Program Concept of "Project Hyper-Sat"

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Abstract. Project Hyper-Sat is the development program of the advanced technology applied to new generation satellite, especially small and high performance satellite. This program goes ahead with the development of the advanced technology in the wide area from parts level to satellite system level, and aims at the realization of new missions which fit this hyper type of satellite early in the 21th century. We have surveyed the new technology which become the objects of Project Hyper-Sat, and extracted the technology which are essential for the achievement of assumed missions. This paper presents the result of the survey of new technology, the feasibility study of dedicated mission.

Introduction

The space vehicle have enlarged. On the other hand the cost and the developing term of them have increased. The larger space vehicle is, the more extensive the damage is when it fails. Therefore big space project like big satellite development is apt to adopt developed technology not advanced technology for avoiding the risk. That makes the progress speed of space technology slow. In this situation the merit of small satellite are being recognized again. In U.S.A or Europe small satellites whose target is "cheaper, faster, better" have been developed since 1990's, and got good results. In Japan commercial technology, for example electronics, computer, materials and so on, have made remarkable progress, while the progress of space technology are falling behind. Project Hyper-Sat has started for the purpose of improving this situation of space technology and accelerating the development of it.

We define that Hyper-Sat is the development conception of the cutting-edge space technology applied to new generation satellite. Objects of Hyper-Sat are leading space technology in the world including technology derived from excellent commercial technology on the ground and unique space technology. In this project we go ahead with the development of advanced space technology in the wide area from parts level to satellite system level, and aim at the realization of new mission which fit this hyper type of satellite early in the 21th century.

We began to study Project Hyper-Sat on 1996. At first we have surveyed the advanced space technology which become objects of Hyper-Sat, and studied missions and satellite systems which suit Hyper-Sat.

Hyper-Sat Concept

The first step of Project Hyper-Sat is to study advanced space technology from various angles and make long-term scenarios for developing technology. Figure 1 shows the study flow of Project Hyper-Sat.

We set up 4 technical targets of Hyper-Sat to extract the developing technology in satellite technology survey.

-High faculty/ high performance
-High density/ high integration
-Enhanced autonomy
-Automation for design and manufacture

High faculty/ high performance makes more difficult mission realized. For example accuracy of attitude and orbit control system (AOCS), data transmitting rate, energy efficiency and so on which have effect on mission feasibility are improved in Project Hyper-Sat. High density/ high integration miniaturize satellite and increases the number of satellite launched per vehicle. We try to make satellite mass per volume and mission weight per total weight increase. Each preliminary goal of the satellite mass per volume and mission weight per total weight is less than $0.001m^3/kg$, (more than $0.003m^3/kg$ at present) and more than 80%. Enhanced autonomy decreases the rate of failure in satellite and the cost of satellite operation. We aim at the command less operation of satellite. Automation for design and manufacture decreases the term and cost of the development of satellite.

We divide missions of Hyper-Sat into 4 categories, and extract the technology required for mission feasibility.

-communication
-earth observation
-service on orbit
-deep space

These missions are main missions in the future as well as now, and have characteristic requirement. We notice the characteristic of missions in 4 categories, assume some mission from these categories, study the mission feasibility, and extract the requirement.

We make not only the survey of technology and the technical study but also the survey of needs, cost, risk and technology trend in the space development. The results support the significance of the realization of technology, satellite and mission.

We select developing technology, developing satellite, and mission which are realized in the future on the basis of results in these surveys and studies. And we make 3 scenario in consideration with the launch of satellite early in 21th century.

-Development Scenario of Space Technology
-Satellite Development Scenario
-Satellite Missions Scenario

As next step, space technology and satellite are developed in accordance with the scenarios.

Hyper-Sat Technology

We have surveyed the advanced space technology from parts, component and subsystem level to system level to achieve 4 technical targets (High faculty/ high performance, High density/ high integration, Enhanced autonomy, Automation for design and manufacture). We selected Figure of Merit (FOM) which is the parameter indicated the character like weight, size, electric power, and so on in each level. We extracted the advanced space technology whose FOM is excellent, or which is satisfied with the requirement of Hyper-Sat mission. The examples of technology extracted in subsystem and system level are as follows.

