not merely interested in reaping fortunes from its technology, though this is no doubt one expected result of its efforts. Space has always conjured up romantic images of the exploration of the unknown, the universality of humankind. And space development is at the forefront of technologies. It effects every moment of our lives, and whether we do it consciously or unconsciously, we are aware at some level of our connection to it all. Japan feels this, too. And it understands, now more than ever, that the development of space is an opportunity for its nation to expand itself economically, politically, and even culturally.

What is striking about Japan up to the present day is its wrestle with a desire to simultaneously remain independent from other countries' larger agencies, while at the same conceding that it needs to contribute to international efforts in order to prove its citizenship, as it were. International cooperation, while possibly diluting Japan's own sense of independence or autonomy, strengthens its implicit need for *interdependence* – something some people might be tempted to call a national, even racial, character of Japanese. Ironically, as this very internationalism becomes infused into Japan's space activities it also allows pursuit of a purely domestic agenda. More specifically, through international efforts Japan gains valuable access to projects that it cannot on its own acquire. It further fulfills its morale obligation to contribute to a global society. Further to point, because the total financial investment is lessened by sharing costs with other nations, Japan is able to focus its limited budget on technologies that will benefit its domestic industries, such as development of the H-II rocket and HOPE-X, both of which will significantly add to the development of a technologically and economically robust space infrastructure.

As we look to the future, Japan still holds aspirations of setting a pace to space that is all its own. Within Japanese circles there is still much talk about lunar bases and missions to Mars, equally or more bold than that found in similar circles in the United States. More impressive is Japan’s private sector full of enthusiasts who are looking to make space viable for the general populace. Unlike the United States who is reliant on large business and government agencies (NASA) to pave the way for new launch systems, many in Japan have been actively researching alternatives. Furthermore, they understand the necessity of a paradigm shift from the current model based on scientific pursuits (that are ultimately without immediate or direct payback) to a solid business model.

A significant departure with Japan from other world space agencies is its open willingness, both politically and practically, of seeing space development as more than a mere ends, but as a means of becoming a catalyst to launch a wide range of industries, both quite literally and metaphorically, into outer space. And in so doing, expand the capabilities of its society and its dreams to the far reaches of outer space.

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Appendix A

ROCKETS

Table 5 – General characteristics of Japan's rockets [54] – [77]

Name	No. Stages	Fuel[1]	Length [m]	Diameter [m]	Weight [ton]	First Launch	Satellites Launched
L-4S	4	1-3 S	16.52	0.735	9.40	2/11/1970	OOSUMI
M-4S	4	1-3 S	23.57	1.41	43.5 – 43.8	2/16/1971	ES SS-01 SS-02
M-3C	3	1-3 S	20.24	1.41	41.5	2/16/1974	ES SS-03 SS-04
M-3H	3	1-3 S	23.80	1.41	49.8	2/19/1977	ES SS-05
M-3S	3	1-3 S	23.80	1.41	49.5	9/16/1978	SS-06 ES SS-07 SS-08 SS-09
M-3S II	3	1-3 S	28.2	1.41	61	1/8/1985	ES SS-10 SS-11 SS-12 SS-13 SS-14 SS-15 ETS-5
M-V	3	1-3 S	30	2.5	128	9/12/1997	SS-16 SS-18 SS-19
N-I	T	1,2 L 3 S	32.57 – 35.40	2.44	90.40 – 135.5	9/9/1975	ETS-I ISS ETS-II ISS-B ECS ECS-2 ETS-III

[1] The following abbreviations are used. S = solid, and L = liquid.

