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Science and Technology, Research

Planning and Evaluation Subcommittee,

Space Development and Utilization

Division (12th meeting) September 4, 2013

Status of the Super Low Altitude Test Satellite (SLATS)

September 4, 2013

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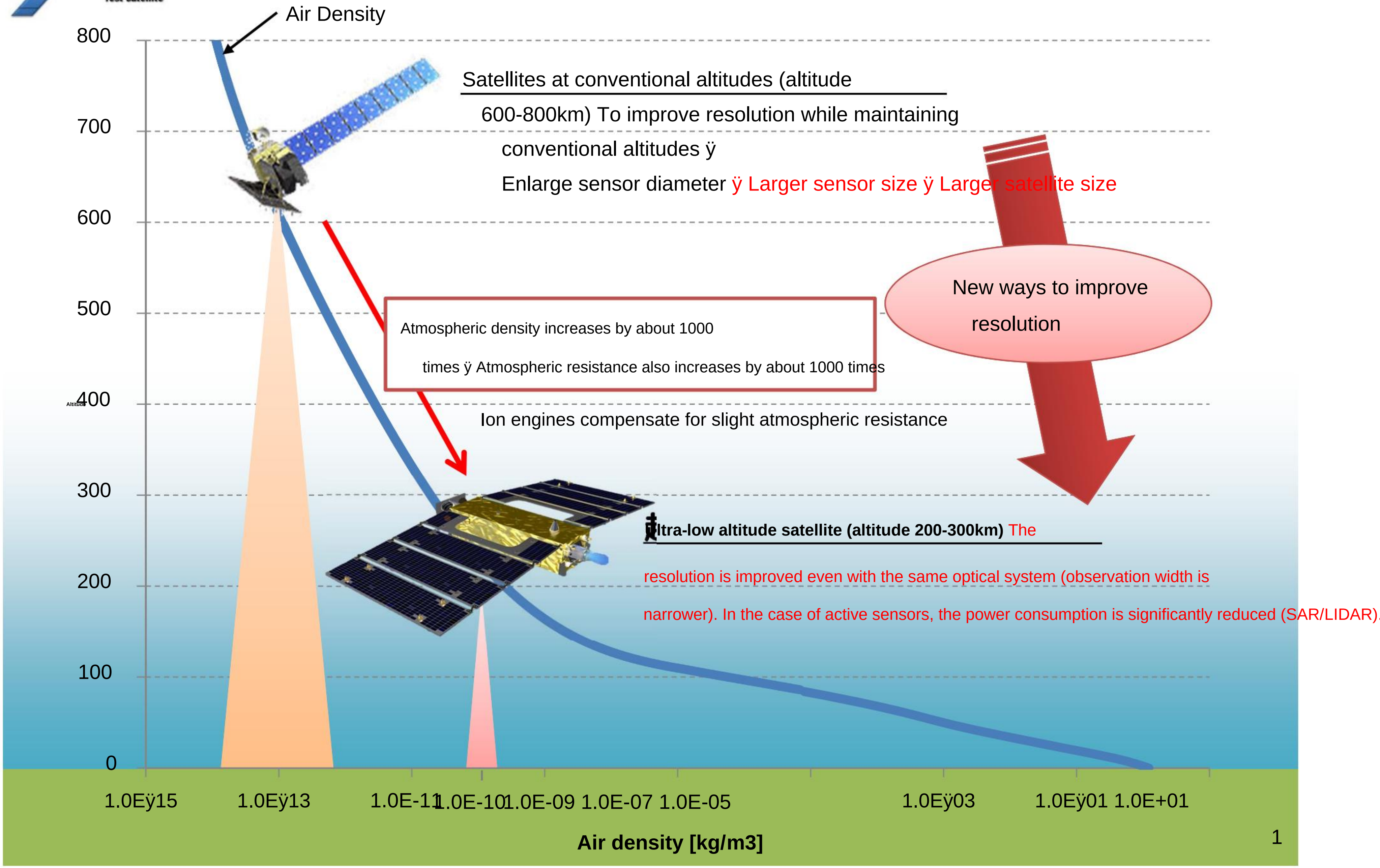
1. Overview of super low altitude satellites



(1) Significance of ultra-low altitude satellites

If ultra-low altitude satellites capable of flying and maneuvering at ultra-low altitudes (200-300 km), which have not been available until now, are realized, the following new possibilities can be expected compared to conventional remote sensing satellites at altitudes (600-800 km): 1) Significant improvement in the resolution of optical sensors (see Reference

Material, p. 10)

Lowering the orbit will ultimately have the effect of improving resolution. 2) Significant reduction in

transmission power of active sensors (SAR, LIDAR) (see reference material, p. 10)

By utilizing the power surplus in SAR*, it is possible to use higher frequencies (broader bandwidth) that require more power, enabling high-resolution observations.

LIDAR** can be made smaller, and by mounting multiple sensors, it is possible to observe new objects such as two-dimensional observation of wind direction and speed. Note) *: Synthetic Aperture Radar, **: Light Detection and Ranging, Laser Radar

3) Significant reduction in satellite manufacturing and launch costs through smaller, lighter sensors

The requirement for high resolution can be met with a compact, lightweight system, reducing manufacturing and launch costs.

