Small Satellite System for Technology Demonstration

T. Hidaka, Y. Kawada, A. Noda, T. Fujita (NASDA)

1. Introduction

The role of technology demonstration in space consists in obtaining meaningful data in conditions which we can't create in the ground test and in estimating adaptability of space-system or space-equipment with actual space-environment, for example zero-gravity, a high degree of vacuum, and cosmic ray. A good knowledge of up-to-date technology, obtained through demonstration, is expected to reduce some risk of big projects in which we develop and operate it, and to promote the reseach of itself.

Because the means for this type of technology demonstration, in principle, have to meet two basic conditions that the total cost of it should be low and the chance of it should be timely, small satellite which professes low cost and short turn-around-time, can be one of the most useful means for technology demonstration. In addition comparatively long operational period on orbit makes small satellite attractive also.

In NASDA, we reseach two type of small satellite system, one is 50kg-class and another is 500kg-class, respectively corresponding to H-2 piggy back, H-2 double launch and J-1, and we create new mission on behalf of technology demonstration(Table1-1).

In this paper we present 500kg-class small satellite system and mission of NASDA in recent years, highlighting Lidar Engineering Test Satelite(LETS) which we are going to start phase-A study from this year.

2. Outline of technology demonstration mission

We study mainly three fields of technology, communication, earth observation and bus technology, but following diversification of mission, there are appearing a various kind of technology demonstrated, for example mechanics like anntena-deployment mechanism(Table2-1). Among these technology 500kg-class satellite is proper to demonstrate technology assembled as a system, but not as parts and equipments fit for 50kg-class satellite or the remaining space in large-scale satellite.

We can't show cost-to-perfomance of technology demonstration for the lack of quantitative data by which we should compare the result obtained through it with the cost of it. But the valuable experience in Engineering-Test-Satellite-6 (ETS-6) suggest that it should be a good policy to plan technology demonstration for critical system whose failure cause the entire system fairure in advance of actual use. Though the result of the ground test is very useful, it is difficult to realize space environment accurately in the ground test, espesially combining some of them. In addition the ground test of system level, whose size is apt to become larger, has a lot of difficulty in the aspect of technique and expense. These things give technology demonstration in space special meaning different from ground test.

When planing technical demonstration in space, we have to give to the satellite so many and proper telemetry channel as to be able to monitor the status of the system or the equipment to be demonstrated according to the purpose of demonstration, enhancing the capability of estimating failure on orbit accurately. Moreover we appropiately have to catch space environment itself to which they are exposed, and to prepare, in advance, the ground test data to be refered. For elaborate invesigation recovery of the mission to the ground will be very useful to demonstrate technology, but too difficult to be realized within limited resorse of small satellite.

In additon to the technical matter like these things, it is very important where the technology demonstration activity in space should be positioned in the whole senario of some space activity to utilize the system or the equipment demonstrated.

3. Outline of Small Satellite System(500kg-class)

In recent years the payroad-efficiency of 500kg-class satellite of NASDA ranges about from 25% to 30%, mainly due to the properant mass determined by orbit element or mission requirement. The volume(dimension) of the satellite is about 1.5m^3(1m×1m ×1.5m) to 2.5m^3(1m×1.25m×2m), because the ratio of volume to weight ranges about from 0.003m^3/kg to 0.005m^3/kg, considering acutual result so far.

ETS-3(*1), ETS-5(*1), MOS-1(*2), OICETS(*3), and LETS(*4) are classified into this class of satellite for the purpose of technology demonstration in NASDA(Table3-1). ETS-3, ETS-5, and MOS-1 in space development of JAPAN had a big target that is establishment of basic bus technology, for example 3-axis stabilized technology, respectively on sun-nonsynchronous orbit, on geo-synchronous orbit, and on sun-synchronous orbit, and so they are classified into the category different from OICETS and LETS whose target is mainly both demonstration of mission technology(refer to Table2-1) and development of low-cost and short turn-around-time platform(bus system).

Common feature of OICETS and LETS bus system is to use worn-out technology as much as possible in order to shorten development period.

