# MISSIONS OF SMALL SATELLITES LAUNCHED BY THE J-I LAUNCH VEHICLE

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## Abstract

This paper presents the concept of the small satellites launched by the J-I launch vehicle of the National Space Development Agency of JAPAN (NASDA). On this concept, the missions of the small satellites are for the experiment and the validation of the earth observation, the satellite communications, and the others on orbit. For efficient achievements of these missions, the common satellite bus will be adopted for the solid launch vehicle J-I, in order to develop the each small satellite system quickly by low-cost.

## 1. Introduction

NASDA has been developing and operating two classes of satellites; for experiment and for validation. These satellites have become larger as the growth of NASDA launch vehicle. NASDA has developed and used liquid launch vehicle series; N-I, N-II, H-I for the launch of satellites[1]. The next liquid launch vehicle H-II will be launched in the winter of 1994.

NASDA has been developing the large satellites launched by the H-II launch vehicle, however, these large satellites seem to be risky for new engineering tests and new experiments. Therefore we study the small satellites for complement of the large satellites of NASDA because of the following reasons:

(1) To reduce the cost
The total cost of small satellite project is one-fourth compared with that of large one.

(2) To reduce the period of development
The period of development for small satellites is around two or three years shorter than that for large satellites.

(3) To achieve the mission efficiently
It's easy to adopt the newest mission requirements of satellites by the reduction of development period.

(4) To develop the satellite efficiently
It's easy to adopt the newest technology of satellites by the reduction of development period.

## 2. Missions of the small satellite

The small satellites in this paper weigh around 400~800kg which are heavier than those by the SCOUT launch vehicle of NASA. We chose this class for our satellites because it can carry the payload of 100~200kg which would apply to big satellites easily after the experiments by the small satellites, and can fly by the J-I launch vehicle as shown later.

Three categorized missions can be considered for these small satellites, that is, earth observation, communications, and other missions. Furthermore, each mission is divided into two from the view-point of technology phase, that is, experiment and validation. This mission category of the small satellites is shown in Table 1.

Table 1. Mission category of the small satellites

| | earth observation | communications | other mission |
|---|---|---|---|
| experiment (main purpose of the small satellites) | (1)experiment of leading-edge technology | (1)experiment of leading-edge technology<br>(2)confirmation of new communications system | (1)establishment of RVD technology<br>(2)test of new components and subsystems for satellite bus |
| validation | (1)observing by small set of instruments | (1)communication system using LEO satellites | (1)small OTV<br>(2)space environment monitor |

## Earth observation mission

For the earth observation mission, the small satellites will carry instruments with leading-edge technologies. These mission will be hardware experiment of instruments, confirmations of observing principles, and development of analysis programs. After the experiments by airplanes and/or the small satellites, instruments of the experimental operation type will be developed for earth observing platforms of NASDA such as ADEOS (Advanced Earth Observing Satellite) series[2].

In the field of earth observation, many satellites have been launched into polar orbits. On the other hand, the J-I launch vehicle can't be launched to high inclination orbits because of the restriction of the launch capability. Several candidates of earth observation missions by the J-I launch vehicle are shown in Table 2.

Table 2. Candidates of earth observation mission

| payload | key technology | assumed weight / power |
|---|---|---|
| advanced microwave sounder | superconductivity device, spectrometer | 150kg / 150W |
| Fabry-Perot interferometer | etalon plate scanning, sun glitter tracking | 190kg / 400W |
| laser radar | laser diode of high power and long life | 200kg / 500W |

## Communications mission

For the communications mission, the small satellites will carry devices or systems with leading-edge technologies such as high temperature superconductivity devices, and the systems which need validations of end-to-end communications.

Many communications satellites have been launched to Geostationary Earth Orbit (GEO). On the other hand, the J-I launch vehicle can't be launched into high altitude orbits because of the restriction of the launch capability. In spite of this orbit limitation, the small satellites would be able to experiment with devices and satellite systems in Low Earth Orbit (LEO). The experiment of optical Inter-Orbit Links (IOL) and the validation of mobile satellites communications might be good candidates.

## Other missions

Besides earth observation and communications, the small satellites will be used to experiments of RendezVous and Docking (RVD) systems, and tests of components and systems of the next generation for satellite buses.

For the establishment of unmanned RVD technology, NASDA has been developing the Engineering Test Satellite-VII (ETS-VII) launched by the H-II launch vehicle in 1997[3]. The RVD experiment mission that the small satellite will be docked to the ETS-VII might be one candidate.