ÿSupports both fixed-point observation and high-resolution observation

Depending on the needs, it is possible to switch between once-a-day observations of a specific area (fixed-point observations) and high-resolution observations at low altitudes on orbit (see reference material p.11 for details).

(2) Purpose of the Super Low Altitude Test Satellite (SLATS)

Toward the realization of a super-low altitude satellite (altitude 200-300km) that will open up new possibilities for future satellite utilization, we will demonstrate orbit maintenance and orbit transfer technology at super-low altitudes using the ion engine technology that JAXA has developed. In addition, we will also acquire and evaluate the following data. * Acquire data on atmospheric density

and atomic oxygen necessary for the design of a super-low altitude satellite * Evaluate the mutual effects of observation/pointing and ion engine control

3. Outlook for super low altitude satellites after the SLATS demonstration

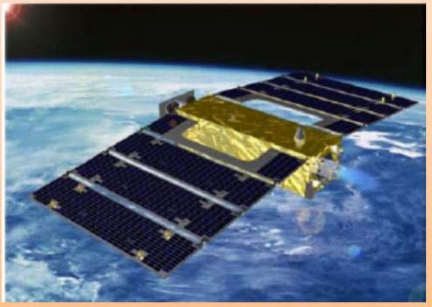
Ion engine technology

Utilization

Super low altitude test satellite

Super Low Altitude Test Satellite

(SLATS)



Opening up new possibilities for satellite use by pioneering new orbits

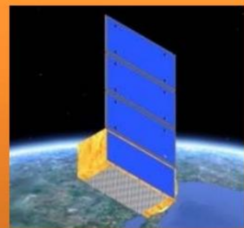
Ultra-low altitude,
flight technology acquisition,
environmental data acquisition,
remote sensing satellite
advance demonstration

Ultra-low altitude satellite

High Resolution Optics

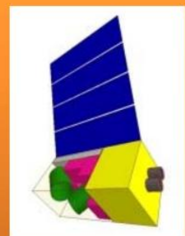
Achieving resolution that exceeds that of overseas commercial satellites while being compact and low cost

High resolution Ku-band SAR



Using Ku-band to achieve resolution exceeding that of foreign satellites

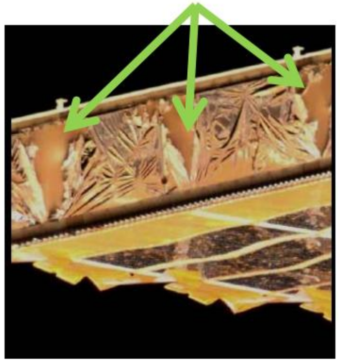
2D wind direction and speed LIDAR



The world's first two-dimensional wind direction and speed observation

4. Overview of SLATS

Deterioration (damage) of thermal control material



Deterioration of the side of the solar panel of the International Space Station (altitude approx. 400 km) due to AO (exposed to space for one year)

SLATS Mission

ÿ Demonstration of ultra-low altitude satellite technology (Confirmation of system concept)

- Confirm the feasibility of autonomous orbital control and satellite operation using ion engines.

ÿ Acquire data on atmospheric density

- Acquire data on atmospheric density at ultra-low altitudes, where actual measurement data is lacking.

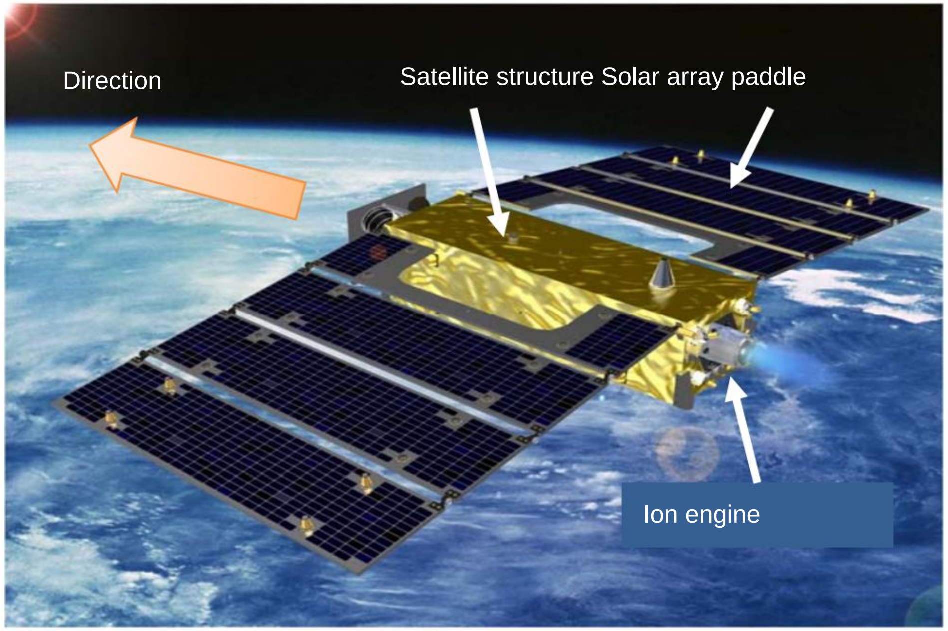
ÿ Acquire data on atomic oxygen.