Table3-2 shows outline of system and subsystem type of 500kg-class satellite.

*1)ETS-3, ETS-5

ETS is abbrebiation of Engineering Test Satelite. ETS-3 was launched in '82, ETS-5 in '88.

*2)MOS-1

MOS is abbrebiation of Marine Observation Satellite. MOS-1 was launched in '87 first.

*3)OICETS

OICETS is abbrebiation of Optical Intersatellite Communications Engineering Test Satellite. It is launched in '98.

*4)LETS

LETS is abbrebiation of Lidar Engineering Test Satellite. It is under pre-phase A, its launch date not determined.

4. LETS System

Table4-1 shows the result of pre-phase A study, in which we study two type of LETS, one is launched by J-1 and another is launched by H-2(double launch).

H-2(double launch) can give a little more resource to LETS mission than J-1 single launch.

5. Conclusion

We will start the phase A study of LETS soon, on the base of the result of the low cost and short turn-around-time 500kg-class satellite bus that we have reserched since the first satellite, OICETS. In the phase A study we will study feasibility of LETS for H-2(double launch) in detail, though we don't give up that for J-1 single launch.

Last fiscal year when studying LETS for J-1 single launch we could get a good co-operation with TOSHIBA CORPORATION, especially in parametric study about distribution of weight, power, communication and so on, between mission and bus. We would like to express our thanks to TOSHIBA CORPORATION.

Table1-1 Comparison of Two Type of Small Satellite of NASDA

Item	50kg-class small satellite	500kg-class small satelle
Way of Cost Cut Down	Use of Civil Parts Handmade by a Few Member Shorten Operational Period	Use of Worn-out Technology and Component. Shorten Operational Period
Turn-Around-Time	About Two Years at Most	About Four Years Shorten Phase B/C
Feature of Bus System	Gravity Gradient S-Band(Bus)/V- or U-Band(Mission)	3-Axis Stabilized S-Band as DT OR Spacenet X-Band as DT
Launch Vehicle	H-2 Piggy Back	J-1 Single Launch H-2 Double Launch
Example of Mission	Demonstration of Advanced Technology of Parts and Component Mainly in progress	System and Subsystem of Mission Equipment Mainly OICETS OR LETS

Table2-1 Classification of Technology Demonstration Mission

Technology to be Demonstration			
Communication	Earth Observation	Mechanism	Others(Include Bus)
Phased Array Anntena Optical Communication High Density Solid Memory	Interferometer LIDAR(Altimeter & Scattrometer) Ozone Monitor	Robotic Arm Anntena Deployment Mechanism Inflatable Paddle Tether Mechanism Soft Docking Mechanism	Battery Small Cooler Electrical Propulsion System Control System Using CMG Monitor of Space Environment

Table3-1 Example of 500kg-Class Satellite

ITEM	ETS-3 .	ETS-5	MOS-1	OICETS	LETS	ETS-6	ADEOS
WEIGHT(kg)	385	550(BOL)	750	550	550	1900(BOL)	3500
POWER(w)	300	1080	640	1300	1300	5800	6700
ORBIT h i	1000km 45deg	GEO	909km 99deg	550km 35deg	500km 40deg	GEO	800km 98deg
PAYROAD(%) EFFICIENCY	16	20	20	26	26	34	36
V/W RATIO	0.004	0.004	0.006	0.003	0.003	0.005	0.006

Table3-2 Major Feature of System and Subsystem

System	3-Axis stabilized earth oriented. Box Type Central Structure	SPS& EPS	Two Extendable Solar Array(Rigid) NiMH Battery 50v non-stabilized bus-voltage
C&DH	S-band(USB). Data Bus or encoder/decoder. Solid Memory	TCS	Passive control(heater + Radiater)
		RCS	Mono-propellant(Hydrazine). Blow down Feed. 1N Thruster
AOCS	Sun/Earth sensor + IRU Onboard computer & Autonomous Fault Torelant Function	STR	Panel or Panel-flame(Al/Al H.C.)

