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The plan for achieving Mid to Long-term Objectives of National R&D Agency Japan Aerospace Exploration Agency (Mid to Long-term Plan) (Draft)

(April 1, 2018 - March 31, 2025)

Japan Aerospace Exploration Agency (JAXA)

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Introduction

The Plan for Achieving Mid to Long-term Objectives ("Mid to Long-term Plan") of National R&D Agency Japan Aerospace Exploration Agency ("JAXA") for a period of seven years from April 1, 2018 to March 31, 2025 pursuant to the provisions of 5-1, Article 35of the Act on General Rules for Incorporated Administrative Agency (Act No. 103 of 1999) will be implemented as stated below. Considering drastic environmental changes and fierce competition in the aerospace sector, the Mid to Long-term Plan will be reviewed in a prompt and flexible manner as required.

In the previous mid to long-term objective period, JAXA was clearly positioned as the core implementing agency which technically supports the government entirely for space exploration, and underwent the transition to a nation R&D agency. In this situation, the technologies and R&D outcomes accumulated in JAXA so far have come into bloom, and the planned missions were almost completed as scheduled.

JAXA not only steadily implements various projects based on the Basic Plan for Space Policy and R&D Plan[1] and promotes R&D, but also aims to create outcomes according to four policies designated in the mid to long-term objectives by strengthening collaboration with the industry, academia and government related organizations while taking into account the accelerated progress of advanced technologies (e.g. 5th-generation mobile communication systems, IoT, AI). In addition, it does not only support the government missions with technologies, but also further contributes to expanding the aerospace sector of Japan as a whole by changing the organization to produce new value useful for society through science and technology, and aggressively proposing resulting new measures to the Basic Plan for Space Policy and R&D Plan. The focus will therefore be placed on the measures* listed below from this mid to long-term objective period on (details are given in Chapter I. and subsequent chapters).

* The square brackets ([ ]) attached at the end of sentence indicates the paragraph numbers in Chapter I.

○ Assurance of security and realization of a safe and secure society

R&D for improving space debris observation and collision prevention technologies and R&D to meet the needs for space utilization in the field of future security including ship detection by satellites, in collaboration with security related agencies, for contributing to

[1] Decided by the Subdivision on R&D Planning and Evaluation of the Council for Science and Technology, Ministry of Education, Culture, Sports, Science and Technology.

assuring security. [1.5., 1.6.] Technologies allowing the removal of space debris at low costs will be demonstrated for the first time in the world as new efforts for assuring the stable use of space, and developing a new market for space debris removal services in collaboration with private sectors. [2.2. (1), 1)]

R&D for improving observation frequency, accuracy and swiftness of satellite data will be implemented in collaboration with disaster management organizations for extensively delivering satellite data directly relating to disaster mitigation, such as the issue of evacuation for contributing to realizing a safe and secure society. [1.2.]

○ Expansion of space utilization and industrial promotion

Space utilization will be expanded through the efforts described below according to Vision 2030 for the Space Industry (decided by the Committee on National Space Policy on May 29, 2017) and the Science and Technology Basic Plan, etc. for contributing to expanding the market of the whole space industry in Japan.

With the aim of increasing Japan's share of fiercely competitive existing markets, extensive R&D (e.g. H3 rockets and Engineering Test Satellite-9) will be conducted on the premise of obtaining a commitment of commercializing resulting launch services from private sectors, and technical viability and feasibility of the development of a reusable transportation system will be clarified through flight demonstration of technologies for reusing the first stage of rocket for further strengthening international competitiveness. [1.3., 1.4., 2.2. (1) 2)]

Efforts will also be made for expanding space utilization in other industries which will contribute to expanding the space industry. In regard to satellite data utilization, new businesses will be created by efficient satellite data processing, new information analysis methods, and a complex use of satellite data in collaboration with private sectors and related organizations having advantages in AI and other advanced technologies in different fields. [1.2.] In regard to low orbit manned station, a wide range services using the Japanese Experiment Module (JEM) "KIBO" (e.g. new drug creation) will be established as a base for R&D supporting science, technology and innovation, and a part of its operation will be privatized. [1.9. (1)]

Also, as efforts for creating businesses based on new ideas of using space, planning and implementation of business and utilization scenarios and technical development and demonstration under a collaborative team system will be promoted in partnership type cooperation with private sectors with a scope up to starting new business. [2.1.]

○ Creation of the world's best outcomes in space science and exploration, and maintenance

and improvement of Japan's international presence, etc.

Collaboration with research institutes in Japan and abroad will be reinforced in space science research, and long-term, strategic scenarios for priority themes will be drawn up and implemented to create the internationally outstanding research outcomes. For space exploration and related research which require long-term perspectives, efficient efforts will be pursued in two parallel operations; creating missions and developing technologies, by programming space science missions. In addition, institutional development for fostering human resources and assuring human mobility will be actively promoted. [1.8.]

JAXA will participate in the "International Space Exploration" with key technologies indispensable for space exploration to maintain and improve Japan's international presence and assure the rights and technologies of Japan. [1.10.]

○ Promotion of the aviation industry and strengthening of international competitiveness

Priority will be placed on R&D for improving the environmental adaptability, economics and safety of aircraft in collaboration with private sectors in preparation for the international joint development projects for next-generation engines by maintaining and improving technological superiority of Japan in the low-pressure engine systems using F7 engine for providing the demonstration environment, and increasing the share of the high-pressure system by developing internationally competitive, new core engine technologies. [3. (1)]

For the development of the aviation industry in the future, R&D of advanced technologies for next-generation aircraft, including low-noise specification of supersonic aircraft, will be promoted to increase superiority of Japan's aviation science technologies that contribute to establishing international standards and technological innovation for significant social change. [3. (2)]

To support these efforts, strengthening of advanced R&D for producing new missions, establishment of the place of new open innovation that orchestrate human resources in different fields, complete observation of project management rules for ensuring the success of development, enhancement of preliminary R&D, and sufficient provision of human resources and facilities for promoting aerospace businesses will be promoted.