- Understand the effects of atomic oxygen (AO) on the ultra-low altitude environment and materials, which can deteriorate satellite materials

ÿ High-resolution imaging using a small, high-resolution optical sensor

- Demonstration experiment of high-resolution ground imaging in coordination with satellite attitude at ultra-low altitude

<Exterior view of SLATS>



<SLATS main specifications>

Orbit	After separation from the rocket, the satellite will maneuver itself to an ultra-low altitude of 250 km.
size	2.5 m (X) x 5.2 m (Y) x 0.9 m (Z) (in orbit)
mass	400 kg or less (provisional)
Design life:	about 2 years (fuel life depends on orbit)
Main Mission Sensors	(1) Atomic oxygen (AO) monitor system (a) AO measurement sensor (b) Material degradation monitor (2) Small high-resolution optical sensor

<Total development cost of SLATS>

Approximately 3.4 billion yen

5. Research and development schedule (results and plans)

(1) Conceptual studies were carried out from FY2006. (2) Mission

Definition Review (MDR) was carried out from October to December 2007, and system requirements review (SCR) was carried out in August 2008.

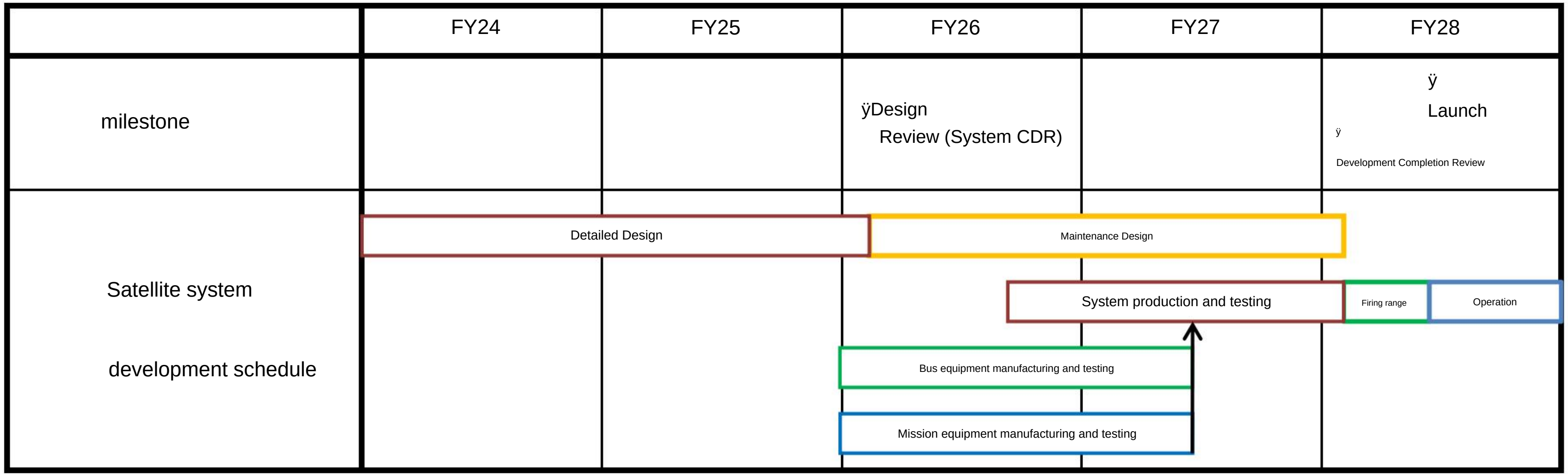
A review (SRR) was conducted.

(3) In May 2009, a System Definition Review (SDR) was conducted to finalize the system and move to the basic design phase. (4) In November 2011, a

review meeting (equivalent to

a PDR) was held against the design baseline and move to the detailed design phase.

Research and development schedule proposal



6. Development Policy

The super low altitude satellite is a cutting-edge and strategic plan that will improve observation accuracy and enable missions that were difficult to achieve with previous technology, and we aim to realize it as soon as possible. To this end, SLATS will be developed based on the following policies.

(1) In order to achieve results quickly, we will conduct technology demonstration using small satellites and develop them in a short period of time at low cost.