Table4-1 Result of Pre-Phase A Study

ITEM	J-1 Single	H-2 Double
Injection Orbit	h=500km i=40deg (Direct)	About h=300km i=30deg (TBD) Orbit Transfer Needed
Attitude on Seperation	spin(120rpm max)	Non-stabilized
Max Dimension on Launch	1.4mϕ ×2m(cylinder section) 1.4mϕ ×1.3m(cone section)	3.7mϕ ×2.8m(cylinder section) 3.7mϕ ×4.4m(cone section)
Target Orbit	the same as Injection Orbit	about h=500km〜600km i=30deg (TBD. Depending on Injection Orbit)
Weight	Total : 550kg mission : 150kg	Total : 800kg(TBD) mission : 200kg〜250kg(TBD)
Generalized Power(BOL)	Under 1.5kw	Over 2kw
Capacity of Communication	0.67Mbit/day use only USB	2.5Gbit/day if X-Band can be boarded

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T.Hidaka Y.Kawada A.Noda T.Fujita

On-Orbit System Laboratory
Office of R&D, NASDA

Role Of Technology Demonstration

- Adaptability Of Space-System, Space-Equipment With Acutual Space-Environment

- Reduction Of Some Risk Of Big Project

- Verification Of System Level For Whose Size Is Too large In Ground Test

Way Of Technology Demonstration In Space

- Small Satellite (dedicated) : 50kg-class
  500kg-class

- Extra Payload Of Large Satellite

- Small Launch Vehicle

- Re-Entry Capsule

- Space Station

Merit Of Small Satellite

- Long Operational Period Comparatively

- Low Cost

- Short Turn-Around-Time

- Dedicated Satellite System For Demonstration

Comparison Between 50kg-class and 500kg-class

Item	50kg-class small satellite	500kg-class small satelle
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Example of Mission	Demonstration of Advanced Technology of Parts and Component Mainly in progress	System and Subsystem of Mission Equipment Mainly OICETS OR LETS

Classification Of Technology Demonstration Mission

1. Communication
   - ·Phased Array Anntena
   - ·Optical Communication
   - ·High Density Solid Memory

2. Earth Obserbation
   - ·Interferometer
   - ·Ozone Monitor
   - ·LIDAR

Classification Of Technology Demonstration Mission (Cont')

3. Mechanism
- Robotic Arm
- Anntena Deployment Mechanism
- Inflatable Paddle

4. Bus Technology and Others
- Battery
- Small Cooler
- Monitor Of Space Environment

Outline Of Small Satellite

Payload Efficiency	: 25% ～ 30%
Volume	: 1.5m3 ～ 2.5m3
Ratio Of Volume To Weight	: 0.003m3 ～ 0.005m3
Attitude Control	: 3-axis Stabilized
Launch Vehicle	: J-1 Single H-2 Double

Major Feature Of Satellite System & Subsystem

System	3-Axis stabilized earth oriented. Box Type Central Structure	SPS& EPS	Two Extendable Solar Array(Rigid) NiMH Battery 50v non-stabilized bus-voltage
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Example Of 500kg-class Satellite Of NASDA