Subsystem Level Technology

Communication and Data Handling

Communication and Data Handling (C&DH) technology have developed with the advance of electric and photo device technology. The commercial technology in this field are advancing remarkably. The space C&DH technology are also expected to be developed by applying the commercial technology.

The requirements of C&DH in Hyper-Sat are
-High Density
-High Integration
-High Data Handling & Transmitting Rate
-Low Power
-High Reliability

Some examples of advanced technology for these requirements show Table 1.

Table 1. Examples of Advanced C&DH Technique for Hyper-Sat

Technical Item	Developing Technique	Figure of Merit	Requirement
Large-scale integrated Package	Multi Chip Module (MCM)	-----------------------------	High Integration/density
Large-scale integrated circuit	DRAM	memory capacity (16Gbit)	High Integration
High Speed Communication	Ka band communication	transmission speed(1Gbit)	High Transmission Rate

Data Compression	MPEG 4	compression rate	High Transmission Rate
Fault Tolerant	Intelligent Redundancy	------------------------------	High Reliability

(Value in the bracket of Figure of Merit is the goal of Hyper-Sat)

Electric Power and Solar Paddle

Samples of technology extracted for Hyper-Sat in electric power and solar paddle technology shows Table 2.

Electric power consists of battery and power control. The requirements of battery in Hyper-Sat are
-High Energy Density (Lightening)
-Long Life Cycle
-Wide Range of Accepted Temperature

Lithium Ion battery are used as commercial technology widely. Its energy density is higher than the that of space-borne battery like NiCd or NiH2.

The requirements of power control are
-High Efficiency (Low Power)
-Lightening and Miniaturization
-Integrated Control

Power control systems also have progressed like C&DH in consequence of the advance of electric devices.

The requirements of solar paddle, especially solar cell are
-High efficiency
-Lightening
-Space Environment Tolerance

In case of applying commercial solar cell of high efficiency to satellite, it must be confirmed that the cell is proof against space environment like radiation.

Table 2. Examples of Advanced Electric Power and Solar Paddle Technique for Hyper-Sat

Technical Item	Developing Technique	Figure of Merit	Requirement
High density battery	Lithium Ion Battery	energy density(150wh/kg)	High Energy Density
Power Control	Soft Switching	------------------------------	High Efficiency
High Efficiency Cell	Multi Junction Cell	conversion rate(27%)	High Efficiency

(Value in the bracket of Figure of Merit is the goal of Hyper-Sat)

Attitude and Orbit Control System

The requirements of Attitude and Orbit Control System (AOCS) in Hyper-Sat are
-Lightening and Miniaturization
-Low Power
-High Accuracy
-Autonomy of decision and control
-High Reliability

AOCS have main 3 components, sensor, calculation, and actuator. In component level the performance of sensor or actuator is improved to satisfy the requirement, and calculator is integrated in Integrated Control Unit (ICU). In subsystem level AOCS is integrated simply by reducing the number of components in order to decrease the weight and improve the reliability. Table 3. shows examples of advanced AOCS technology for Hyper-Sat.

Table 3. Examples of Advanced AOCS Technique for Hyper-Sat

Technical Item	Developing Technique	Figure of Merit	Requirement
Simple AOCS	1 board GPSR	weight (-1kg)	Lightening
Micro Sensor	Micro Gyro	weight (20g)	Lightening
High Accurate Sensor	Star Sensor	accuracy of attitude decision	High Accuracy

(Value in the bracket of Figure of Merit is the goal of Hyper-Sat)

Propulsion

The requirements of propulsion technology in Hyper-Sat are
-Lightening and miniaturization
-High performance (High specific impulse)
-High Reliability (Long Life)

Propulsion is the original technology for spacecraft, and has been developed by applying military technology rather than commercial technology. Table 4 shows examples of advanced propulsion technology for Hyper-Sat. Recently 5N class micro thruster whose weight is about 5g has been developed (1), and the miniaturization of thruster has been progressed.