I. Measures in specific works to achieve objectives in the aerospace policy

1. Implementation of space projects to achieve the goals in the space policy scheme

1.1. Satellite positioning system

In regard to positioning satellite, R&D of satellite positioning fundamental technology, including multi-GNSS advanced demonstration tool for orbit and clock analysis (MADOCA) and precise orbit control technology will be conducted for enhancing satellite positioning system in Japan and implementing high precision positioning data distribution service with a view of assuring security and promoting industries in Japan, while the progress of satellite positioning technologies in the world and needs of the government and private sectors for overseas operations are taken into consideration. The knowledge obtained from these efforts will be made available to help private business operators start positioning based businesses, such as high precision positioning data services, in collaboration with the government and private sectors.

1.2. Satellite remote-sensing

Satellite data has been widely used and its utilization is becoming commonplace in a variety of areas including security. Accordingly, JAXA will transfer R&D outcomes as a mediator by promoting collaboration with the government and other public offices and private business operators which make use of satellite data. It will also provide solutions for various social issues by means of the planning, R&D and demonstration, operation and utilization of advanced remote sensing satellites according to new needs of users. Efforts for maritime domain awareness and early warning capacity using satellites will be addressed in 1.6.

To contribute to disaster prevention and response in Japan and abroad in collaboration with disaster management agencies and realize a safe and secure society, data on crustal movements, etc., obtained from satellites, will be promptly and accurately delivered to disaster management agencies and local governments with an attempt to improve observation frequency, accuracy and swiftness of operation for disseminating such data as information directly tied to the issue of evacuation call or other disaster mitigation measures. Use of satellite data will also be promoted in marine observation such as sea surface temperatures and sea-ice distributions, and land management including land area, ports and ground coverage classification by promoting application study and demonstration of advanced satellite data in collaboration with organizations that use data. Satellite data will be distributed in multiple ways suitable for using data from multiple satellites, and a system will be built for transferring necessary information to the government, local governments

and international disaster management organizations in a way that data can be easily understood on site along the timeline of user activities.

To contribute to countering climate change with solutions for global issues, satellite data relating to climate change will be distributed to users in Japan and abroad in a continuous manner for supporting climate change remedies based on the government policies and promoting international cooperation. In response to the need identified through these efforts, R&D for improving the accuracy of observation sensors thereby enhancing the accuracy of climate change monitoring modeling, calibrating and verifying observation data will be conducted. These efforts are intended to make satellite data as judgment or evaluation criteria in climate change counteraction such as reduction of greenhouse gases.

From perspective of industrial promotion, satellite data utilization will be promoted by improving the usability of satellite data through R&D and demonstration of efficient satellite data processing or new information analysis methods, and implementing a complex use of satellite data, in collaboration with private sectors and government agencies having advantages in different advanced technologies, such as AI, for contribution to adding high value in the existing businesses and creating new services and industries in the future.

In consideration of overseas trends and government policies, proper management and distribution of various data obtained from satellites as big data for potential use in a wide range of industry including the investigation into the required data format and data utilization environment, and R&D of advanced satellite related technologies including the investigation into functional integration of satellites will be promoted in collaboration with the government and private sectors.

R&D and operation of the following satellites will be conducted to complete efforts in 1.2 and 1.6, and solutions for the issues identified through these efforts will be studied in an integrated manner throughout JAXA:

(Satellites subject to operation)

- Greenhouse gases Observing SATellite “IBUKI” (GOSAT)
- Global Change Observation Mission-Water “SHIZUKU” (GCOM-W)
- Small Demonstration Satellite-4 (SDS-4)
- Advanced Land Observing Satellite-2 “DAICHI-2” (ALOS-2)
- Global Precipitation Measurement/DUAL-frequency Precipitation Radar (GPM/DPR)
- Global Change Observation Mission-Climate “SHIKISAI” (GCOM-C)

• Super Low Altitude Test Satellite “TSUBAME” (SLATS)

(Satellites subject to R&D and operation)

• Greenhouse gases Observing SATellite-2 (GOSAT-2)

GOSAT-2 is follow-up to GOSAT missions for the high-precision calculation and estimation of the concentration distribution and amount of greenhouse gases absorption and emissions.

• Earth Clouds, Aerosols and Radiation Explorer/Cloud Profiling Radar (EarthCARE/CPR)

The Cloud Profiling Radar (CPR) jointly developed by JAXA and National Institute of Information and Communications Technology (NICT) is the world’s first cloud profiling radar that is installed in EarthCARE, a satellite developed by ESA, and measures the upward and downward flow velocity within a cloud while observing its vertical structure.

• Advanced Land Observing Satellite (ALOS-3)

ALOS-3 is follow-up to the optical component of ALOS, and used for the high-frequency observation of the entire Japan at a resolution of 1 m or less for meeting various needs including disaster prevention and management, and acquisition and update of geographical and geospatial information.

• Advanced Land Observing Satellite (ALOS-4)

As the follow-up L-band SAR mission of ALOS-2, resulting from the technological development required for wide-area, high resolution observation for continuous and highly accurate monitoring, is used for all-weather disaster observation, forest observation, sea-ice monitoring and ship tracking, and so on.

An AIS developed and installed in ALOS-4 is the world’s first system for improving ship identification in dense areas while maintaining wide-area observation using narrow-band receiving areas and signal processing technology for multiple signals simultaneously received.

• Advanced Microwave Scanning Radiometer 2, follow-up mission

A successive microwave radiometer to Advanced Microwave Scanning Radiometer 2 (AMSR2) will be developed and installed in Greenhouse gases Observing SATellite-3 (GOSAT-3) for supporting agencies dealing with or using weather forecasting, fisheries information, seaway information and food control, as well as continuous monitoring of environmental changes such as polar sea ice, El Nino and La Nina phenomena and abnormal climate, and clarification of their mechanisms.

1.3. Satellite telecommunication

The target for promoting the space industry in Japan is a 10% or more share of international geostationary commercial communications satellite market in the 2020s by private business operators through R&D and demonstration of next-generation communications satellite bus technologies having international competitiveness such as electric propulsion, high waste heat management and geostationary GPS receiver technologies.

Large-capacity data transmission will be implemented to support national security and industrial promotion through R&D of optical inter-orbit communications technologies with better confidentiality in data transmission, and on-orbit demonstration of optical data transponders and the Advanced Land Observing Satellite (ALOS-3) etc.