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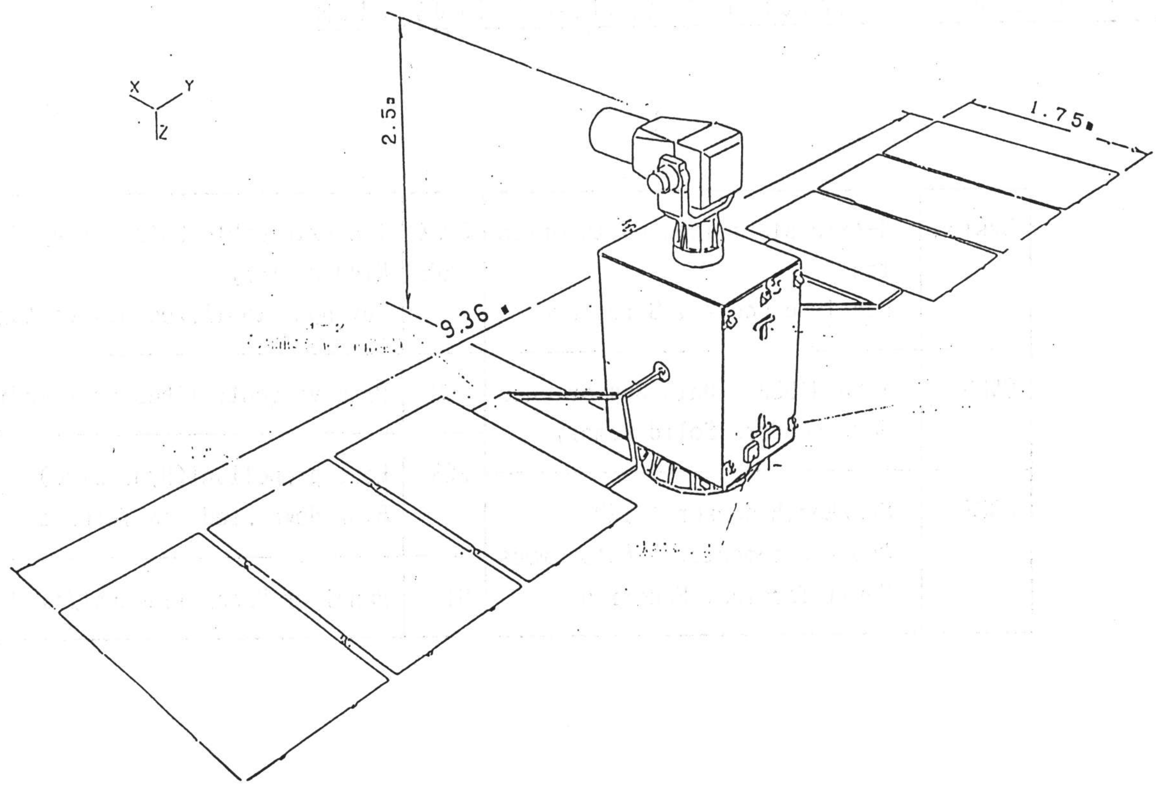
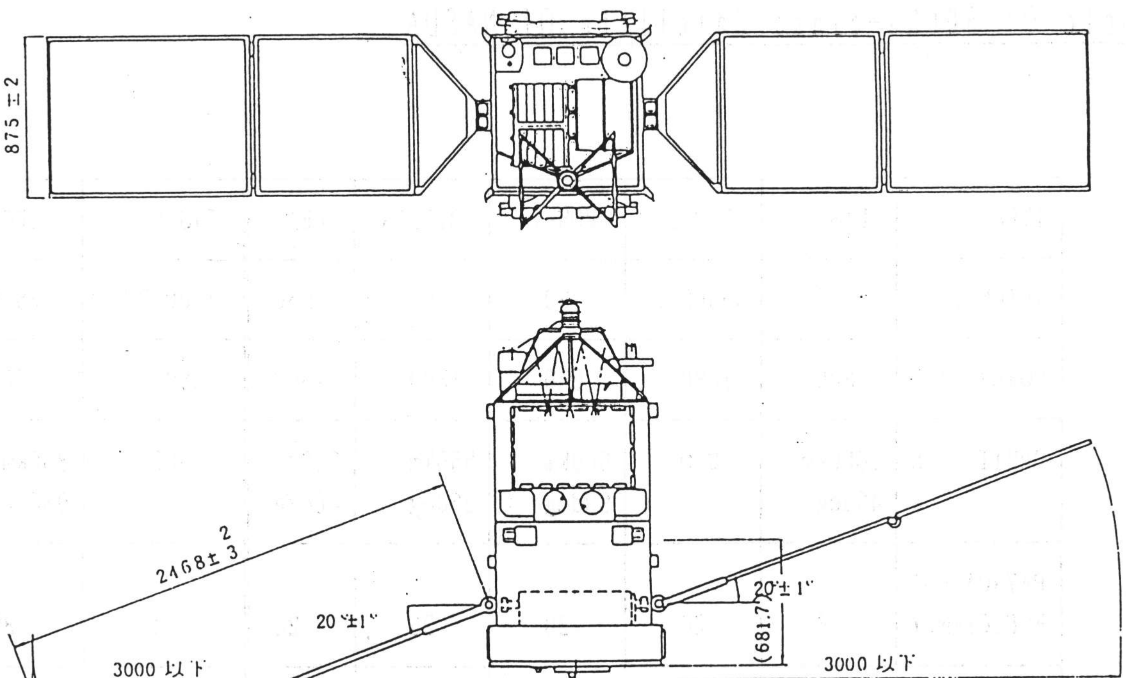
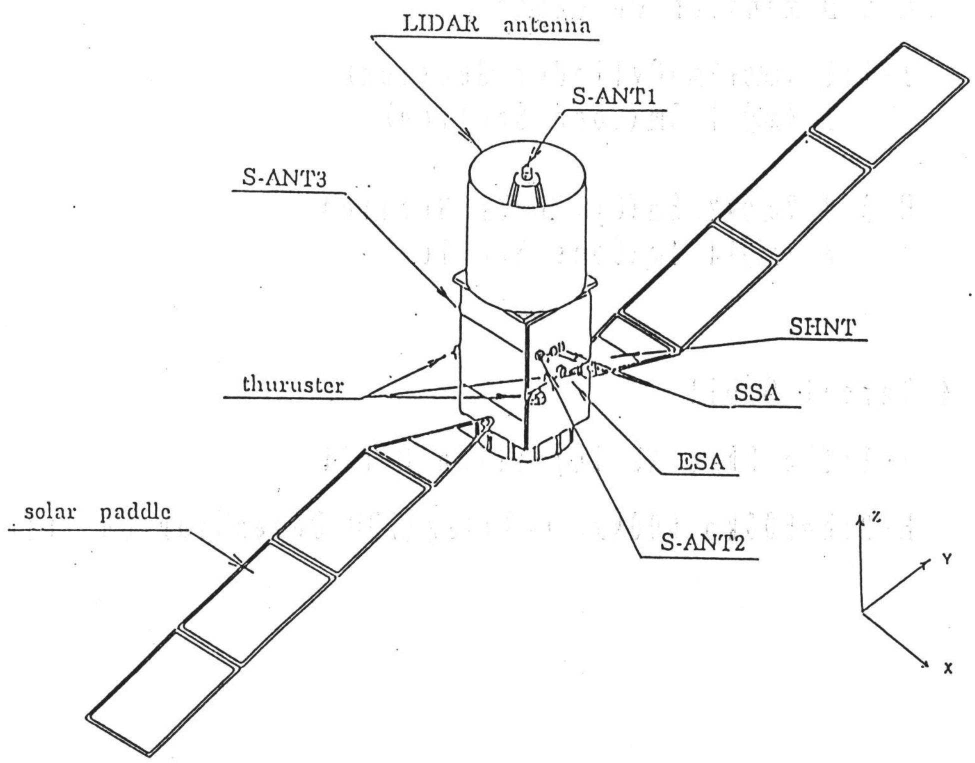
OICETS (Optical Intersatellite Communication Engineering Test Satellite)