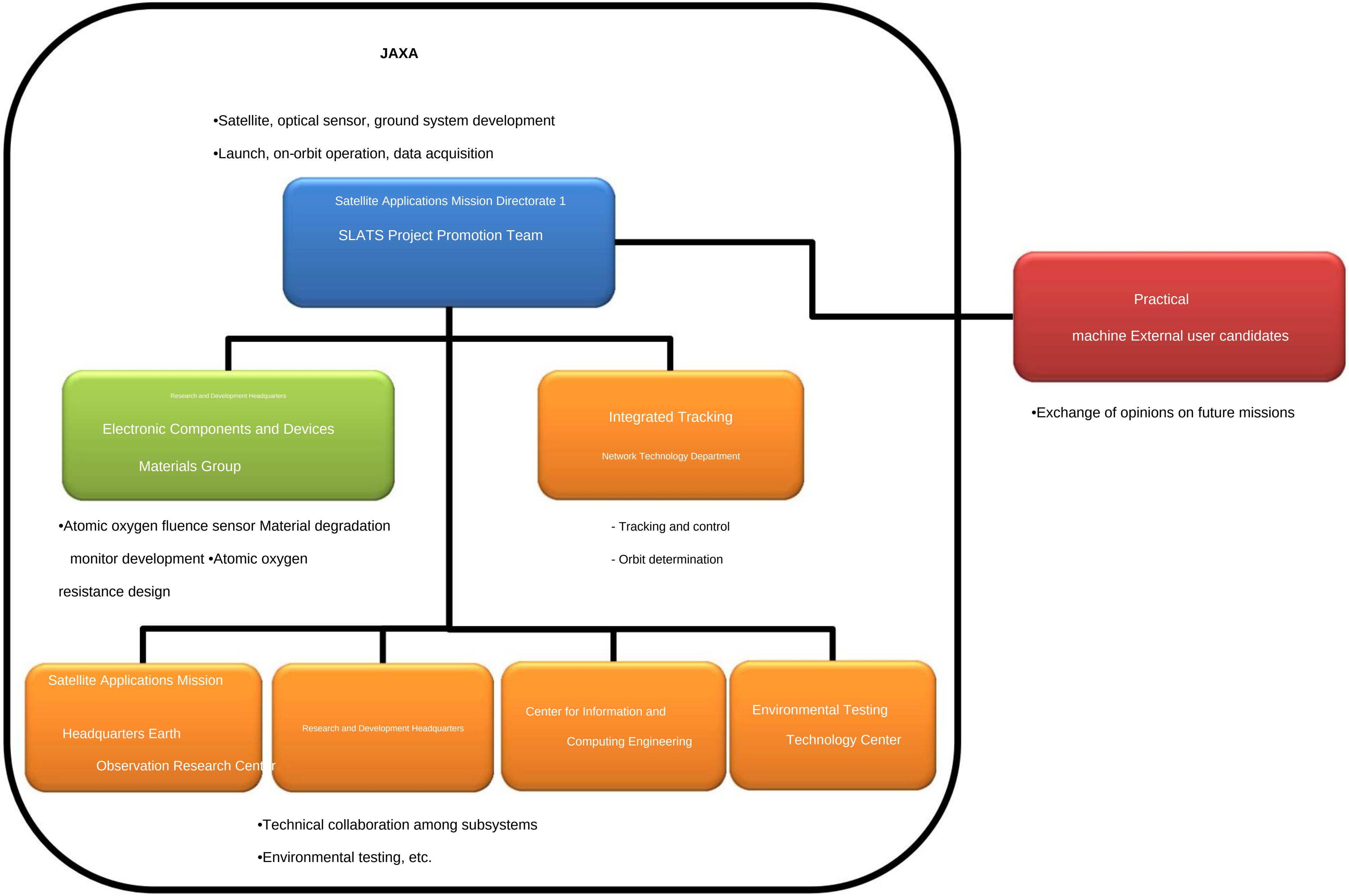
cormorant.

(2) Existing technologies, including those from overseas, will be utilized as much as possible for onboard equipment. For equipment that needs to be newly developed, a one-stage development method will be adopted in which the results of front-loading will be utilized to quickly manufacture and launch the PFM.

(3) Overcome technical challenges and promote efficient development through collaboration among experts from all JAXA agencies, including the Research and Development Headquarters.

(4) Through the development of SLATS, we will accumulate the technology and know-how necessary for designing a practical aircraft.

7. Development Structure



References

1. Relationship between orbit altitude and observation sensor performance

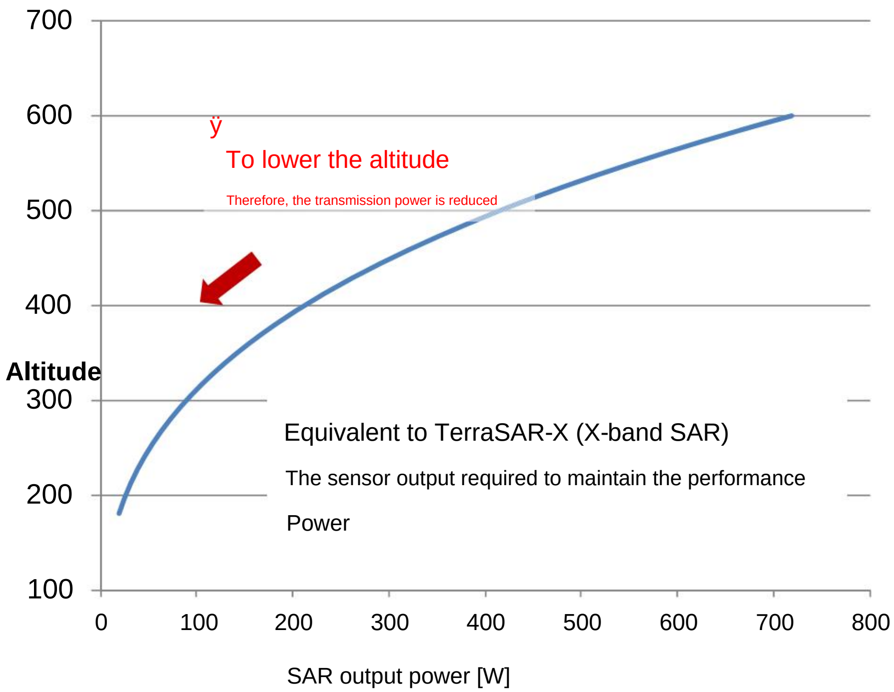
(1) Ground resolution for optical and thermal infrared observations:	Resolution ÿ Altitude
(2) Radar transmission power in SAR observation:	Transmit power ÿ altitude cubed
(3) Laser transmission power for LIDAR observation:	Transmit power ÿ altitude squared