## 3. Launch vehicle

The small satellites will be launched by the J-I launch vehicles. The J-I launch vehicle has been developed by the Launch Vehicle Program Department in NASDA headquarters. The J-I launch vehicle will be the two- or three-stage launch vehicle using solid motors to all stages. Characteristics of the J-I launch vehicle are shown in Table 3. The capability of satellite launch is shown in Fig. 1 and its configuration is shown in Fig. 2. This launch vehicle can launch the satellite of 500kg with the altitude of 600km and the inclination of 30deg.

The two-stage type of the J-I launch vehicle will be used for a ballistic flight mission, and its three-stage type will be used to launch a small satellite. The First flight of J-I which will be the two-stage type, is planned to be launched in 1996.

Table 3. Characteristics of the J-I launch vehicle

| | |
|---|---|
| total height | about 33m |
| 1st stage | modified Solid Rocket Booster of H-II |
| 2nd stage, 3rd stage | modified upper stages of M-3SII developed by the Institute of Space and Astronautical Science (ISAS) |

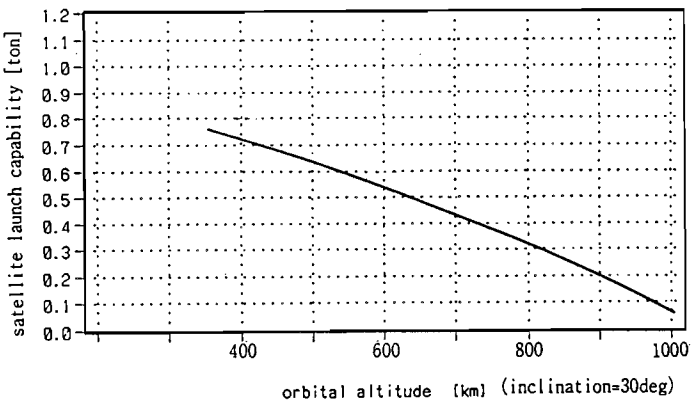


Fig. 1. Launch capability of the J-I launch vehicle

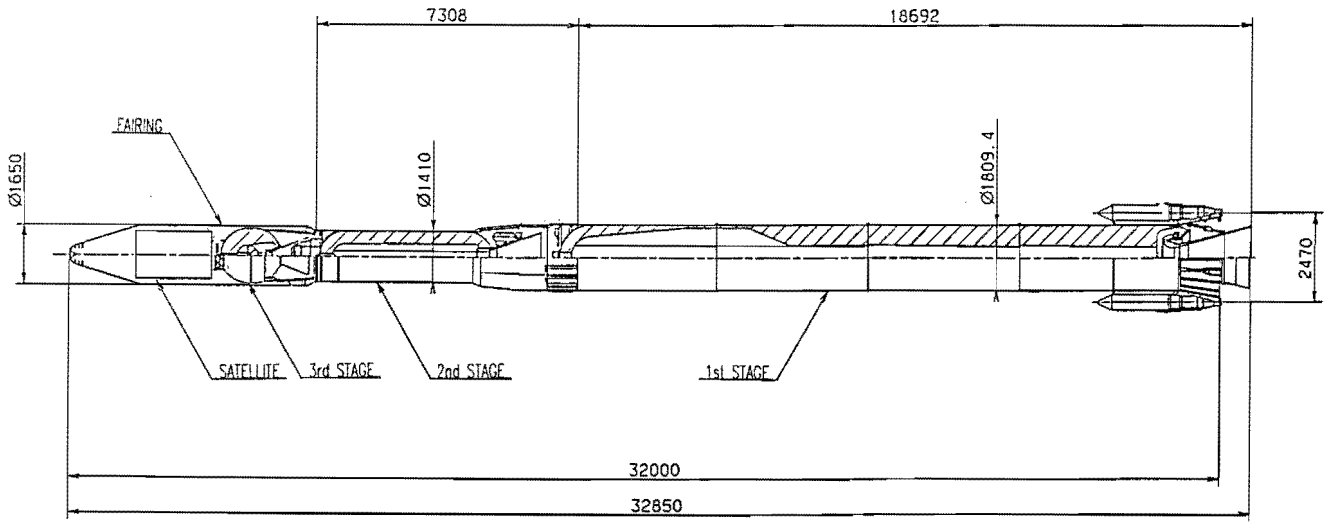


Fig. 2. Configuration of the J-I launch vehicle

## 4. Concept of the common satellite bus

The phase-A study of the small satellite has started from last April. The small satellites can use the common satellite bus. Of course, some subsystems of the common satellite bus should be modified to adopt for each mission. We think that the satellite structure will be one of subsystems modified. The assumed characteristics of the small satellites using the common satellite bus is shown in Table 4 and Fig. 3.