Name	No. Stages	Fuel[1]	Length [m]	Diameter [m]	Weight [ton]	First Launch	Satellites Launched
N-II	3	1,2 L 3 S	35.40	2.44	134.7 – 135.5	8/11/1981	GMS-2 ETS-IV CS-2 CS-2A CS-2B BS-2A GMS-3 BS-2B MOS-1
H-I	3	1,2 L 3 S	40.3	2.44	149.2	8/13/1986	EGS JAS-1 MAVES ETS-V CS-3A CS-3B GMS-4 DEBUT JAS-1B MOS-1B ERS-1
H-II	3	1,2 L 3 S	49	4	264	3/18/1992	GMS-5 OREX VEP ETS-VI SFU ADEOS ETS-VII
H-IIA (2 ton)	3	1,2 L 3 S	52	4	283		
H-IIA (3 ton)	3	1,2 L 3 S	52	4	394		
J-I	3	1-3 S	33	1.8	87		

Appendix B

SATELLITES

Table 6 – General characteristics of Japan's satellites [54] – [77]

Name[1]	Mass [kg]	Orbit[2]	Range [km]	Rocket	Launch Date	Mission
ADEOS-II	3500	E-SUN	800	H-II	2001	International contribution of surveillance of earth environment's global changes
ADEOS; MIDORI	3500	E-SUN	800	H-II	8/17/1996	International contribution of surveillance of earth environment's global changes
ALOS	4000	E-SUN	690	H-II A	2002	Cartography; earth observation; resources survey
BS-1; YURI	355	E-GEO	35800	USA	4/8/1978	Establish implemented technology for broadcasts from satellites
BS-2A; YURI-2A	350	E-GEO	35800	N-II	1/23/1984	Broadcasting satellite technology demonstrator
BS-2B YURI-2B	350	E-GEO	35800	N-II	2/12/1986	Broadcasting satellite technology demonstrator
CS-1; SAKURA	340	E-GEO	36000	USA	12/15/1977	Establish implemented technology for communications from satellites

[1] Japanese satellites can be slightly confusing due to translations, acronyms, et cetera. The first entry is the bureaucratic name. These are abbreviated, whenever possible, as follows: BS = broadcasting satellite; COMETS = communications and broadcasting test satellite; CS = communications satellite; DRTS = data relay transmission satellite; ECS = experimental communications satellite; ERS = earth resource satellite; ES = experiment satellite; ETS = engineering test satellite; FMPT = first generation material properties tests; GMS = geosynchronous meteorology satellite; ISS = Ionosphere satellite; JAS = japan amateur satellite; MDS = mission development satellite; MOS = meteorological observation satellite; OICETS = optical inter-orbit communications engineering test satellite; TS = technology satellite; and, SS = science satellite. Next, the second entry, delineated by a semi-colon ";", is either its christened name, or as is the case with many science satellites (SS), they also have a sub-class. Christened names, whenever available, are the last entry and further delineated by a semi-colon ";" when necessary.

[2] The following abbreviations are used to denote orbital orientation: E = Earth; L = Lunar; S = Sun; and, M = Mars. Furthermore, further orbital information can be provided with the following abbreviations. CIRC = circular; ELL = elliptical; POL = polar; SUN = always aligned with Sun; MON = always aligned with Moon; GEO = geosynchronous; and, TRA = geosynchronous transfer. For example, E-GEO denotes a geosynchronous orbit around Earth.

Name[1]	Mass [kg]	Orbit[2]	Range [km]	Rocket	Launch Date	Mission
CS-2; SAKURA-2	347	E-GEO	35800	N-II	2/4/1983	Establishment of satellite communications systems
CS-2A; SAKURA-A	350	E-GEO	35800	N-II	2/4/1983	Communications satellite technology demonstrator
CS-2B; SAKURA-B	350	E-GEO	35800	N-II	8/6/1983	Communications satellite technology demonstrator
CS-3A; SAKURA-3A	550	E-GEO	35800	H-I	2/19/1988	Continuation of communication services originally provided by CS-2 series; diversification and enlargement of communications envelope management; development of communications satellite technology
CS-3B; SAKURA-3B	550	E-GEO	35800	H-I	9/16/1988	Continuation of communication services originally provided by CS-2 series; diversification and enlargement of communications envelope management; development of communications satellite technology
CS-4; COMETS; KAKEHASHI	2000	E-GEO	35800	H-II	2001	Integration of precision, moving body communications technology, inter-satellite communications technology; other various satellite communications technology
DEBUT; ORIDURU	50	E-ELL	900 – 1700	H-I	2/7/1990	Extension and contraction of boom; atmospheric friction experiments
DRTS-E	1400	E-GEO	35800	H-II A	N/A	Ongoing experiments of gathering earth observation data; mid-sized satellite bus technology demonstration
DRTS-W	1400	E-GEO	35800	H-II	2002	Ongoing experiments of gathering earth observation data; mid-sized satellite bus technology demonstration
ECS-2; AYAME-2	130	E-GEO	35800[1]	N	2/22/1980	Communications satellite; millimeter wave communications experiments; establishment of pursuit control technologies
ECS-1; AYAME	130	E-GEO	35800[2]	N	2/6/1979	Communications satellite; millimeter wave communications experiments; establishment of pursuit control technologies