R&D and operation of the following satellites will be conducted to complete the above-mentioned efforts, and solutions for the issues identified through these efforts will be studied in an integrated manner throughout JAXA:

(Satellites to operate)

- Wideband InterNetworking engineering test and Demonstration Satellite (WINDS)

(Satellites subject to R&D and operation)

- Optical data relay system

  A terminal for geostationary orbit satellites will be developed using optical inter-orbit communication technologies to drastically decrease the size and weight of inter-satellite communication equipment for data relay satellites to adapt to upgraded, high-resolution remote sensing satellites in the future.

- Engineering Test Satellite-9

  In consideration of strengthening international competitiveness, next-generation geostationary communication satellite bus will be developed using new development technologies such as high-power, high waste heat and all-electric satellite technologies as well as geostationary GPS receiver based autonomous control technologies.

1.4. Space transportation systems

In the light of maintaining the independent space transportation capability without interruption to assure security, R&D for maintaining and developing core rockets and industrial infrastructure will be conducted as described below. In addition, R&D for strengthening international competitiveness in space transportation systems will be

conducted as shown below for commercial space transportation services in Japan to acquire a certain amount of demand into the future, and continuously assure the independence of the space transportation capability in Japan with private sectors as main players.

(1) Liquid fuel rocket system

In regard to a new core rocket, H3 rocket, a comprehensive system that integrates rocket fuselages and ground systems will be developed in collaboration with private business operators dealing with launch services by reducing costs and improving convenience of users for improving self-governing launch capability and strengthening Japan's international competitiveness, and transfer the operation to launch service businesses will be completed.

After transfer, an attempt will be made at the initial stage of operation to increase the maturity in operating H3 rocket until the operation of H3 rocket is stabilized as the launch service mainly managed by private business operators, and R&D for strengthening international competitiveness will be conducted.

In addition to the development of the above-mentioned rockets, reusability of the first stage of rocket will be studied in an integrated manner throughout JAXA to improve space transportation technologies, and plans for practical application will be discussed with private sectors.

Continuous efforts will be made for improving reliability of the current H-IIA/H-IIB rocket and maintaining core technologies including those for coping with aging launching sites during the period of transfer to H3 rocket smoothly to ensure response to launch plans for the government owned satellites and various other satellites in Japan and abroad.

(2) Solid fuel rocket system

The satellite launch plans by the government using Epsilon Launch Vehicle, viewed as a critical solid fuel rocket as a strategic technology, will be completely implemented. For seamless operation of Epsilon Launch Vehicle during transfer of H-IIA/H-IIB to H3 rocket, and strengthening of international competitiveness, development and flight demonstration having synergy effects with H3 rocket will be conducted. Transfer to launch service businesses managed mainly by private business operators will be completed for flexible and efficient response to various demands such as a commercial satellite inside and outside Japan, in addition to the demand of the government for earth observation and space science and exploration.

1.5. Space Situational Awareness

R&D of space situational awareness (SSA) will be implemented as described below for assuring the operation of satellites and supporting continuous and stable utilization of space in national security and commercial areas.

JAXA will improve and operate its SSA related facilities, conduct R&D to improve technologies for monitoring space debris and preventing proximity and collision, and provide technical support for the government including personnel exchange with related agencies to establish an SSA system in an integrate manner by related government agencies with the increase of space debris in mind.

1.6. Maritime Domain Awareness and early warning functions

JAXA will make the efforts described below to assure security in collaboration with the Ministry of Defense and other security related agencies.

Support will be provided for the government to investigate into the maritime domain awareness by distributing knowledge about advanced earth observation satellites, etc. in collaboration with related security agencies. Also promoted is R&D to improve the ship detection rate of the automatic identification system (AIS) for obtaining information on advanced earth observation satellites and vessels from satellites, and demonstration of technologies for accurately identifying ship navigation state through coordinated observation using the Advance Land Observing Satellite (ALOS-4).

In regard to the early warning capacity, infrared sensors will be installed in the Advanced Land Observing Satellite (ALOS-3) for the demonstration of these sensors in space planned by the government in collaboration with government security related agencies, and R&D relating to element technologies required in the future will be conducted based on the result of government investigation into the assurance of Japan’s early warning capacity.

The collaboration with the government security related agencies will be reinforced and R&D to meet the needs of space utilization in the field of future security will be promoted.

1.7. Enhancement of the overall mission assurance of space systems

Support will be provided for the government to investigate into the mission assurance including the form of launching sites, quick reaction type small satellites and the space system as a whole in collaboration with the Cabinet Office, Ministry of Defense and other security related agencies to contribute to achieving mission assurance.

Based on the “Fundamental Approach for Strengthening of Mission Assurance” (joint meeting of relevant government offices for strengthening the survivability, April 20, 2017), vulnerability of space system owned by JAXA, important for national security, public lives and social and economic activities, will be evaluated and required measures taken.

1.8. Space sciences and exploration

Research of space science and exploration will be promoted in collaboration with research institutes in Japan and abroad for exploiting new space development and utilization by creating intellectual properties common to humankind, and obtaining innovative and exploratory technologies. Specifically, JAXA focuses on such objectives as “Clarification of cosmic origin and structural formation of universe from galaxies to planets,” “Clarification of solar system and origin of life” and “Innovation in space engineering for spacecraft and space transportation systems” for achieving world-class research outcomes.

(1) Promotion of academic research

JAXA will develop and implement long-term and strategic scenarios to promote space science research, including the proposal of missions using the inter-university system, in which flexible and diversified form of joint activities are conducted by researchers from universities, and for space exploration which needs efforts from long-term perspectives, effective promotion (e.g. programming) with both mission creation and technical development in mind as well as in consideration of international cooperation and collaboration in international space exploration. The technical targets required for achieving these scenarios (Space Science and Technology Roadmaps) will be set for promoting technological development from long-term perspectives.

Advanced investigation capability covering the start to end of missions will be enhanced to accelerate bottom-up mission proposals, especially proposals of new fields of science and technology, in addition to the expansion and improvement of the inter-university collaboration base.

According to these basic policies, all processes from development to launch and operation of satellites, probe vehicles and experimental small flying objects (observation rockets, large balloons) will be managed in a consistent manner using “strategic medium missions,” “open-type small missions” and “multiple small projects (strategic international cooperation plans, small-scale plans) stipulated in the Basic Plan on Space Policy.

Close collaboration not only with space science institutes but also the whole structure of JAXA is required for developing satellites and probe vehicles for ensuring the development of increasingly large and complicated systems of satellites and probe vehicles. The world’s best observation data produced from these projects (including extraterrestrial material samples) will be published in a user-friendly manner for the wide use in the world.

