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Birth and Evolution of the ISS: Past, Present and Future

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Abstract

As most of large-scale international joint projects, participation of Japan to the Space Station program proposed by the United States of America (US) was initiated by a political decision made by US President Ronald Reagan and Prime Minister Yasuhiro Nakasone in a so-called Ron-Yasu talk. This project, later called 'Program' took place in 1982 as a post-Shuttle project, and the completion of the Space Station was targeted in 1992, which was the 400 anniversary of Columbus discovery of the new continent. In addition to Japan, European Space Agency (ESA) and Canadian Space Agency (CSA) participated. In this article, based on the author's experience spent at the Space Station Program Office in Science and Technology Agency (STA) from 1985 to 1986 and follow-on activities until now, an overview of the International Space Station (ISS) and manned space activities of Japan will be presented with emphasis on including story of hard negotiations among participating countries, and also between National Aeronautics and Space Administration (NASA) Head Quarters (HQ's) and field centers. Transition of the names of the space segment of this program may symbolize political influences. Furthermore, participation of Russia after collapse of the Union of Soviet Socialist Republics (USSR) gave a huge impact on the operational aspects of the ISS. We should observe carefully some political implications of space activities in addition to scientific and technical aspects of the venture.

Keyword(s): International Space Station, ISS, Post-Shuttle Project
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1. Introduction

Space Station was a dream of mankind as described in a science fiction written by J. Verne in the middle of the 19th Century. A Russian scientist, Tsiolkovsky who is called 'Father of Rocketry' drew a sketch of space station in 1903. Big names in space technology and development such as Oberth and Von Braun were also interested in space station but still within a dream. When space race started between the US and the USSR, space stations of the first generation were launched to orbit. NASA launched 'Skylab' in 1973 by using a left-over rocket of Apollo project[1]. USSR launched 'Salute' and 'Soyuz' to conduct various experiments under microgravity condition. Around the middle of 1980's, US pronounced a space station project as a 'Next Logical Step' with intention to maintain the leadership in space science and technology. In this article, based on the author's experience spent at the Space Station Program Office in STA from 1985 to 1986 and follow-on activities until now, an overview of the ISS and manned space activities of Japan will be presented with emphasis on including story of hard negotiations among participating countries, and also between NASA HQ's and field centers. Transition of the names of the space segment of this program may symbolize political influences. Furthermore, participation of Russia after the collapse of USSR gave a huge impact on the operational aspects of the ISS.

2. Birth and Evolution of Space Station

2.1 Birth

As pointed out in references [2, 3], 'Space Station Program' was initiated by a top level political decision. The program begun with President Reagan's announcement in 1984 that US intended to build a permanently inhabited civil space station on the earth orbit, finally labeled "International Space Station", and in connection with the announcement, he invited other countries, in particular Canada, European countries and Japan, to participate in this project. This invitation was subsequently accepted by several countries, including the members of the ESA such as Belgium, Germany, France, Italy, the Netherlands, Norway, Spain, the United Kingdom in addition to Canada and Japan. Many years of negotiations followed, mainly between NASA and the respective national space agencies, regarding development, construction, operation and utilization of the ISS, to formulate so called "Level-13 Teams" in addition to "Level-A Teams" such as International Operational Concepts Working Group (IOCWG) and International Utilization Coordination Working Group (IUCWG). It was not until September 29, 1988, that the "Intergovernmental Agreement (IGA) 1988" was signed between NASA and the CSA, ESA, and in March 1989, with Japan. The IGA 1988 set forth the general principles for carrying out the ISS mission. In addition to this multilateral

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agreement, several bilateral agreements (Memoranda of Understanding) were executed between NASA and the relevant national space agencies to determine and regulate the technical and administrative details of such cooperation.

2.2 Merge of ISS and Mir

It was a frightening news that the US and USSR agreed upon merging Mir of USSR to the ISS program. Indeed, it was the dramatic change in world politics in the early 1990s, and in particular the decision to include Russia (changed the name from USSR) in the Program led ultimately to an invitation to join the Program. Russia had the longest experience and was most advanced in the area of human space flights and long term operation of the Russian space station Mir. Upon Russia's acceptance, an agreement was soon reached to merge the Russian and American space station programs as explained as follows [4].