[1] Failed geosynchronous orbital insertion

[2] Failed geosynchronous orbital insertion

Name[1]	Mass [kg]	Orbit[2]	Range [km]	Rocket	Launch Date	Mission
EGS; AJISAI	357	E-CIRC	1500	H-I	8/13/1986	Correction of domestic survey information; island separation determination; establishment of Japanese survey origin
ERS-1; JERS-1; FUYOU-1	1200	E-SUN	560 – 570	H-I	2/11/1992	Attempt to establish active observation technology; main objective to survey resources, farming, forestry, and fishing industries; environment preservation; fire prevention; ocean bottom observations
ES; MS-T4	180	E-ELL	350 – 600	M-3S		Confirmation of M-3S rocket capabilities; sun orientation control experiments; solar panel construction experiments
ES; MS-T5; SAKIGAKE	138	S	N/A	M-3S II	1/8/1985	Confirmation of M-3S II rocket capabilities; Halley comet and plasma observations
ES; TANSEI	63	E-ELL	990 – 1110	M4-S	2/16/1971	Satellite environmental and functional experiments
ES; TANSEI –2	56	E-ELL	290 – 3240	M3-C	2/16/1974	Measure rocket characteristics, engineering experiments related to satellite
ES; TANSEI-3	129	E-ELL	790 – 3810	M-3H	2/19/1977	Confirmation of artificial satellite launch capabilities; satellite attitude control experiments
ES; TANSEI-4	185	E_ELL	520 – 670	M-3S	2/17/1980	Confirmation of artificial satellite launch capabilities; instrumentation performance experiments
ETS-5; KIKU-5; EXPRESS	800	E-CIRC	250	M-3S II	1/15/1995	Cutting-edge industry technology demonstrator for space environment utilization necessary for planetary probes
ETS-I; KIKU	83	E-ELL	980 – 1110	N	9/9/1975	Rocket launch capabilities confirmation, satellite management technology, antenna deployment experiments
ETS-II; KIKU –2	130	E-GEO	36000	N	2/23/1977	Establishment of geosynchronous technologies
ETS-III; KIKU –3	638	E-ELL	220 – 35820	N	2/11/1981	Confirmation of N-II launch capabilities
ETS-IV; KIKU –4	385	E-ELL	970 – 1320	N-II	9/3/1982	Large power generation for artificial satellites and space instrumentation experiments
ETS-V; KIKU-5	550	E-GEO	35800	H-I	8/27/1987	Confirmation of H-I rocket (3 stages) capabilities; establishment of 3-axis stationary satellite bus; moving body communications experiments