The institutional structure for human resource development, mobility and diversification, fundamental needs for ensuring to continuously create the world’s most

advanced outcomes, will be established. Specifically, measures to meet these needs include the invitation of researchers having international achievements, proactive employment of foreigners and women for teaching post in permanent employment (tenure), establishment of an assistant professor system in special definite term employment with possibility of permanent employment (tenure track), development of a system to encourage move-out to universities, and utilization of the cross-appointment system.

(2) Satellites and probe vehicles subject to R&D and operation

1) Clarification of cosmic origin and structural formation of universe from galaxies to planets

- Development and operation of a substitution of X-ray astronomy satellites for observing high wavelength resolution of X-ray originated high-temperature plasma in space
- Investigation into a project for next-generation Space Infrared Telescope for Cosmology and Astrophysics (SPICA) for observing space using infrared rays with unprecedented sensitivity

2) Clarification of solar system and origin of life

- Development of a Mercury exploration plan/Mercury Magnetospheric Orbiter (BepiColombo/MMO) for observing the magnetic fields, magnetosphere, and inside and surface of Mercury, as well as operation of the preparatory work for sending the probe to Mercury
- Development and operation of the Demonstration and Experiment of. Space Technology for INterplanetary voYage (DESTINY$^+$) for observing interplanetary dust and parent bodies of dust coming into the earth
- Development and operation of Martian Moons eXploration (MMX) for observing Mars and its satellites in proximity, and recovering samples from the satellites
- Development of observation equipment for JUpiter ICy moons Explorer (JUICE) for observing Jupiter and its satellites in proximity, and operation of preparatory work for sending the probe to Jupiter
- Operation of other satellites and probes vehicles

  Magnetosphere Observation Satellite (GEOTAIL)
  Solar Physics Satellite “HINODE” (SOLAR-B)
  Venus Climate Orbiter “AKATSUKI” (PLANET-C)
  Spectroscopic Planet Observatory for Recognition of Interaction of Atmosphere

"HISAKI" (SPRINT-A)
Geospace exploration satellite (ERG)
Asteroid Explorer HAYABUSA 2

3) Innovation in space engineering for spacecraft and space transportation systems
- Development and operation of small lunar landing demonstrator (SLIM) for demonstrating high-precision landing technologies to land a small probe vehicle to a self-gravitational celestial body
- World's highest level R&D to innovate deep space observation including engineering technologies to drive projects such as system and propulsion technologies, atmosphere entry technologies, self-gravitational celestial body landing technologies, and surface exploration technologies according to the "Space Science and Technology Roadmaps" described above, in addition to the research of exploratory technologies including the investigation into system and propulsion technologies for future space transportation

4) Other
- Preliminary investigation into the organization of a project for the candidate missions for the space science project (lite satellite for the study of B-mode polarization and inflation from cosmic microwave background radiation detection LiteBIRD and Solar Power Sail, etc.) by improving the initial feasibility study and R&D in the initial stage (front loading activities)
- Development of ground stations for deep space exploration in the light of Japan's independent space science and exploration missions and support for missions of overseas organizations in international cooperation to secure Japan's international presence
- Upgrading of small flying objects and experiment and test equipment for use in a variety of needs for experiment, in particular, large equipment which will be maintained and improved by the whole organizations of JAXA in an efficient manner
- Efforts for social return of outcomes resulting from space science research projects including contribution to industrial promotion

(3) Cooperation for postgraduate education

Cooperation for postgraduate education will be provided in collaboration with the Graduate University for Advanced Studies and Graduate School of the University of Tokyo, and using a cooperation system of graduate schools for fostering human resources representing future Japan not only in the aerospace but in diversified fields of science.

1.9. International Space Station

Efforts will be made in relation to the International Space Station as listed below.

(1) Effort for expanding and commercializing low-earth orbit utilization

To meet the civilian needs for government policies on science and technology, fixed time intervals (availability at a regular interval of time), high frequency and stylization (development into platform) will be promoted for the priority "KIBO" utilization services (support for new drug design and anti-aging study, discharge of ultra-small satellites and use of outboard ports). The scope of experimental techniques will be expanded for the utilization services developed into a platform to increase opportunities for utilization by improving utilization capacity and technologies in quality and quantity, developing new experimental methodologies and linking operations to ground experimental equipment.

Utilization services potentially creating new concepts and values will be established and implemented as a new platform through cooperation and support for research having large social impacts.

In addition, collaboration with universities and national research institutes capable of human resource development and those having experience and the capability to develop ultra-small satellites as strategic partners will be reinforced, and technologies and knowhow will be transferred to selected private business operators who provide stylized services to end users for developing domestic and overseas users.

These activities will contribute to realizing a wide use of "KIBO" by the industry, academy and government as a R&D base for supporting science, technology and innovation by 2020, and based on the results, independent businesses will be launched using part of "KIBO" to start utilization businesses mainly operated by private business operators by 2024.

As the efforts after the end of the ISS program, feasibility of new businesses using low-earth orbits, evolving from R&D, will be pursued to create businesses by putting an ad for ideas of utilization in view of commercialization by private business operators, and demonstrating these ideas in "KIBO."

According to these efforts, technical investigation will be made into the scale, capacity, function and operation form of possible low-earth orbit manned space activities after 2025 as well as cooperation with other nations and private sectors for supporting the government.

(2) Efforts for maintaining and improving Japan's international presence through the ISS program

Relationships with Asian nations and United Nations will be reinforced in addition to the ISS participating nations by playing the core role based on the international agreement on the ISS program, and expanding opportunities for using the ISS through Japan to other nations.

Specifically, stable and efficient operation of “KIBO” and “KOUNOTORI,” and outstanding performance of Japanese astronauts will be focused. A new space station transfer vehicle (tentatively HTV-X) will be developed by upgrading “KOUNOTORI” and operated steadily to improve transportation capability to the ISS and reduce operation costs, and at the same time, provide opportunities for technical demonstration using the opportunity of transporting materials to the ISS to implement efficient manned space activities and promote industries in Japan. Additionally, the opportunity of using “KIBO” by overseas organizations will be increased in the framework of the United Nations and universities collaborating with overseas bodies for human resource development.