At the United States-Russian summit meeting on April 3-4, 1993, US President Clinton and Russian President Yeltsin issued a joint statement announcing Russian participation in the planned construction of the space station. Cooperation on the space station effort is a result of the September 2, 1993, Joint Statement of Cooperation in Space issued by the US-Russian Commission on Energy and Space chaired by Vice President Gore and Prime Minister Chernomyrdin. Following the statement of participation, an interim agreement between the NASA and the Russian Space Agency (RSA) was concluded.

2.3 Evolution of Space Station

Figure 1 illustrates a brief history of Space Station from 1984 to 2010 when the ISS construction was completed with its final configuration. **Figure 2** illustrates the transition of space station configurations.

As illustrated in **Fig.2**, the configuration started with the "Power Tower" (1981-85) and was converted in 1985 into the "Dual Keel" configuration, which anticipates the ability to construct and maintain large structures in orbit to combine scientific research and industrial processing with a general-purpose space operations base. It, like its predecessors, is as much a product of its political environment. As they designed one space station after another, NASA engineers had to adapt not only to the ambiguous and occasionally conflicting desires of NASA's various constituencies but to available launch vehicles as well: The latter served as technologically givens which are external to the program of the space station. During the period of 1985 to 1988, hot debates were exchanged between the Johnson Space Center (JSC) and the Marshall Space Flight Center (MSFC) in front of the NASA/HQ's and the foreign partners.

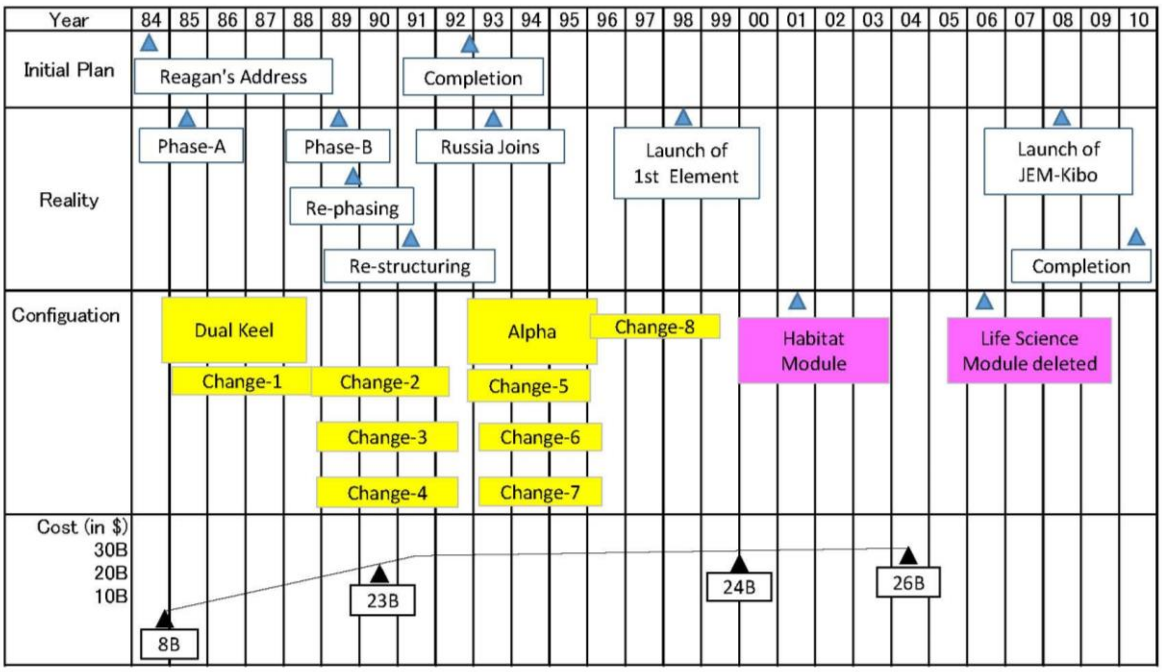
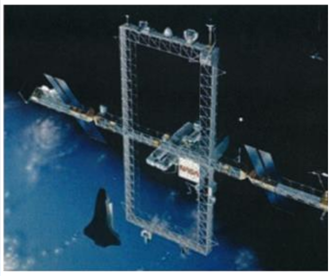
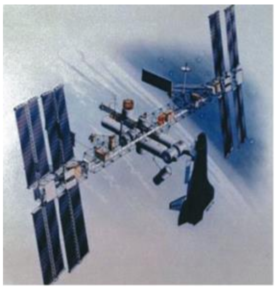