Name[1]	Mass [kg]	Orbit[2]	Range [km]	Rocket	Launch Date	Mission
ETS-VI	2000	E-GEO	35800	H-II	8/28/1994	Rocket launch capabilities confirmation, satellite management technology, antenna deployment experiments
ETS-VI I; ORIHIME	2860	E-CIRC	550	H-II	11/28/1997	Establishment of rendezvous docking technology
ETS-VI II	3000	E-GEO	35800	H-II A	2003	Establishment of rendezvous docking technology
FMPT				USA	9/12/1992	Conduct material experiments on board USA Space Shuttle
GEOTAIL	N/A	N/A	N/A	USA	11/18/1983; 7/24/1992	Earth night-side enlarged magnetic field tail structure and dynamics observation research
GMS-1; HIMAWARI	315	E-GEO	35800	USA	7/14/1977	Earth atmosphere development project (GARP): observation from space of weather and constituent distribution
GMS-2; HIMAWARI-2	296	E_GEO	35800	N-II	8/11/1981	Development of atmospheric satellite technology and improvement of imaging bureau
GMS-3; HIMAWARI-3	303	E-GEO	36000	N-II	8/3/1984	Development of weather satellite technologies; improvement of Meteorological Bureau
GMS-4; HIMAWARI-4	350	E-GEO	36000	H-I	9/6/1989	Development of meteorological technology
GMS-5		E-GEO	35800	H-II	3/18/1992	Improvement of Meteorological Bureau and atmospheric satellite technology
HOPE-X	N/A	E-CIRC	N/A	H-II A	2004	Unmanned winged transport vehicle demonstrator; necessary for future reusable transport vehicle research
HTV	7000	E-CIRC	350 – 460	H-II A	2003	Transport of goods to international space station system
ISS-B; UME-2	141	E-ELL	980 – 1220	N	2/16/1978	World-wide distributions of Ionosphere critical frequency and radiation noise observations
ISS; UME	139	E-ELL	990 – 1012	N	2/29/1976	World-wide distributions of Ionosphere critical frequency and radiation noise observations
ISS; UME-2	141	E-ELL	980 – 1120	N	2/16/1978	World-wide distributions of Ionosphere critical frequency and radiation noise observations
JAS-1; FUJI	50	E-CIRC	1500	H-I	8/13/1986	Amateur wireless satellite communications
JAS-1b; FUJI-2	50	E-ELL	919 – 1748	H-I	2/7/1990	Amateur wireless satellite communications
JEM				USA	2003	Conduct: materials experiments; life science experiments; science and earth observations; et cetera

Name[1]	Mass [kg]	Orbit[2]	Range [km]	Rocket	Launch Date	Mission
MABES	295	E-CIRC	1500	H-I	8/13/1986	Magnetic flywheel in zero gravity environment experiment
MDS-1	480	E-TRA	35800	H-II	2000 - 2001	International contribution of surveillance of earth environment's global changes
MOS-1; MOMO-I	750	E-SUN	900	N-II	2/19/1987	Oceanic phenomenon observations; and establishment of terrestrial observation from satellites
MOS-1b; MOMO-IB	740	E-SUN	909	H-I	2/7/1990	Oceanic phenomenon observations; and establishment of terrestrial observation from satellites
OICETS	500	E-CIRC	550	J-I	2001	Optical linkage between satellite technology experiments
OOSUMI	24	E-ELL	340 – 5140	L-4S	2/11/1970	Launch/satellite feasibility
OREX	865	E-CIRC	450	H-II	2/4/1994	Accumulation of fundamental re-entry aerodynamics data
SELENE	2900	L-CIRC	100	H-II A	2004	Lunar structure and origin research; gather date for future lunar surface probe; development of fundamental technology for lunar landing
SEPAC	N/A	N/A	N/A	USA	11/18/1983; 3/23/1992	Aurora emitted light structure; elucidation of plasma particle momentum, and wave surge observations
SFU	3000	E-CIRC	500	H-II	3/18/1995	Geology experiments; astronomical observations; development of leading-edge technologies for industries; improve JEM design and implementation
SS-01; SHINSEI	66	E-ELL	870 – 1870	M4-S	9/28/1971	Ionosphere, space radiation, short-wave, and solar phenomenon observation
SS-02; DENPA	75	E-ELL	250 – 6570	M4-S	8/19/1972	Plasma waves, magnetic waves, terrestrial magnetism observations
SS-03; TAIYOU	86	E-ELL	260 – 3140	M-3C	2/24/1975	Effect of solar radiation on terrestrial troposphere
SS-04; CORSA; HAKUCHOU	93	E-ELL	550 – 650	M-3C	2/21/1979	Space radiation (X, alpha, and gamma rays), particle observations
SS-05; EXOS-A; KYOKKOU	95	E-ELL	350 – 4500	M-3H	2/4/1978	Electron density, temperature, energy distribution; Aurora particle observation
SS-06; EXOS-B; JIKIKEN	70	E-ELL	300 – 30000	M-3S	9/16/1978	Electron density, particle, and plasma wave observations
SS-07; ASTRO-A; HINOTORI	120	E-ELL	350 – 600	M-3S	2/21/1981	Solar-generated X-ray flares; solar particle measurements