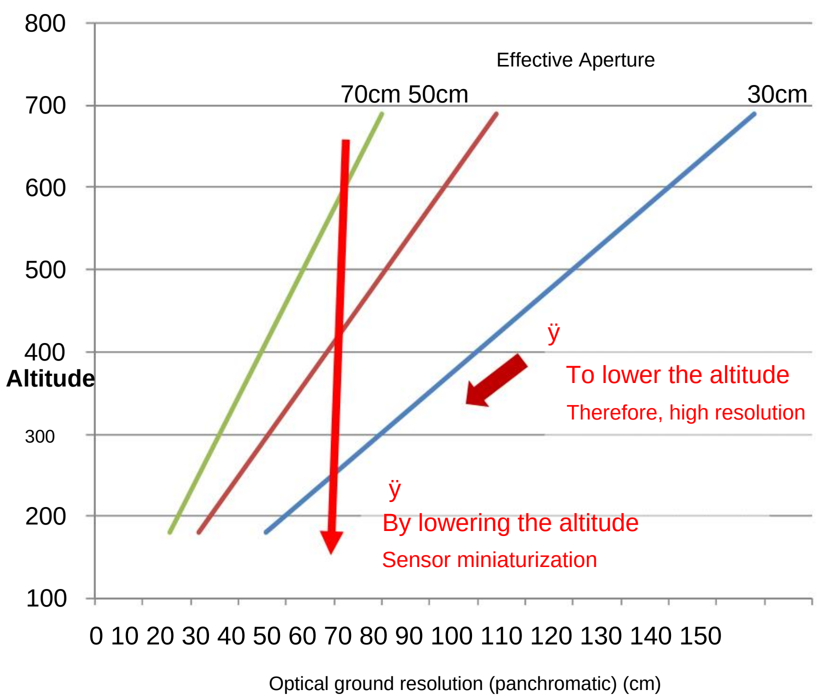
2. Lowering the altitude improves the following performance:

1. Improving the resolution of optical sensors

ÿ Reducing the transmission power of active sensors (SAR, LIDAR, etc.)

3) If the performance is the same, the sensor can be made smaller and consume less power.





*This figure assumes that the resolution is the same as the diffraction limit of the aperture diameter.

Flexible orbital transfer brings new uses

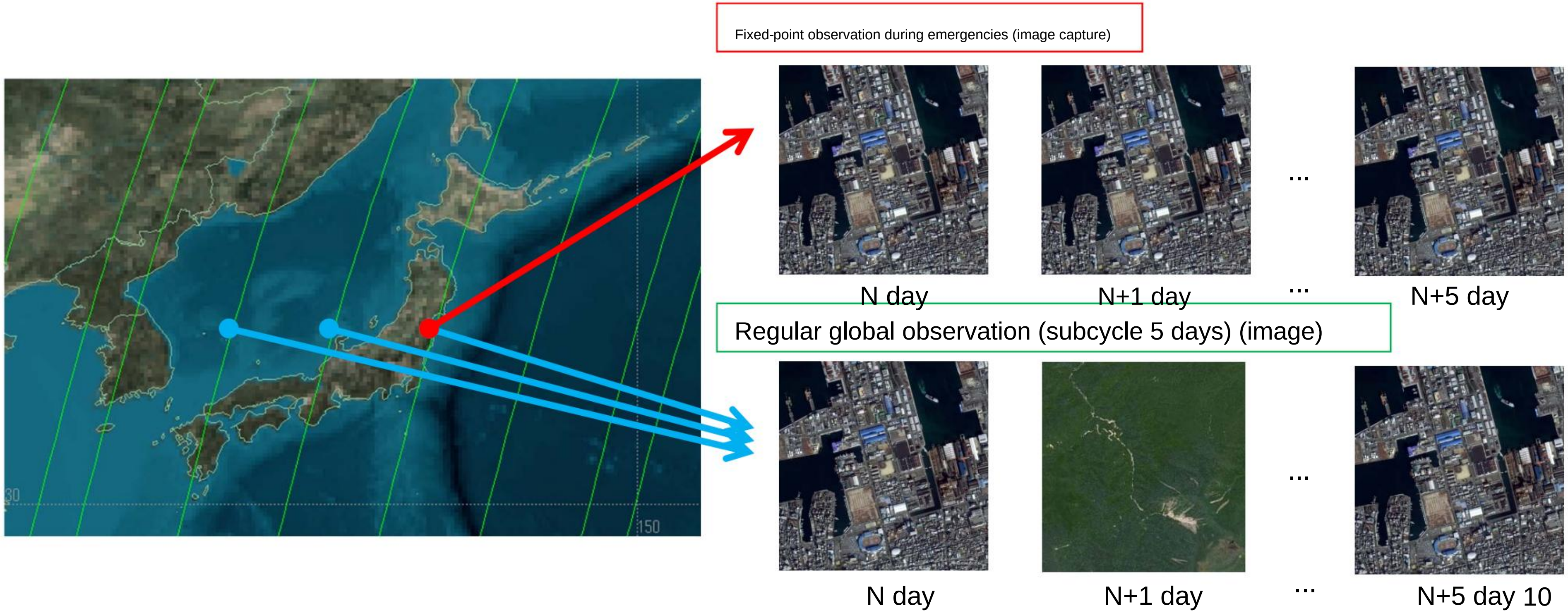
Satellites with unprecedented freedom ÿ Ultra-low