The outcomes from contributions of Japan and the U.S.to the ISS program will be maximized with new insights obtained from joint technological researches useful for international space exploration, demonstration in the ISS and HTV-X (tentative), joint experiment by Japanese and American researchers, mutual utilization of experimental equipment, and exchange of test samples based on the Japan-US Open Platform Partnership Program (JP-US OP3) to reinforce the relationship between Japan and the U.S.

Manned residency technologies including regenerative environmental control aiming at large reduction of water and air supply, automated and self-governed technologies that replace formulaic crew work, and space medicine and health control technologies required for the crew in ultra-long stay in space or stay in space further than low-earth orbit by making maximal use of the ISS for contributing to international space exploration and future low-earth orbit manned space activities.

1.10. International human space exploration

In view of contribution to reinforcing international cooperative relations such as the Japan-US cooperative relations, a space exploration plan of Japan will be presented and implemented in the “International Space Exploration” (including unmanned exploration preceding to manned exploration) for expanding human activities in space through international cooperation. The plan will be made according to the collaboration of space science and exploration, scientific significance of missions, succession of technological outcomes such as JEM/HTV, and the growth of private business operators including those of different business arena.

With an eye on the participation in the construction of a manned site near the moon, planned by the U.S., and moon landing and exploration through international cooperation, proactive plans of Japan, including technical aspects, will be investigated to put international programs into shape, and strategically participate in the international space exploration projects. Of critical technologies in manned space exploration, technologies potentially proving the superiority of Japan and having spillover effects will be pursued in close liaison with unmanned exploration in space science and exploration. This includes early demonstration of deep space supply technologies (e.g. rendezvous and docking technologies) and manned space residency technologies (e.g. environmental control technologies) for constructing manned bases near the moon, self-gravitational celestial body takeoff and landing technologies (e.g. high-precision navigation technologies) and self-gravitational celestial body exploration technologies (e.g. surface movement technologies, drilling techniques, water and ice analysis technologies) for manned moon landing and exploration activities.

These activities contribute to strengthening the relationship with the ISS partners, and constructing the relationship with new partners in collaboration with the government, supporting new international cooperation systems and rulemaking, and promoting industries by disseminating newly available technologies.

1.11. Platform technology to support development and operation of systems including satellites (tracking technology, environment testing technology, others)

The efforts will be made for tracking and maneuvering, and environmental test techniques which are core technologies required for the stable operation and steady development of satellites.

(1) Tracking and maneuvering techniques

Facilities and equipment, such as antennas, will be maintained and operated for tracking control and data acquisition to assure the accomplishment of missions specified for satellites. R&D relating to tracking network systems will be conducted with the aim of efficient maintenance and operation of equipment, and cost reduction. Systems are developed so as to enable future missions with high-performance services and high additional value in network capability.

To acquire new frequency from wireless stations and continue to use existing frequencies required by JAXA, allocation of frequencies for the aerospace sector will be maintained and promoted by joining in international and domestic rulemaking, coordinating with other wireless stations for frequency and acquiring approval and license

for specific frequencies from wireless stations to accomplish missions.

(2) Environmental test techniques

Environmental tests will be completely conducted using the environmental test equipment owned by JAXA to accomplish missions, in addition to R&D for improving environmental test techniques. Specifically, secure and efficient maintenance and operation of environmental test equipment will include anti-aging measures and technological development for mitigating test conditions for vibration and thermal vacuum and improving test efficiency. The accumulated environmental test techniques and equipment will be offered to other industries by promoting exchange with these industries.

2. Works in cross-disciplinary research and development

2.1. Works to promote the industry and grow space utilization through Public-Private Partnership and the like

Partnership type cooperation will be promoted on even ground with not only existing space related companies but various new private business operators ranging from ventures to large companies with the aim of creating new businesses competitive in international society and difference fields. Specifically, JAXA and a private business operator jointly create a utilization and operation scenario, provide funds and human resources, form a collaborative team system for technological development and demonstration, create a business mainly by the private business operator, and extend efforts for open innovation including the joint operation with different fields for acquiring technologies linking to new space utilization. JAXA will also distribute its R&D outcomes, strive to discover ideas inside and outside JAXA in collaboration with private business operators, and promote an investigation into commercialization to start new venture businesses using its R&D outcomes, and through these efforts, contribute to fostering human resources who carry on the space industry.

With the progress of these efforts, institutional improvements, such as strategically more flexible rules of handling intellectual properties, will be promoted to increase space utilization and create private businesses using intellectual properties of JAXA.

Private funds such as contribution to commissioned or joint research from private business operators will be proactively used, and collaboration with financial institutions will be promoted for increasing investment to the space industry.

Various support will be provided for strengthening the international competitiveness of private sectors, including the introduction of space equipment in market, consolidation of contacts to a single contact concerning opportunities for space demonstration such as the

launch of ultra-small satellites by private business operators, promotion of utilization of facilities and equipment owned by JAXA, and improvement of accessibility to satellite data.

Knowhow of installing specific equipment or device in a rocket will be transferred to private sectors as part of provision of opportunities for space demonstration to achieve self-governing private businesses.

2.2 Maintaining and enhancing space industry platforms and scientific technology platforms for creating new value (including platforms to counter space debris and space solar energy generation)

The subsequent paragraphs cover the critical technologies intended to be developed during the period of this Mid to Long-term Plan for promoting self-governing and continuous space activities of Japan and strengthening international competitiveness of related industries through technological innovation to enable the development of new business areas and lead the world.

R&D will be based on the analysis of international technological trends and conducted by clarifying impacts on space systems, exit objectives, and allocation of roles and responsibilities with the industry as common recognition between JAXA and the industry. Cross-appointment and innovation fellow systems will be used for selecting outstanding personnel for the leader of research, and personnel exchange will be promoted not only in the aerospace sector but also other sectors Japan has advantages.

Key technologies for international competition will be registered as intellectual property, and the intellectual property system will be improved for promoting its utilization in the industry.

(1) Advanced R&D for creating new value in space development

1) R&D for the assurance of security and realization of a safe and secure society

Creation of new markets and increase in Japan’s international competitiveness will be achieved in collaboration with private sectors that establish space debris businesses. Technical demonstration of the world’s first low-cost debris removal service for large rocket will be conducted as a critical issue. In regard to technologies for preventing the generation of debris, the usability of highly reliable satellite and rocket technologies, which are advantages of JAXA, will be improved, and R&D of technologies for changing the orbit of debris and safely putting it into atmosphere will be conducted for application in the increasingly expanding civilian use of space. For creating space debris businesses, JAXA will contribute to the early realization of international rulemaking at the United Nations or a relevant organization based on the outcomes of technical

demonstration in collaboration with the government and related organization inside and outside Japan.