Table 4. Examples of Advanced Propulsion Technique for Hyper-Sat

Technical Item	Developing Technique	Figure of Merit	Requirement
Micro Thruster	Micro Cold Gas Thruster	weight(10g per 5mN thrust)	Lightening
Micro Thruster	Micro Bipropellant Thruster	weight(100g per 200N thrust)	Lightening
Micro Thruster	Chip Size Thruster	weight(-1g per 1mN thrust)	Lightening

(Value in the bracket of Figure of Merit is the goal of Hyper-Sat)

Structure and Thermal Control

The requirements of structure technology including mechanism in Hyper-Sat are
-Lightening
-High reliability in mechanism
-Integration with structure of other subsystem

The rate of structure in total satellite weight is more than 5%. The goal of the rate in Hyper-Sat is less than 2.5%. Integration with structure of other subsystem is needed in order to achieve the goal. Mechanical Technology like deployment mechanism are critical for satellite, and need high reliability. Inflatable Structure (2) is one of the candidates of technology satisfied with such requirements.

The requirements of thermal control technology in Hyper-Sat are
-Lightening
-High Performance (High capacity for rejecting heat)

As high density is one of the target in Hyper-Sat and decreases surface area of satellite, the improvement of capacity for rejecting heat per unit area is required. High performance heat transfer technology must be developed. Table 5 shows examples of advanced structure and thermal control technology for Hyper-Sat.

Table 5. Examples of Advanced Structure and Thermal Control Technique for Hyper-Sat

Technical Item	Developing Technique	Figure of Merit	Requirement
Light Structure	Integration of Structure	rate of structure (-2.5%)	Lightening
Light Deployment Mechanism	Inflatable Structure	weight	Lightening
Light Thermal Control	Light Thermal Louver	weight	Lightening

(Value in the bracket of Figure of Merit is the goal of Hyper-Sat)