Name[1]	Mass [kg]	Orbit[2]	Range [km]	Rocket	Launch Date	Mission
SS-08; ASTRO-B; TENMA	120	E-ELL	350 – 0600	M-3S	2/2/1983	X-ray stars, X-ray galaxies, gamma bursts, and X-ray nebula observations
SS-09; EXOS-C; OOZORA	200	E-ELL	300 – 30000	M-3S	2/14/1984	Stratosphere atmospheric research and elucidation of Ionosphere plasma's unique phenomenon
SS-10; PLANET-A; SUISEI	125	S	N/A	M-3S II	8/19/1985	Inner planets' plasma research; Halley comet observation research
SS-11; ASTRO-C; GINGA	400	E-ELL	350 – 0600	M-3S II	2/5/1986	Active galaxy X-ray emissions, celestial objects' variety of X-ray observation
SS-12; EXOS-D; AKEBONO	300	E-ELL	400 – 10000	M-3S II	2/22/1987	Electron density, particle radiation, plasma wave observations
SS-13; MUSES-A; HITEN	190	M-ELL	10000 – 1300000	M-3S II	1/24/1990	Orbit necessary for planetary observation; attitude control research; lunar swing-by experiments
SS-14; SOLAR-A; YOUKOU	420	E-ELL	550 – 600	M-3S II	8/30/1991	High precision stereo-optic daily observation of solar flares pertaining to next generation solar waves
SS-15; ASTRO-D; ASUKA	430	E-CIRC	550	M-3S II	2/20/1993	Target space deep regions; variety of celestial object X-ray and X-ray spectral detailed observations
SS-16; MUSES-B; HARUKA	700	E-ELL	1000 – 20000	M-V	9/12/1997	Large-scale parabolic antenna development structure research
SS-17; LUNAR-A	585	L-CIRC	100	M-V	2002	Confirm Lunar mantle structure
SS-18; PLANET-B; NOZOMI	700	M-ELL	1000 – 20000	M-V	7/4/1998	Martian atmospheric structure and solar wind interaction
SS-19; ASTRO-E	1300	E-ELL	500 – 600	M-V	2/1/2000	High energy celestial object X-ray emission observations; cosmology research
SS-20; MUSES-C	490	S	N/A	M-V	2002	Return sample mission from primordial celestial object
SS-21; ASTRO-F	960	E-SUN	700 – 900	M-V	2003	Conduct far-infrared observations for confirmation of universe's origin
SS-22; SOLAR-B	900	E-SUN	600	M-V	2004	Detailed solar surface magnetic mapping; determination of solar activity source
TRMM	3600	E-CIRC	350	H-II	1998	Indispensable observation of tropical regions for determination of scale of earth-scale energy
USERS	1700	E-CIRC	500	H-II A	2002	Space environment non-manned system; super-conductor material experiments

Name[1]	Mass [kg]	Orbit[2]	Range [km]	Rocket	Launch Date	Mission
VEP; MYOUJOU	2400	E-ELL	450 – 36200	H-II	2/4/1994	Confirmation of H-II orbital insertion precision; compatibility of new detection equipment

Appendix C
VARIOUS JAPANESE SPACE ORGANIZATIONS

The following appendix is meant to introduce to the reader the three significant national agencies in Japan associated with space development. Also, an organization chart is provided to show how various functions of Japan's domestic space development are shared among various related ministries and smaller agencies.

NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)[1]

NASDA was founded on October 1, 1969 with the objective of peacefully developing and utilizing outer space for its citizens. The major divisions of its labor are: artificial satellites; rocket development; launches; mission control; space environment utilization; corps of astronauts; and so forth. In 1977 it first successfully launched its experimental communications satellite KIKU-2 on its liquid-fuel rocket, N-I. It was third behind the former Soviet Union and United States in launching a satellite into geosynchronous orbit. Thereafter, development of N-II and H-I rockets, broadcasting and communications satellites, meteorological satellites, earth observing satellites and others proceeded to be conducted. In 1994, NASDA successfully launched its high-powered large-scale H-II rocket, inducting Japan into the lucrative international space launching market. Presently, with emphasis on increased performance while reducing costs, it is in the process of developing the H-IIA rocket. To date NASDA has participated in

[1] The following text is translations by the author taken from H. NAKAMURA's very informative book 「宇宙開発がよくわかる本」, p. 6.