altitude satellites are small in size and equipped with ion engines with high fuel efficiency (specific impulse), making it possible to actively perform orbital maneuvers. This allows for flexible orbital maneuvers not available with conventional satellites to be repeatedly performed during the operation period.

ÿ Until now, satellites have been operated in a fixed orbit during the mission period, but by switching the operating orbit, such as changing to a perfect recurrent orbit, the number of recurrent days, or a direct nadir orbit, depending on the situation , new uses for satellites can be opened up. [Operation

example] Normal time: Quasi-recurrent orbit (altitude 320 km) ÿ Perfect recurrent orbit (altitude 268 km, fixed point observation)

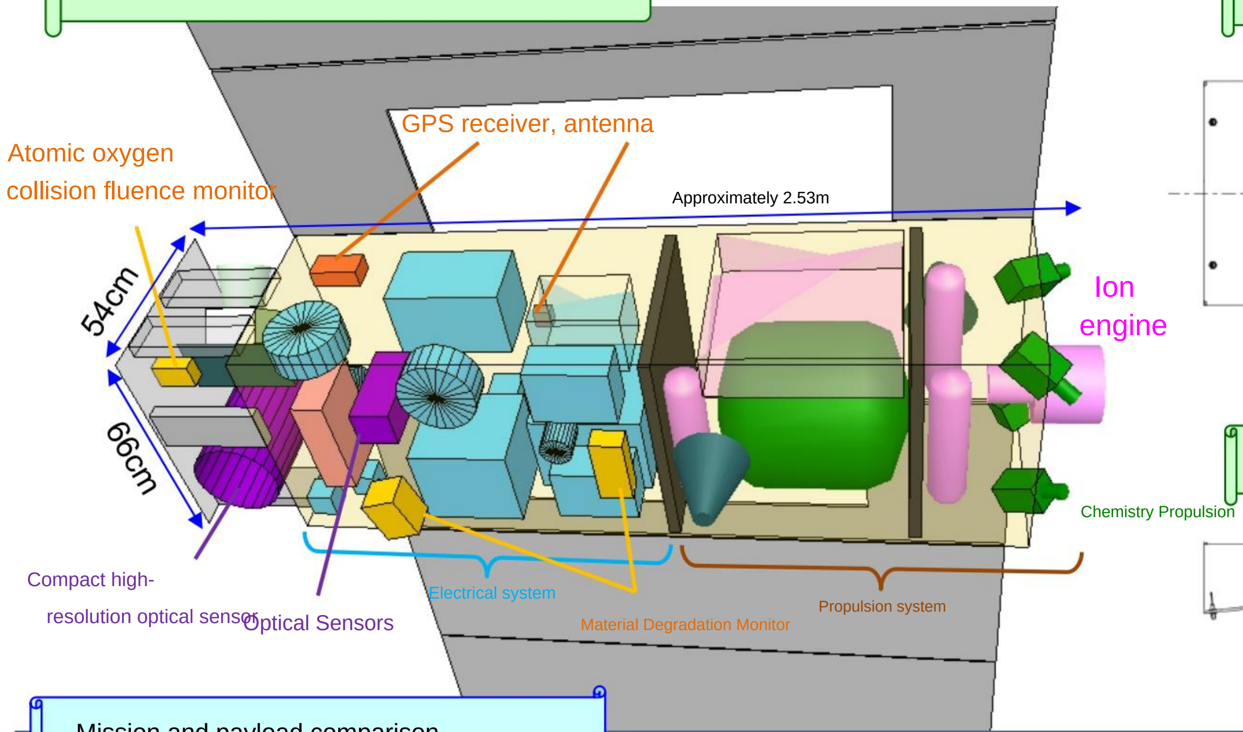
*Intensive observation is possible when the observation target is identified.