R&D will focus mainly on technologies of high social value, including those for improving the time and space resolution of observing sensors, communication security technologies, and space environmental measuring and rocket propulsion technologies applicable to hypersonic flight, with the discovery of needs in collaboration with related agencies.

2) R&D contributing for expansion of space utilization and industrial promotion

R&D and technical demonstration will be conducted in the fields of communication and earth observation by forecasting market needs in cooperation with private sectors to create the world's first utilization services and internationally competitive systems. Specifically, a highly feasible system initiative will be established with the following as priority issues, and key technologies will be developed:

- Reuse technologies for realizing highly reliable and economic space transportation services
- Optical and digital communication technologies for realizing low-cost, large-capacity and high-speed satellite communication networks
- Ultrahigh-precision large optical sensor technologies enabling constant observation from geostationary orbits

With the view of the next ten years, R&D and demonstration of element technologies will be promoted as new, innovative technologies for space development and utilization, including wireless components in satellite systems, device replacement and supply and recovery services by robots in orbit, and application of satellite data to AI. At the same time, new missions based on these technologies will be planned and published to find potential user needs and identify ideas for commercialization.

3) R&D for creating world's best outcomes and maintaining and improving international presence

R&D will be conducted for original technologies having competitiveness for the priority issues of environmental control and life support, radiation protection, access to self-gravitational celestial bodies, and observation and analysis on self-gravitational celestial bodies.

Human resources and knowledge will be consolidated for implementing R&D using the place for open innovation to improve international technological superiority in space

exploration, and disseminate technologies to other industries, as well as extensively introducing most advanced technologies including those in different fields.

(2) Strengthening of science and technology infrastructure for supporting the space industry and projects

Competitive and private funds will be introduced in simulation and highly reliable software technologies and system development method, which are advantages of JAXA, and onboard devices and components with high international competitiveness, while industry-academy-government collaboration reinforced with JAXA acting as the core agency for the maximization and the spillover effects of outcomes across Japan. For the fields required for improvement and reinforcement according to the extensive space utilization in the future, efforts will be made to expand the science and technology infrastructure by promoting mobility of personnel and open type research system to consolidate advanced knowledge in the space and other sectors including knowledge outside JAXA.

In regard to medium to long-term plan for energy transmission and reception technologies and liquid natural gas (LNG) propulsion technologies used for space solar power generation systems, R&D will be conducted with long time horizons of space development with attention to spillover effect resulting from the demonstration of element technologies.

Efforts for promoting new technologies, commercial products and ultra-small satellites include the on-orbit demonstration of core components and new element technologies, effective transfer of outstanding Japanese commercial products and technologies, and civilian use of space technologies.

Anti-aging measures will be taken for the R&D infrastructure, indispensable for maintaining and improving R&D environments, and R&D facilities relating to internationally competitive fields over the years to come strengthened.

3. Aeronautical Science and Technologies

R&D to meet social needs, R&D of advanced technologies determining the direction of future generation, and R&D of basic aviation technologies required for the sustainable development of the aviation industry will be conducted. Collaboration with related agencies in Japan and abroad, transfer of technologies to private sectors and dissemination of outcomes will be promoted, as well as measures that contribute to the standardization of aviation technologies and enhancement of standards in a fair and neutral position will be taken by making use of a system to promote open innovation.

(1) R&D to meet social needs

From the perspective of improving environmental adaptability, economics and safety, R&D of next-generation engine technologies, airframe technologies for low noise operation and component technologies for sensors and avionics will be promoted in collaboration with private sectors for demonstrating technologies that lead to strengthening of international competitiveness and transferring these technologies. Specifically, in addition to maintaining and improving technological superiority of Japan in the low-pressure engine systems, R&D newly focusing on the technical demonstration of low NOx combustion chambers and high temperature, high efficiency turbines for core engines in high-pressure systems will be accelerated. At the same time, F7 engine will be developed as the engine for technical demonstration for improving the maturity level of various engine technologies. Through flight demonstration, R&D of noise and body resistance reduction technologies for next-generation passenger carriers, installation of new components for preventing aircraft accidents, reducing weather effects and supporting pilots, R&D for enhancing the function of these technologies, and R&D of technologies for expanding aircraft utilization based on disaster resistive aircraft technologies and unmanned vehicle technologies will be promoted in collaboration with related agencies. This will ultimately contribute to increasing the share of private business operators in international joint development projects, and developing completed aircraft and appliances businesses in Japans.

(2) R&D of advanced technologies determining the direction of future generation

Propulsion airframe integration design technologies for silent supersonic aircraft which are based on low-sonic boom design technologies, and innovative technologies for drastically reducing CO_2 emissions caused by aircraft will be acquired. Specifically, a framework of international cooperation will be built for the propulsion airframe integration design technologies which simultaneously satisfy low-sonic boom, low resistance, low noise, and weight reduction, and participation of domestic private business operators promoted with a view of conducting R&D covering technical demonstration. R&D will also be conducted for innovative technologies such as electric aircraft technologies that combine primacy technologies of Japan. For the development of the aviation industry, these efforts will contribute to improving the international superiority of aviation science technologies of Japan, providing international standards and realizing technical innovation for drastic social changes.

(3) R&D of basic aviation technologies required for sustainable development of the aviation industry

Basic technologies for test, measuring and material evaluation will be maintained and improved in addition to drastic improvement of numerical simulation such as computational fluid dynamics (CFD). Specifically, R&D of integrated simulation technologies, which combine a number of technological fields including test and measuring based on the unsteady CFD analysis technologies. Basic facilities and equipment required for R&D of aviation technologies, including wind tunnel test equipment and aircraft for experiment, will be kept in good conditions and development of test technologies, including anti-aging measures, promoted to meet the demand for utilization inside and outside JAXA adequately so as not to hamper aviation activities in Japan. These efforts will contribute to establishing aircraft design technologies for prompt and efficient development of aircraft, and continuous development of the aviation industry in Japan.