Table 4. Assumed characteristics of the small satellite

| | |
|---|---|
| total weight | about 500kg |
| configuration | 1.cubic main structure<br>2.payload is boarded on upper panel of main structure<br>3.function peculiar to mission is optional in the common satellite bus |
| orbit | altitude;400~600km<br>inclination;30~45deg. |
| launch vehicle | J-I |
| mission period | 1 year |

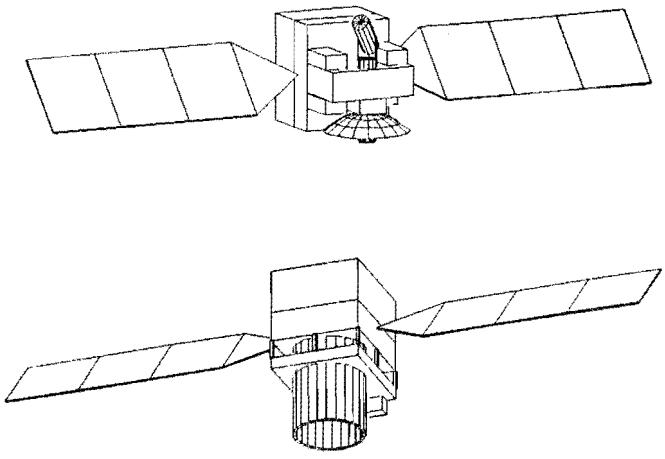

Fig 3. Candidates of the small satellite configurations

## Structure

A fundamental design requirement of satellite structures mainly comes from the J-I launch vehicle. The J-I launch vehicle consists of solid motors and separate the satellite with 120rpm rotation. Therefore the cylindrical tube is necessary to attach to the Payload Attach Fitting (PAF), and the conventional structure design might be required because of the maximum acceleration up to around 10G.

## Communication and data handling subsystem

The communication function of the common satellite bus for telemetry, tracking, and command is considered to use the Unified S-Band (USB) on a basis, and to use of IOL by data relay satellites system of NASDA as a option. The communication function for earth observation data will be also optional. The outline of communication network is shown in Fig. 4.

The data handling function of this bus for telemetry and command includes execution of stored commands on time, and telemetry storage for operation out of link coverage. A solid state memory is considered as a candidate. Data storage for earth observation data will be optional.

## Attitude and orbit control subsystem

The attitude and orbit control function of this bus needs earth pointing ability. Two types of different abilities are considered as shown below:

type1; cheap, rough pointing accuracy (less than about 1deg.) to earth or sun, without guidance and navigation function

type2; expensive, precision pointing accuracy (less than about 0.2deg.) to earth or sun, with guidance and navigation function

## Electrical power subsystem

Power output capability is determined by solar array and batteries, and these components are massive. Moreover, solar array has closed relations with the attitude requirement, the field of view, and the others. Therefore configuration and size of solar array will be designed for mission requirements, and battery size will be also selected from 20AH, 35AH, and 50AH. Use of the Nickel-Metal Hydride (NiMH) battery cell is planned to accumulate flight data of new cells.

The switching shunt regulator for power control of solar array is considered as battery charge regulator from viewpoint of simplicity.