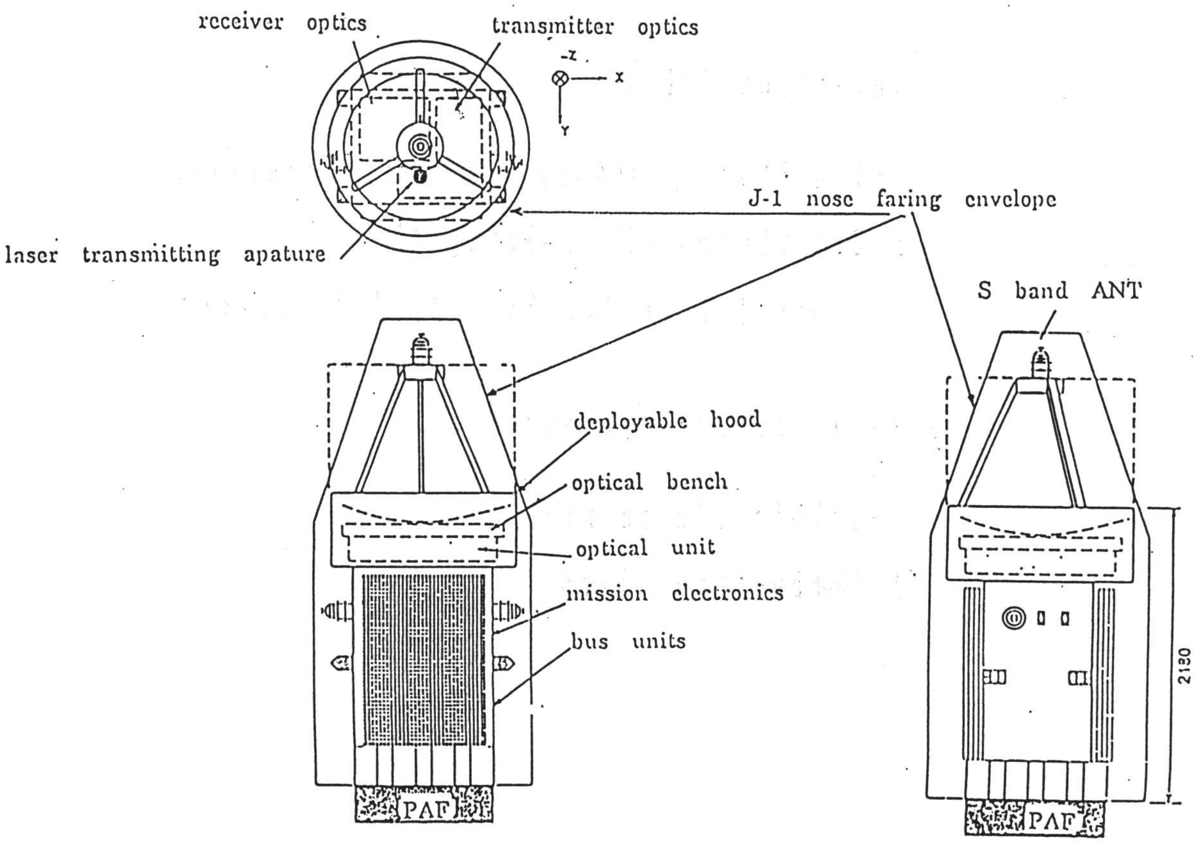
ETS-3 (Engineering Test Satellite - 3)