II. Important matters to support the achievement of objectives of aerospace policies

1. Cross-sectoral matters

1.1. Promotion of international cooperation and development overseas and research and analysis

(1) Promotion of international cooperation and overseas operations

Operations such as increasingly active international space exploration or efforts for climate change measures will be accomplished in an efficient and effective manner in the future by sharing management level concerns with major space organizations abroad through continuous and strategic dialogues, and R&D will be promoted on a reciprocal basis. In the implementation of the R&D described above, political significance will be increased in consideration of diplomatic value by maintaining the close liaison with diplomatic authorities, the United Nations and related organizations.

Needs for space utilization in various nations will be searched and found out by maintaining closer liaison with overseas space utilizing organizations, development assistance agencies (e.g. Japan International Cooperation Agency (JICA) and Asian Development Bank (ADB)), and space utilization in these nations will be increased to the level at which it is taken for granted as social infrastructure. For this purpose, human resources capable of establishing and maintaining mutually beneficial relations with target nations will be developed. This will increase domestic demand for space related

technologies and support overseas deployment of space infrastructure under the government-private sector collaboration promoted by the government, contributing to maintaining and strengthening Japanese industrial infrastructure.

In particular, publication of new possibilities of space utilization, and formation and reinforcement of communities including political level will be promoted using the framework of the Asia-Pacific Regional Space Agency Forum (APRSAF). Common issues such as disaster management and environmental measures will be tackled according to the needs of a nation through bilateral cooperation or cooperation through international organizations in Asia.

International rulemaking for space utilization by the government at the Committee on the Peaceful Uses of Outer Space (COPUOS), etc. will be supported. Potential legal issues in the future in space development and utilization will be studied in cooperation with external experts, and human resources for leading these issues will be developed.

(2) Survey and analysis

Trend surveys on aerospace areas in Japan and abroad, and analysis of survey results will be promoted for planning more strategic and effective missions, maximizing outcomes, and designing Japanese national policies. Specifically, survey and analysis information will be used for developing JAXA strategies and distributed to the government. And, recommendations will be made based on the distributed information by improving collaboration with research agencies and universities in Japan and abroad, promoting dialogues with recipient of information, expanding survey and analysis areas and conducting in-depth analysis according to the issue.

1.2. Fostering of understanding by our citizens and contributions to train human resource who will carry the next generation

(1) Increasing public awareness

Diversified information suitable for advanced information society will be distributed with assurance of immediacy, transparency and interactivity of information in mind according to environmental changes in around aerospace operations and JAXA.

- Detailed explanation to the media and extensive opportunities for dialogue with them for not only press release but in a press conference and briefing for timely distribution of information on the significance and outcomes of JAXA operations
- Distribution of detailed and easy-to-understand information using PR tools owned by JAXA (web sites, videos, symposiums, in-house magazines, exhibition and open facilities at local offices, dispatch of lecturers to lecture meetings) and introduction of

latest information distribution tools

- Active promotion of collaborative operations with external organizations for extensively distributing information to the layer of people to which JAXA itself is difficult to get in touch with

JAXA will achieve accountability to the public and society and further accelerate public awareness in the light of the importance of clarifying the significance of promoting aerospace R&D as a national R&D agency and the value of outcomes with these efforts.

(2) Fostering human resources of next generation

Nurturing young people of future society will be extensively promoted for fostering multiple ways of looking at things and thinking, and self-governing, independent and continuous learning by extensively using outcomes and insight obtained from aerospace R&D as educational materials, and providing support for school and social education activities and opportunities to experience and learn.

Programs and materials supporting lessons will be developed for complementing school curriculum to support school education, and lesson support and on-the-job training will be provided in collaboration with teachers and teachers colleges.

Programs and materials to help parents and society provide an environment of in-depth learning for children will be developed to support social education activities in collaboration with space education instructors and education-related persons in the community. Space education instructors will be fostered to continue activities in the community.

Learning by participation will be provided by using JAXA facilities and equipment as well as opportunities for experts and international exchanges including astronauts. Also, learning information will be distributed using JAXA owned distribution tools and external organizations such as collaborating bodies, in addition to provision of actual learning opportunities.

1.3. Project management and ensuring safety and reliability

The efforts for accomplishing project activities safety and securely, maximizing mission outcomes, and contributing to strengthening international competitiveness will be described below. In the event of significant revision or cancellation of the plan, or loss of mission, the cause including operation processes and management activities will be investigated to prevent recurrence.

(1) Project management

Maintenance and improvement of processes and systems, and accumulation of knowledge and lessons obtained from trainings and activities, in regard to project management, will be promoted for maintaining and improving the management capability of JAXA as a whole.

An organization independent from the related departments will evaluate projects objectively and strictly in terms of project management by understanding the implementation state of individual projects, and accurately feed evaluation results back to the plan.

Initial investigation and trial R&D at planning and preparation stages prior to the start of a project will be fully provided to increase the value of missions and reduce risks after the start of the project.

(2) Safety and reliability

Capability of ensuring safety and reliability of the entire JAXA will be maintained and improved to reduce accidents and defects by raising the awareness of people concerned including the management in quality assurance and management processes, system operation and improvement, and continuous education and training for assuring safety and missions, succeeding and accumulating technologies by using well-designed databases for common technologies and revision of standards and criteria, and continuously improving management methodologies.

An organization independent　the related departments will evaluate projects objectively and strictly in terms of safety, reliability and quality assurance by understanding the implementation state of individual projects, and accurately feed evaluation results back to the plan.

1.4. Utilization of information systems and ensuring information security

(1) Use of information systems

The information system common to all members of JAXA will be subject to new forms of usage, such as transfer of operation dependent on conference rooms, papers and mail, and developed and operated with proactive improvement and satisfaction of staff in mind to maintain and improve efficiency in clerical work and suitable work environment.

Information technologies in various R&D efforts will be upgraded for promoting the development, improvement and utilization of the basic information system to vitalize open innovation including the improvement of usability for sharing the system with other research institutes and private business operators on satellites and simulation data owned by JAXA.

(2) Assurance of information security

Thorough education and training, operational improvement, and system monitoring will be continuously reinforced for preventing information security incidents and improving the security of the information system indispensable for the operation of spacecraft according to internal and external trends including government policies.