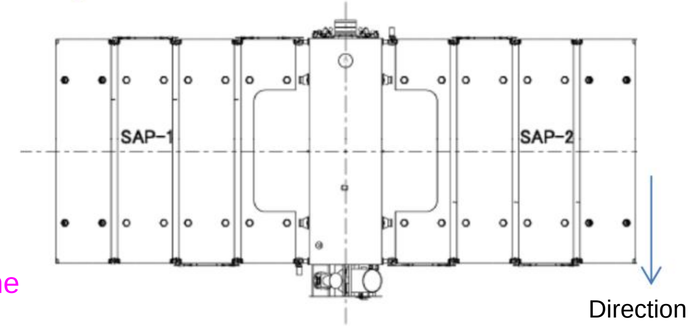
SLATS Super Low Altitude Test Satellite

SLATS: Satellite System Overview

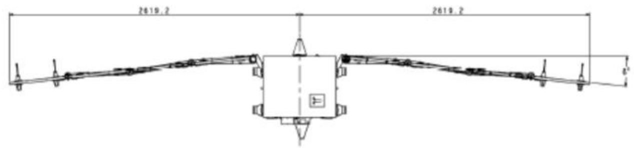
SLATS/Perspective drawing



SLATS (Top View)



SLATS (Front View)



Mission and payload comparison

SLATS Mission (Reposted)

1. Demonstration of ultra-low altitude satellite technology (verification of system concept)
2. Acquisition of data on atmospheric density 3. Acquisition of data on atomic oxygen 4. High-resolution imaging using a small, high-resolution optical sensor

SLATS onboard equipment

ÿ Ion engine (for atmospheric resistance compensation) ÿ GPS receiver (for orbit determination) ÿ Atomic oxygen collision fluence monitor, material degradation monitor ÿ Small optical sensor

Success Criteria (draft)

the purpose	Goals to be		
	Minimum Success	achieved Full	Extra Success
Ultra-low altitude satellite technology demonstration	Successful insertion into ultra-low altitude orbit [Decision time: when altitude reaches 250km]	success 1) Maintain altitude autonomously for more than 27 days at an altitude of 220km (nominal)*3, and satisfy altitude maintenance accuracy of ±1km (1 ÿ) 2) Capable of taking images using optical sensors from different altitudes	Demonstrate the usefulness of emergency altitude ascent operations
Acquiring air density data	Capable of acquiring data on atmospheric density at altitudes above 250 km [Decision time: when altitude reaches 250 km]	Capable of obtaining atmospheric density data for 90 days at altitudes between 250km and 180km	1) Capable of obtaining data on atmospheric density for more than 90 days at altitudes between 250km and 180km 2) Capable of obtaining data on atmospheric density at altitudes below 180km 1) Capable of measuring FAO for
Atomic oxygen data acquisition	The atomic oxygen collision fluence sensor must function normally. [Decision period: 3 months after launch]	Capable of measuring atomic oxygen impact fluence (FAO) for 90 days at altitudes between 250km and 180km.	more than 90 days at altitudes between 250km and 180km ÿ FAO can be measured at altitudes below 180 km. New knowledge can be
	All functions of the material degradation monitor equipment must be functioning normally. [Decision period: 3 months after launch]	The material degradation status can be obtained together with the atomic oxygen collision fluence at altitudes of 180 km or more.	obtained about material degradation caused by atomic oxygen.
High-resolution imaging using a small, high-resolution optical sensor	Capable of capturing images with a small, high-resolution optical sensor at altitudes above 250 km. [Decision time: when altitude reaches 250 km]	Capable of high-resolution imaging in coordination with satellite attitude control in ultra-low altitude orbit (altitude 250 km or less)	In ultra-low altitude orbit (altitude 250km or less), it is possible to evaluate the effect of improving image quality through coordinated control with the satellite attitude, and the effect of atmospheric resistance and ion engine thrust on image quality.

*1: Full success will be judged at the end of the normal phase. *2: Minimum/extra success will be judged for each item. *3: Altitude will be the value of "mean orbital semi-major axis - equatorial radius." *4: Environmental models will be evaluated and analyzed using data that can be obtained during the mission period.

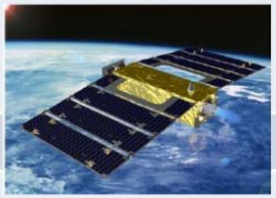
Comparison with other countries' super low altitude satellites

In March 2009, ESA launched the Gravitational Observation of Earth (GOCE) satellite into a very low orbit (approximately 260 km) to obtain scientific data on the Earth's gravity field.

ÿ Although this is a precedent example that utilizes an ultra-low altitude environment, the main purpose of the mission is to observe the gravity field, so the orbital altitude needs to be maintained with high precision, which makes the ion engine control complicated and increases both mass and size .

ÿ We have not yet acquired the pointing technology and basic design data (data on atomic oxygen and material degradation) required to realize a practical remote sensing satellite and to operate it in a super low altitude orbit for a long period (5 years or more).

- SLATS will acquire the technological elements (pointing, efficient orbit control technology, etc.) required to realize a practical remote sensing satellite in a super low earth orbit environment ahead of other countries.