United States Space Shuttle missions, taken lead on space environment utilization activities, and even overseen astronaut missions. It also actively involved in participating in the International Space Station (ISS), and is responsible for Japan Experiment Module (JEM), a part of the ISS.

INSTITUTE OF SPACE AND ASTRONOMICAL SCIENCE (ISAS)[1]

In 1955, professor H. ITOKAWA of Tokyo University Production Engineering Research Center successfully launched a pencil rocket. It would become the dawning of Japan's space development. In 1964, the same center joined with Tokyo University Aerospace Research Center to establish what would later evolve into the ISAS. In 1981 the organization was dissolved, and was reformed as a research branch of the Ministry of Education. In its present form it conducts development and launching of artificial satellites and rockets for the purposes of space observation and research.

Since the pencil rocket, solid-propellant rockets BABY, KAPPA, and LAMDA were developed. In 1970, Japan successfully launched its first artificial satellite, OOSUMI. Japan was fourth behind the then Soviet Union, United States and France in launching a satellite of its own by its own means into outer space. Since then M-4S, M-3C, M-3H, M-3S, and M-3SII rockets along with space observation and research science satellites, Halley comet survey probe, and so forth have been developed and launched. In 1998, be means of its solid-propellant large-scale M-V rocket, Japan launched its inaugural Mars survey probe, christened NOZOMI.

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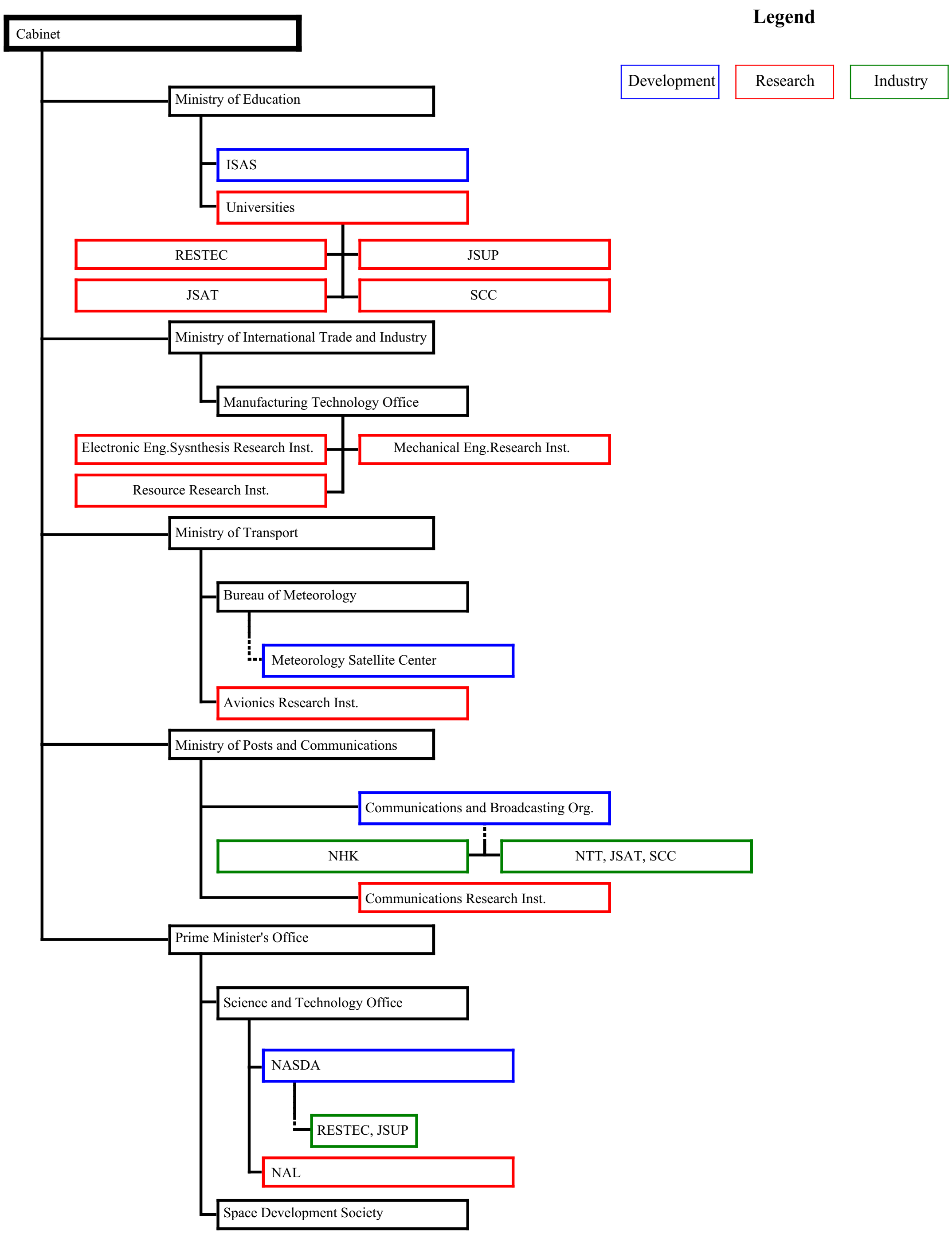
[1] The following text is translations by the author taken from H. NAKAMURA's very informative book 「宇宙開発がよくわかる本」, p. 7.