1.5. Matters concerning sites and facilities

An action plan will be established for replacing aged components, reducing risks of natural disasters and keeping safety, improving energy efficiency and prolonging the life of infrastructure to maintain and operate the facilities and equipment common to projects with certainty for effective utilization.

Technical proposal will be made based on expertise to upgrade and improve the facilities and equipment with priority and systematically upon request of project operating sections.

Survey and investigation of facilities and equipment will be promoted before implementing the above-mentioned efforts.

2. Contracting intelligence gathering satellites work from government

A system required for executing operations of information gathering satellites, commissioned by the government, will be established using the advanced R&D capability of JAXA.

3. Common to agencies

3.1. Internal governance

A suitable internal control system will be established and operated with certainty for accomplishing operations including project management rationally and efficiently in compliance with related laws and regulations under the president’s leadership using the PDCA cycle for the planning, doing and checking of projects efficiently to implement appropriate internal control. Specifically, basic elements of internal control (control environment, risk evaluation and response, control activities, information and communication, monitoring, observation of ICT) will always be inspected for proper implementation, and reviewed as required according to the internal control implementing guidelines based on the business and service documents. In particular, effective efforts such as education will be promoted for clarifying a system of preventing research misconduct and

person in charge, and preventing misconduct in research activities and illegal use of research expenses according to the government guidelines.

The plan for project management that constitutes a part of the internal control system is addressed in 1.3.

3.2. Matters concerning human resource

Personnel management and work environment will be constantly improved with the aim of making the organization present new value of science and technology to society.

Specifically, efforts include the recruitment and development of a variety of outstanding human resources having high disciplinary, technical power or research capability, job assignment according to the state of projects, and appropriate evaluation and treatment of personnel to raise their motivation in a systematic manner by maintaining and revising personnel education implementation policies and operation by the personnel development committee.

In particular, a cross-appointment system will be promoted for employing outstanding human resources in Japan and abroad who are active on the front lines to create innovation, and the human resources platform will be reinforced by employing or mutually exchanging personnel of private sectors and other external bodies.

Work-Life Innovation will be promoted for providing healthy and active work environment and encouraging every one of members to select diversified and productive way of working.

4. Encumbrances beyond the Medium to Long-term objectives for the period

Debt burden exceeding the mid to long-term objective period will be determined when judged as adequate by the president in consideration of the necessity of said debt burden and effects on the fund plan, because it is rational that the period of a R&D project may exceed the mid to long-term objective period.

5. Usage of reserve funds

Of the balance of financial reserve in the final fiscal year of the previous medium-term objective period, the amount of money approved by the competent minister will be allocated to the financial resources of operations specified in the Act on the Japan Aerospace Exploration Agency.

III. Measures to be taken for achieving the objectives concerning the improvement of

the efficiency of the running of the operations

The improvement and streamlining of the following will be promoted for accomplishing the operations described in Chapter I smoothly and maximizing research outcomes:

(1) Effective and efficient development of organization

The total power of JAXA will be improved by developing a flexible and effective organization based on social situations and other factors to achieve the aerospace policy objectives of Japan. The organization is intended to make active proposals to society and create new value in science and technology to lead society.

On this account, the organization will be adaptive to changes in the external environment in that new projects may be created or planned in cooperation with private sectors or public research institutes, or the organization may be reformed for improving the proposed capability with the pillars of the "R&D capability" for creating innovation and new missions, "project implementation capability" for promoting the development for the success of missions, and "capability common to management and operation" for supporting these activities.

(2) Streamlining of the entire operations

Effective management and rational operation and expenditure will be pursued with continued efforts for constant review of organization, streamlining of procurement, and assurance of efficient operation system. With these efforts, creation of new businesses to meet political and social needs, and social return of outcomes will be promoted in an effective and rational manner. Appropriateness of personnel expenses will be addressed in the subsequent section.

(Numerical targets for the efficient management of operations will be set according to the adjustment in the mid to long-term objectives.)

The Plan for Streamlining of Procurement, etc. will be launched every fiscal year pursuant to the "Policy for Streamlining Procurement by Incorporated Administrative Agencies" (decision of the Minister of Internal Affairs and Communications on May 25, 2015) for rational procurement to achieve aerospace policy objectives with the fairness and transparency in mind.

(3) Appropriateness of personnel expenses

An appropriate wage standard will be maintained according to the government policies by investigating the wage of executives and regular employees and taking into account the

special characteristics of operations, and investigation results and state of implementation will be published. The wage will be determined as required in a flexible manner for creating innovation and taking hold of outstanding researchers in Japan and abroad who are active on the front lines, and the explanation convincing the public will be provided.

IV. Measures on matters concerning improvement of the financial conditions

(1) Improvement of financial conditions

Budgets will be implemented efficiently in consideration of outstanding obligations such as operating expenses grant, and appropriate financial conditions achieved based on the "accounting standards of independent administrative agencies" with an effort to disclose financial information. Assets owned by JAXA and approved as unnecessary will be disposed properly, and transfer of important assets proceeded according to the plan.

1) Budgets (including estimate of personnel expenses), income and expenditure plans, and fund plans

See the appendix.*

* Provided in the future based on the figures in the budget in FY 2018.

2) Limits of short-term borrowing

The limits of short-term borrowing will be xxx million yen.* Short-term borrowing is possibly caused by the delay of receiving operating expenses grant.

* The amount will be determined based on the budget in FY 2018.

3) Plans for disposing unnecessary assets

The necessity of assets will be examined in time, and those approved unnecessary will be disposed properly according to the procedures specified in the Act on General Rules for Incorporated Administrative Agencies.

4) Plans for transfer or collateralization of important assets

Important assets will be transferred or collateralized according to the procedures specified in the Act on General Rules for Incorporated Administrative Agencies.

5) Usage of Surplus account

Surplus account will be used for complementing operations of JAXA, renovating facilities, or supporting staff education, etc.

(2) Promotion of increases in self-revenue

In addition to efforts for implementing policies or social needs with operating expenses grant, etc., increases in self-generated income will be encouraged for creating new businesses, returning outcomes to society, and efficiently promoting outstanding research planned by the researcher, and acquiring external funds by obtaining competitive research funds or strengthening collaboration with internal and external private business operators and public research institutes for providing knowledge of aerospace technologies owned by JAXA, through proactive efforts such as sharing best practices in JAXA and a system of allocation of research funds mainly to the theme that acquires competitive research funds (addition of incentives).