Fig. 1 Schedule of the ISS construction – Planned and realized.

(1) Power Tower (1984)



(2) Dual Keel (1986)



(3) Freedom (1991)

(4) Alpha (1995)

(5) International Space Station (ISS, as in 2008)

Fig. 2 Transition of ISS configurations.

The proposal for the construction of an international space station named "Alpha" replaced the name of the Space Station Freedom, which was to be a space station constructed by the US, Canada, Japan, and ESA. According to the Alpha Agreement, Canada, Japan, and ESA have become partners in the Alpha project on an equal basis with Russia. Russian involvement would have saved the US money between two and four billion dollars and allowed the station to be completed two years earlier than expected.

The US could anticipate other benefits from the Alpha Agreement. One such benefit was learning from Russia's experience in managing space stations like the Mir which had been orbiting since 1986. In addition to the management aspects, the US will benefit from data being compiled from the Russians on human presence on-board a space station.

Fig. 3 Launch of TT-500A from Tanegashima in 1983.

A final benefit for the US is the operational access to heavy launch vehicles such as Soyuz. This has been proven in the case especially after retirement of Space Shuttle. This knowledge is crucial to the US space program as the U.S. space shuttle is incapable of lifting certain space station components.

2.4 Microgravity Experiments on ISS

Many kinds of equipment and supporting tools for microgravity experiments are installed inside the pressurized modules provided by NASA, ESA and JAXA. Utilization and major results are reported (for example[7-9]). Although Life Science Module was cancelled, ISS still has a variety of equipment for this purpose, and impacts of space environment on human have been investigated for astronauts to stay for 6 months on board the ISS.

3. Japanese Participation to ISS

3.1 Precedent Activities

Before deciding to participate to the ISS in 1989, National Space Development Agency (NASDA, later JAXA) launched a series of sounding rockets, TT-500A (later TR1A), dedicated to microgravity experiments from Takesaki Launch Site of Tanegashima. **Figure 3** shows the No. 13 of the TT-500A launched in 1983. In addition to such short time experiments using sounding rocket, ground-based experiment has been conducted by drop-tower facilities and airplane parabolic flights. These experiments are still going on for relatively fast physical phenomenon such as surface tension of molten metals [6]. In addition, STA of Japan joined in the SPACELAB Program onboard Space Shuttle to be realized in 1992 by NASDA. This experiment is called First Materials Processing Test (FMPT). Astronaut Dr. Mohri executed various microgravity experiments and physical demonstration of microgravity as the first Japanese in space environment.

Fig. 4 Members of G7 including President Reagan and Primer Nakasone.

3.2 Participation of Japan to the ISS

The first step to participation of Japan to the ISS was initiated by Ron-Yasu relationship of the two leaders of the US and Japan symbolized by the G7 meeting in 1984 as shown in **Fig. 3**. It was eventually followed by the Phase-B Study Agreement in 1985 and finally by the commitment of development agreed in 1988. Government of Japan has decided to develop Japanese Experiment Module (JEM, and later named 'KIBO') with a share of 8 % of the total system. The final configuration of KIBO is shown in **Fig.4**, including additional facilities such as Airlock, Remote Manipulator System (RMS), and Exposed