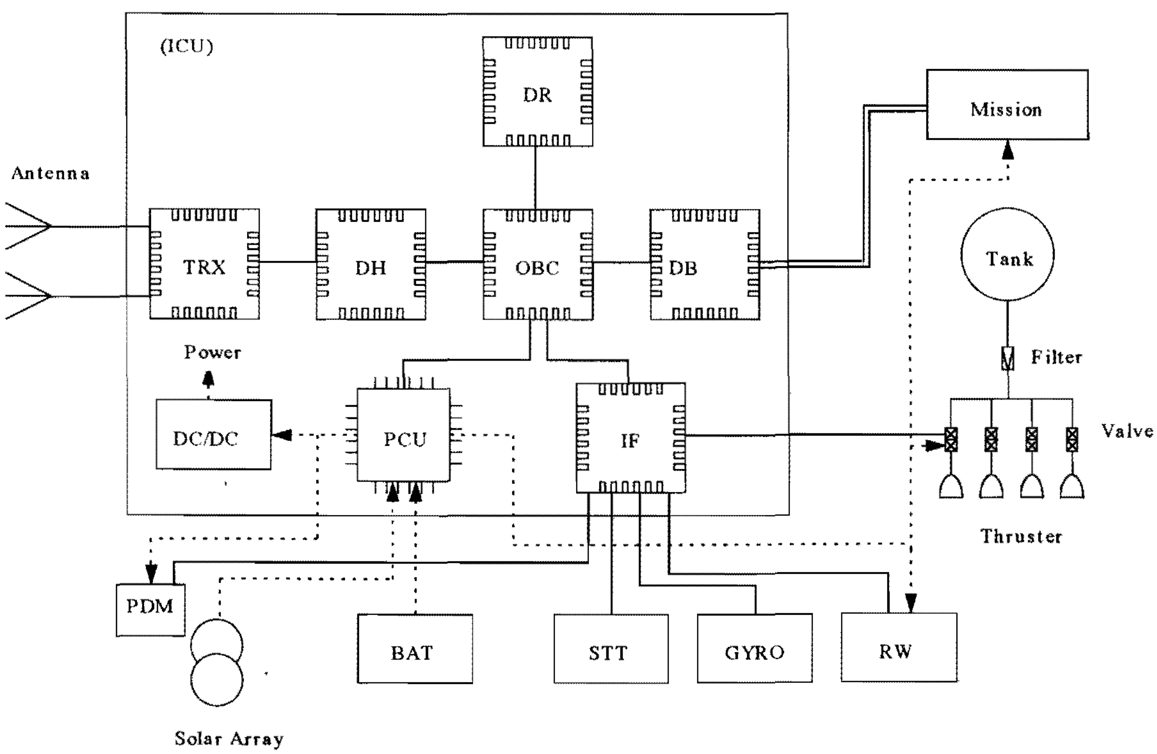
System Level Technology

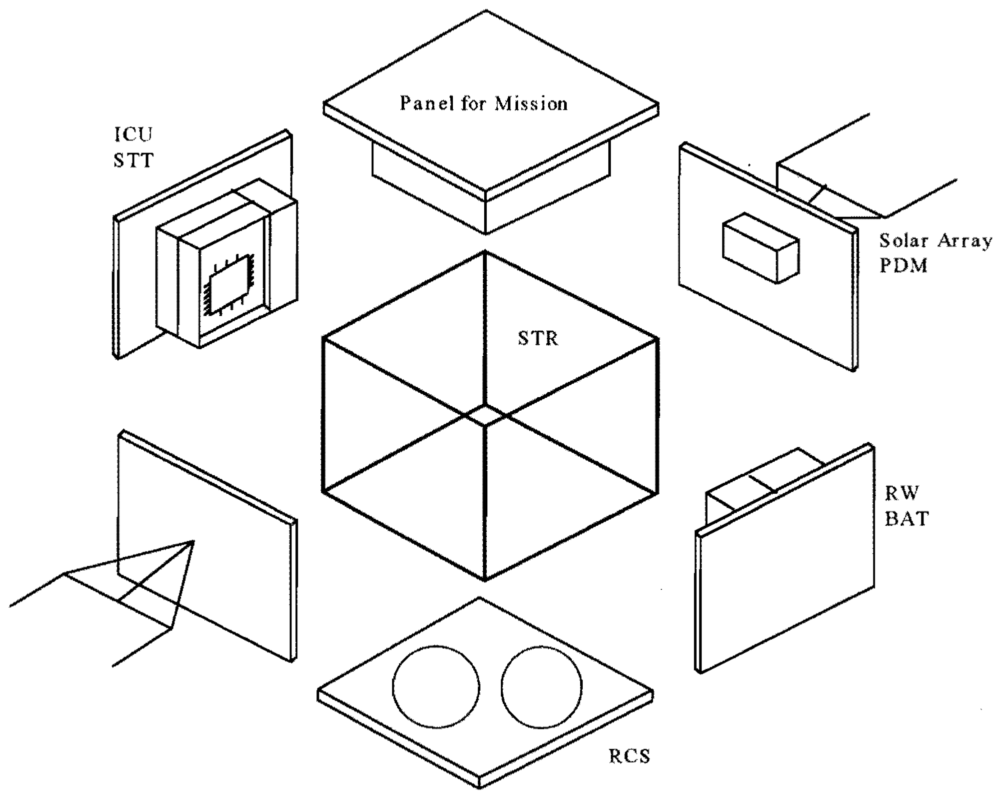
Integrated Technology

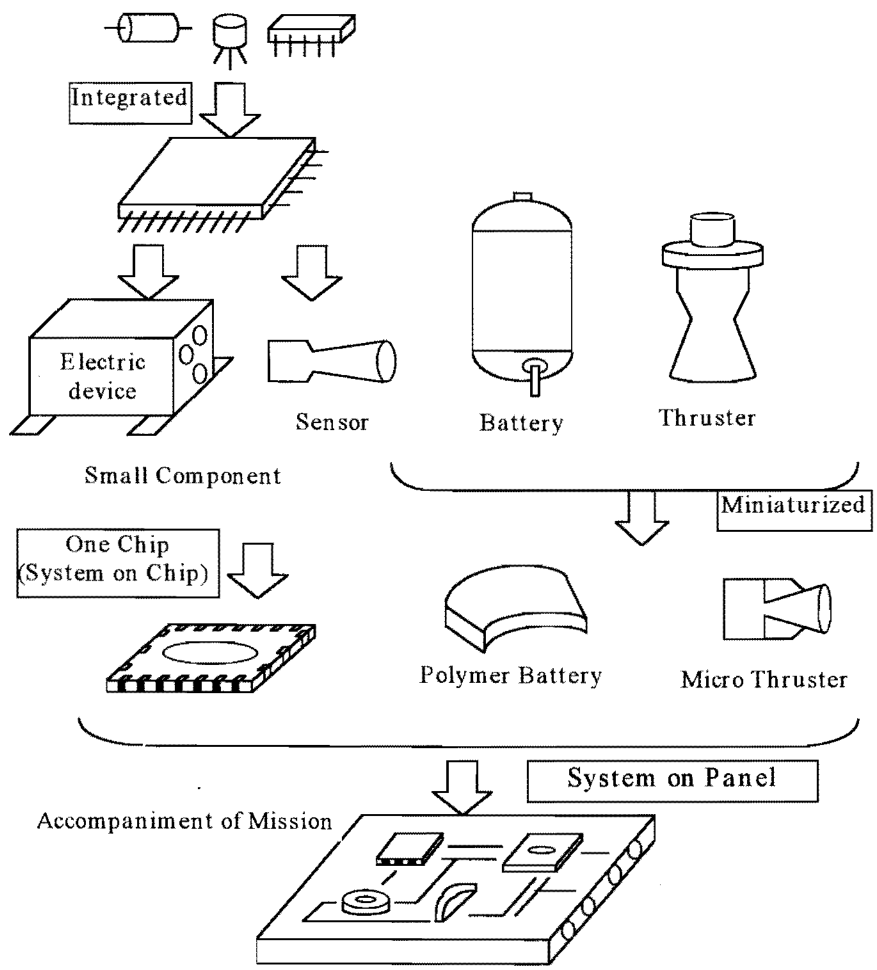
Integrated technology is needed in order to promote lightening and miniaturization of satellite. As to electrical integration, distributed control components of each subsystem are made to integrated into one component as Integrated Control Unit (ICU). Figure 2. shows example of the system block diagram as an example of integrated system. In the design for the integration of structure, each subsystem itself supports the load of satellite to decrease the weight of structure. Figure 3. shows example of the integration of structure. Each subsystem is embedded in structure panel and itself support the load of satellite.

System on Panel

The ultimate goal of high integration/ high density is system on panel which is to make all subsystem miniaturized to chip size and nest bus system in one panel. And the modularized bus panel can be the accompaniment of mission. Figure 4. shows the image of system on panel. The realization of system on panel can decrease the rate of bus weight in total weight remarkably and relax the limitation of mission from bus. But as matter of fact some component like propellant tank and solar array is difficult to be miniaturize by chip size. We must study the compact integration of mission, bus panel, and component which can't be nested in bus panel.




Panel for Mission
ICU
STT
Solar Array
PDM
STR
RW
BAT
RCS


Integrated
Electric device
Sensor
Battery
Thruster
Small Component
Miniaturized
One Chip (System on Chip)
Polymer Battery
Micro Thruster
System on Panel
Accompaniment of Mission

Hyper-Sat Mission Study