	SLATS (JAXA)	GOCE (ESA)
Launch	FY2016 target (GCOM-C1 shared ride)	Launched in March 2009 (Rockot) In operation
mission	1. Demonstration of ultra-low altitude satellite technology (verification of system concept) 2. Acquisition of data on atmospheric density 3. Acquisition of data on atomic oxygen 4. In-orbit demonstration of new components 	Earth gravity field observation (Earth observation sensor, reaction wheel, atomic oxygen monitor equipment are not installed) 
mass	Under 400kg	1100 kg
Satellite Size	2.5(X) x 5.2(Y) x 0.9m(Z)	5.3(X) x approx. 1m (ÿ)
Total Cost	3.415 billion yen	Approximately 45 billion yen (350 million euros converted at the exchange rate at the time)
Ion engine control:	Orbit is maintained by simply switching ON/OFF once per revolution (orbital eccentricity maintenance) (Uses atmospheric effect to maintain stability. JAXA's unique method)	Weak atmospheric resistance detected by a high-precision accelerometer is constantly cancelled by ion engine thrust.

It has also been reported that the UK, Germany, China and other countries are considering developing super-low altitude satellites. For this reason, early demonstration by SLATS is necessary so that Japan can lead the world in pioneering the use of super-low altitude satellites, a new orbit.

Corresponding points in policy documents and medium-term plans (1/2)

Basic Space Plan (Decided by the Space Development Strategy Headquarters on January 25, 2013)

Chapter 3: Measures that the government should implement comprehensively and systematically regarding space

development and utilization 3-1. Four social infrastructures to expand space utilization and ensure autonomy

B. Remote Sensing Satellites

(3) Goals for the next 10 years

(Omitted) As for remote sensing satellites, we will continue to work on map creation, resource exploration, utilization in agriculture, forestry and fisheries, disaster monitoring, marine observation, etc., and by expanding the use of satellite data, we will realize further sophistication and efficiency of industry and government.

(4) Five-year development and

utilization plan ÿ Systematic construction of

satellite system In order to expand the use of remote sensing, we will collect the usage needs of the public and private sectors as well as overseas needs and reflect them in the

setting of satellite specifications. (Omitted) Specifically, we will develop a constellation of remote sensing satellites in collaboration with Asian countries that support the "ASEAN Disaster Prevention Network Construction Initiative" that utilizes the strengths of Japan's satellite technology, and aim to expand the use of remote sensing satellites not only in Japan

but throughout Asia. (Omitted) We will promote research and development necessary to advance such satellite systems as social infrastructure.

3-3. Eight cross-cutting measures to promote the strategic development and utilization of outer space (2)

Building a robust industrial base and promoting effective research and development

ÿ Five-year development and utilization plan

b) Strengthening of industrial base

(Omitted) In order to strengthen the international competitiveness of private businesses, we will provide opportunities for space demonstrations and support research and development, while also working to improve reliability and reduce costs by continuously maintaining and improving

technological standards. (Omitted) The communications and broadcasting sector accounts for approximately 75% of the commercial satellite market, so capturing this market is important for maintaining the industrial base. For communications and broadcasting satellites, we will develop and demonstrate technologies that can flexibly respond to larger buses and changes in demand. In addition, for earth observation satellites, we will develop and demonstrate technologies that meet market needs, such as low costs, high-resolution sensors, and technologies for the coordinated operation of multiple satellites, through public-private collaboration.

SLATS
Super Low Altitude Test Satellite

Corresponding points in policy documents and medium-term plans (2/2)

Measures to promote the space sector at the Ministry of Education, Culture, Sports, Science and Technology (Space Development and Utilization Subcommittee, December 2012) III.

Direction of the Ministry of Education, Culture, Sports, Science and Technology's efforts

2. Supporting space (1) Strengthening the technological base ÿ Other technological bases A. Significance (Omitted) Specifically, (omitted), it is necessary to develop new technological fields and link them to practical use while taking into account social needs. In particular, research and development of advanced satellite technology and research that leads to new possibilities for space utilization (omitted) are of great significance from the perspective of

investment in the future. C. Specific promotion measures

From the perspective of supporting space, it is important to provide a technological foundation that can meet user needs while working on technological innovations that will open up possibilities for future space utilization, and a mechanism for this purpose should be

established. (a) Link with actual utilization a. Acquisition of technologies that meet user needs

From the very start of a project, efforts should be made to reflect user needs. (Omitted) However, as space development and utilization progresses, in order to expand future use, it is necessary to realize projects that consolidate and utilize user needs from a wide range of fields, and to develop satellite and sensor technologies. (Omitted)

Third Mid-term Plan 1.

(2) Remote Sensing Satellites ÿ Research and development of satellites that contribute to disaster prevention, etc. In order to strengthen Japan's disaster prevention, disaster countermeasures and security systems, promote land management and ocean observation, and the use of remote sensing satellite data, maintain and improve the space industry base through the overseas expansion of Japan's space systems, improve the disaster response capabilities of ASEAN countries, and cooperate with international cooperation such as human resource development and problem solving in partner countries, we will develop remote sensing satellites in cooperation with relevant ministries and agencies. In doing so, we will work on satellite development to create a satellite constellation (omitted) consisting of optical (mainly visible range) and SAR (omitted). Specifically, (omitted) we will conduct research on future satellites and observation sensors such as geostationary earth observation missions that contribute to security and disaster prevention, and small infrared cameras for detecting forest fires.

4. (2) 1) Strengthening fundamental and cutting-edge technologies and contributing to strengthening international competitiveness (Omitted) In order to strengthen the international competitiveness of private businesses, we will provide opportunities for space demonstrations, etc. (Omitted)