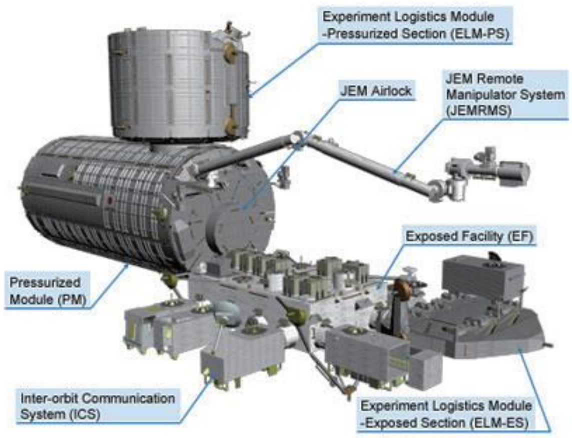


Fig. 5 Elements of JEM/KIBO (JAXA homepage).

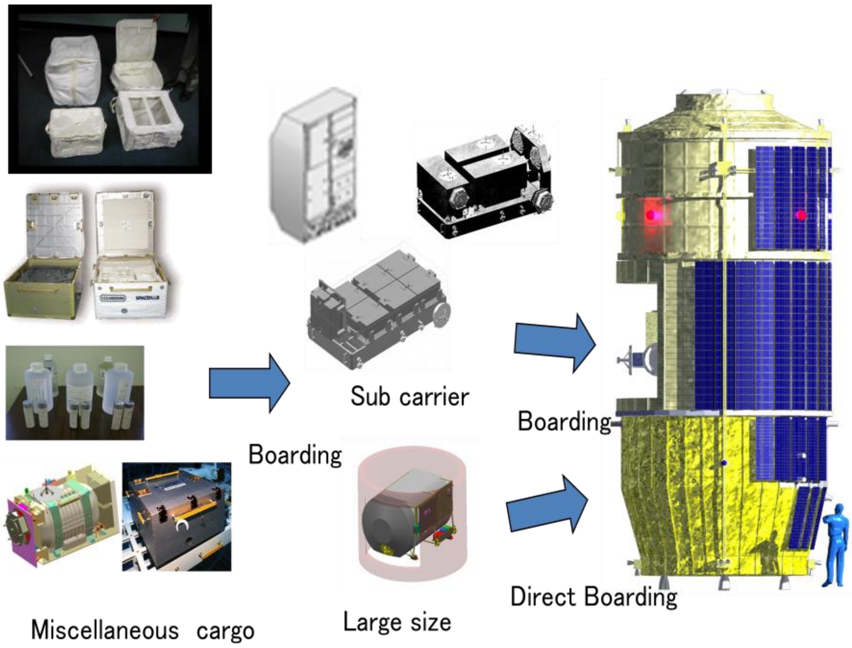


Fig. 6 HTV and Resupply Elements.

Table 1 Resources of KIBO Exposed Facility.

SITE	No. PORTS	POWER	ACTIVE COOLNG	DATA MGT.
ITA (NASA)	4× 4990kg	3kw (total)	none	1553B, High Rate
COLUMB US (ESA)	2× 227kg	2.5kw (total)	none	1553B, Ethernet, Video
KIBO EF (NASDA)	10× 500kg	10kw (total)	10kw (total)	1553B, Ethernet, Hi-Rate, Video

Facility (EF) and so on. KIBO has a variety of functions in addition to the equipment for microgravity experiments inside the Pressurized Module. It is to be noted that the Exposed Facility is unique with support of the robot manipulator JEMRMS and Airlock. **Table 2** shows the resources provided by the KIBO/EF in comparison with NASA/IIA and ESA/COLLOMBUS. As one of the most important contribution of Japan to the ISS program other than KIBO, JAXA has also developed their own cargo transportation system, H-II transfer Vehicle (HTV shown in **Fig. 6**).