National Aerospace Laboratory (NAL)

The National Aerospace Laboratory mandate is broader than the two agencies presented above. The author was unable to find definitive information about the laboratory, even from its own information packets. However, its first project was to develop the YS-11, which commenced sometime in 1962. In 1964 the laboratory took on the development of V/STOL technologies that continued until 1979. STOL technology development continued until the early 1990s. It has also been responsible for overseeing development of the JR-100/200 series engines used in VTOL development. In 1971 development of FJR7100 series jet engine (5,000 kg thrust class) was commissioned by the Ministry of International Trade and Commerce. NAL has been actively involved with rocket engine development, satellites, and so forth. Most notably, it has participated in development of HOPE and its three technology demonstrators, OREX, AFLEX, and HYFLEX.

JAPAN'S DOMESTIC SPACE DEVELOPMENT ORGANIZATIONAL CHART



VITA

The author was born in Rochester, New York on December 18, 1973. When he was twelve, his family moved to Skaneateles, New York where he graduated from high school in June of 1992. He would venture to Japan as a Rotary International Exchange Student in 1992. He returned one year later after living with five wonderful host-families: Demura; Kochihara; Kitagawa; Fumuro; and, Fuwa. Afterwards, he entered Purdue University in the fall of 1993, where he would remain for one year as a freshmen engineering hopeful. However, the taste of Japan was too strong in his memory, and he would never again be satisfied unless he was exploring his two passions: engineering and Japanese. And so, in September of 1994 he would transfer to SUNY at Buffalo located, aptly enough, in Buffalo, New York. After one year at Buffalo, Ward returned to his second home, Kanazawa, Japan to study at Kanazawa University. Upon the return to the United States he befriended Timothy J. Curry; without his friendship, encouragement, and assistance Ward would have never have succeeded as he did. He would also befriend L. Phida Ung, with whom he has shared as many splendid moments as any one person can hope for. In June of 1998, the author graduated from SUNY at Buffalo with a B.S. in aerospace engineering. In the fall of 1998, Ward moved from the East coast to the West coast, settling in Seattle, Washington where he entered the University of Washington graduate program as a research assistant with Uri Shumlak of the Plasma Dynamics Group of the Department of Aeronautics and Astronautics. Since then he pursued concurrently two Master of Science degrees in aerospace engineering and technical Japanese. Ward again departed for Japan for a third time in September of 2000, where he worked as an intern at ZEXEL Corporation. He returned in early of 2001, where he and L. Phida continue to live in wonderful Seattle, Washington.