LETS (Lidar Engineering Test Satellite) For J-1



LETS (Lidar Engineering Test Satellite) For J-1



Result Of Pre-Phase A Study Of LETS (Cont')

3. Max Dimension On Launch

J-1: 1.4mØ*2m (Cylinder Section)
     1.4mØ*1.3m (Cone Section)

H-2: 3.7mØ*2.8m (Cylinder Section)
     3.7mØ*4.4m (Cone Section)

4. Target Orbit

J-1: The Same As Injection Orbit

H-2: h=500km 600km、i=30deg (TBD Depending On Injection Orbit)

Result Of Pre-Phase A Study Of LETS

1. Injection Orbit

J-1: h=500km、i=40deg   Direct Injection

H-2: h=300km (TBD)、i=30deg (TBD)
     Orbit Transfer By Satellite Needed

2. Attitude On Seperation

J-1: Spin (120rpm max)

H-2: Non-Stabilized

Result Of Pre-Phase A Study Of LETS(Cont')

5. Weight

J-1: Total 550kg、 Mission 150kg

H-2: Total 800kg(TBD) Mission 200kg 250kg(TBD)

6. Electric Power

J-1:Under 1.5kw

H-2:Over 2kw

7. Capacity Of Communication

J-1:0.67Mbit/day(Use Only USB)

H-2:2.5Gbit/day(If X-Band Can Be Boarded)

Purpose Of Phase A Study

- Selection Of Optimal Target Orbit For LETS
- Selection Of Bus System Under Limitting Budget
- Construction Of Bus System Fit For Demonstration Especialy Orbit Maintenance & Data Handling