4. Future of the ISS

Looking at the current status of the ISS in terms of operations and maintenance, it has been carried out by peaceful joint efforts and by mutual understanding and inter-dependency of many countries. This situation was not conceivable in the age of the Cold War. Indeed, the ISS is operated by not only a selected astronauts, but also a huge number of people distributed over various locations and transportation systems. The ISS program is a joint venture of the participating nations. In addition to the significant contributions of the ISS to human kind, we should note the following future aspects of space use: ISS as transportation node to Mars and/or Moon, privatization of operations/utilization, and technological and cultural heritage to the next generation[10].

4.1 Transportation Node

From the beginning of space station concept design, there has been a strong opinion that it should play a central role as a transportation node to Mars and/or Moon. This idea is re-vitalized recently since man to Mars attracts many engineers and scientists[11,12].

4.2 Advanced Technology Test-bed and Privatization

Followings are a few examples of advanced R&D mission candidates (including on-going ones):

(1) The science behind the so-called “A Year in Space” experiments with the Kelly twins, Mark and Scott. Scientists have been trying to clarify what is the long-term impact of spaceflight on human beings by comparing identical twin astronauts, one of whom is currently spending a year at the ISS. The post-flight results will be disclosed sometime soon in 2016.

(2) Several advanced technology experiments for the ISS, including the Attitude Control and Energy Storage Experiment (ACESE) led by NASA Lewis Research Center, funded by Engineering and Research Technology Program at NASA Johnson Space Center (JSC) [13].

(3) HoloLens. NASA wants to use the HoloLens as an effective way to replace verbal instructions with holographic illustrations, beginning by the end of the year. HoloLens and other virtual and mixed reality devices are cutting edge technologies that could help drive future exploration and provide new capabilities to men and women conducting critical science on the ISS.

(4) Commercialization. As commercialization of ISS activities, a Japanese cargo spacecraft arrived at the ISS with six liquor samples for experimentation. These experiments are planned with NASA’s blessing, but received a criticism by a whiskey expert that the whiskey that Suntory shipped to the ISS could be any different one aged on Earth, calling the idea an absurdity, and that the experiment is more of a gimmick than actual science.

(5) Commercial scientific research. It is pointed out that we should emphasize the need to broaden the appeal of the ISS platform beyond government and NASA use. An industrial R&D leader for Center for the Advancement of Science in Space (CASIS) (which has a broader ability to do commercial work than what NASA is currently allowed) discussed how the ISS is now being used for commercial scientific research such as testing of flame-retardant materials in zero gravity or pharmaceutical lab experiments.

4.3 Inspiring the Next Generation, Student

One of the important objectives of space R&D has been to inspire the next generation for science and technology. Space organizations such as NASA, ESA and JAXA have a unique ability to capture the imaginations of both students and teachers.

(1) The presence of human beings onboard ISS for more than five years now has provided a foundation for numerous educational activities aimed at capturing that interest and motivating study in the sciences, technology, engineering and mathematics. ‘Fuwatto-92’ conducted by Astronaut Mohri is a good example of physics showing an ‘Inertial Coordinate System’ which is visible not on Earth but only on a microgravity environment.

(2) As NASA’s protein crystal growth experiments, many of the protein samples had been prepared with the help of middle and high school students from across the country. From very early on, it was thus recognized that students would have a

strong interest in the ISS, and that this provided a unique opportunity for them to get involved and participate in science and engineering projects on the ISS [15].

In the first five and a half years of continuous human presence on the ISS, a wide range of student experiments and educational activities have already been performed by the United States, the 16 International Partner countries officially participating in the International Space Station Program (ISSP), and a number of other countries under special commercial agreements. Many of these programs still continue, and others are being developed and added to the station tasks on a regular basis.

Recent news, as of December 31, 2015, has reported that the ISS operations are to be extended until 2024 with participation of 15 countries. Canada and Russia have already expressed to agree and Japan is discussing with a positive attitude. In Japan, however, critics demand Government and JAXA for visible and comprehensive explanation on the balance of the international coordination and budgetary burden. Financial authority claims for drastic cut of the operations cost. In order to cope with such criticism, strong supports from the public and from academic/industrial societies as well will be inevitable.

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