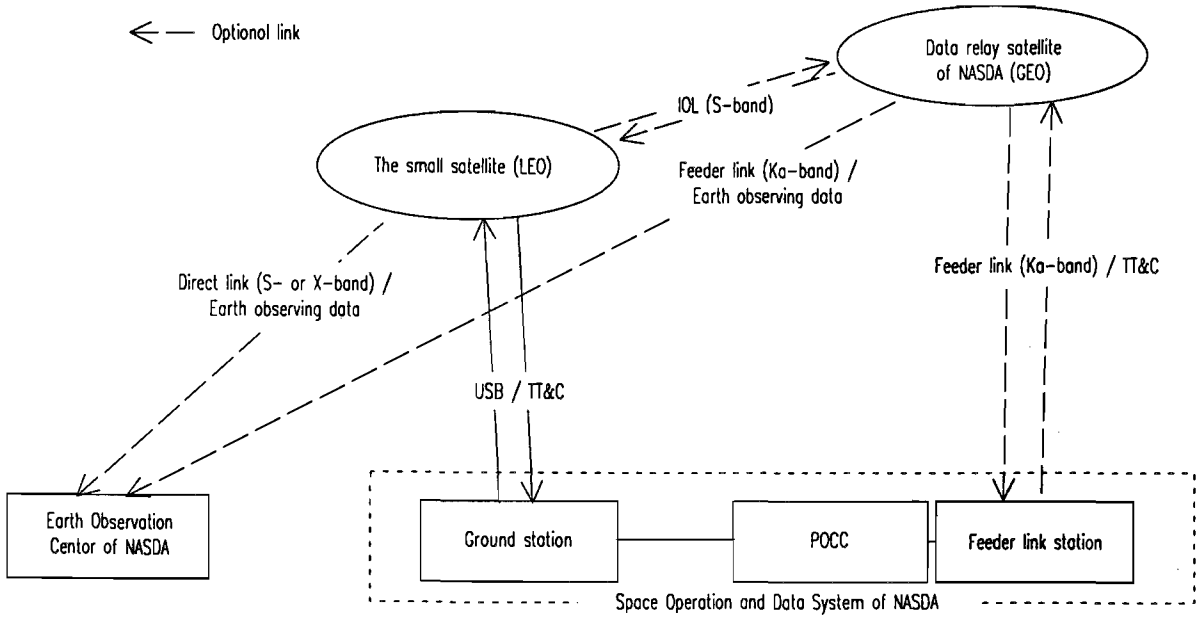


Fig 4. Outline of communication network of the small satellite

## 5. Example of applications

As the first mission of the small satellite, the satellite whose mission is the optical IOL experiment between LEO and GEO has been studied. The small satellite for this mission will carry the equipment for the optical IOL experiment, and will be launched into LEO. ARTEMIS, the geostationary technology communication satellite of ESA, is considered as a GEO station of this experiment. The assumed cooperative experiment system with ARTEMIS is shown in Fig. 5. The characteristics of the optical IOL equipment onboard the small satellite is shown in Table 5. The development schedule of the small satellite is shown in Table 6.

Table 5. Characteristics of the optical IOL equipment

| | |
|---|---|
| weight | less than 140kg |
| power | max. 300W |
| size | optical unit; 1250x1100x1000(mm)<br>electronics unit; 500x300x500(mm) |
| data rate | forward link; 2Mbps<br>return link; 50Mbps |

As the follow-on missions of the small satellites, the RVD experiment to ETS-VII above mentioned and the earth observing experiment are assumed. The instrument candidates of the latter mission are a atmospheric limb sounder and a laser radar.

## 6. Conclusion

Small and low-cost satellites are indispensable for the development of new technologies in the case of NASDA. The J-I launch vehicle can carry these satellites with appropriate weight. We believe the cost of this system is the most important to succeed this concept. Therefore, we must study the common satellite bus and shorter period of development in detail.

## 7. Reference


1. M. Miyazawa, "Homegrown technology for Japan's heavy-lift launcher", IEEE spectrum, March 1989, P.51-55.
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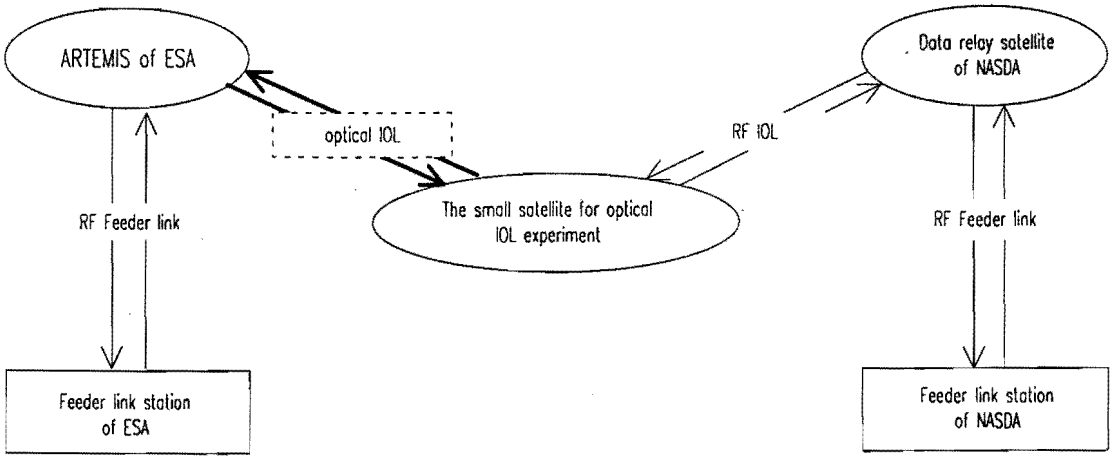


Fig 5. Assumed cooperative optical IOL experiment system with ARTEMIS

Table 6. Development schedule of the small satellite for optical IOL experiment