We have studied the feasibility of satellite system in 4 mission categories of Hyper Sat (communication, earth observation, service on orbit, deep space). The missions we assumed are difficult to be realized in the present space technology. We have made the study of feasibility of each mission and the extract of necessary technology to realized the mission. This paper shows the result of the study of 50kg class satellite on low earth orbit and nano sat for monitoring mother satellite (Eye-Ball).

50kg class satellite on low earth orbit

We have studied the system of 50kg class satellite on low earth orbit which is assumed to be used in the mission of communication or earth observation. Table 6 shows assumed system requirement. The approach of the system study is to miniaturize 500kg class satellite in the present space technology to 50kg class satellite by applying Hyper-Sat technology. Table 7 shows weight and power distribution of 50kg class satellite in comparison with 500kg class satellite which NASDA has been developing. Consequently the payload efficiency (mission weight/ total weight) is 76% though the first goal is 80%.

50kg class satellite is feasible by applying the advanced commercial technology. But some technical problems must be solved. The problems are

-miniature of ICU to chip size

-light reaction wheel or development of actuator instead of wheel

-further high efficiency of power control, battery, and solar cell

-integration of structure in each component like power control, battery, solar array, propellant tank, thermal control device and so on.

Table 6. Assumed System Requirement

system or subsystem	required parameter	mission requirement
satellite system	size : 0.4m x 0.4m x 0.4m weight : 50kg power : 100w	altitude : 500km circular orbit inclination : 45deg
communication & data handling	data transmitting rate to earth: 1kbps-(telemetry/command) 15Mbps-(mission data) data storage : 10Gbit	mission data rate : 100kbps
AOCS	attitude control accuracy : -0.1deg attitude determination accuracy : $-2x10^{-4}$deg attitude stabilization : $-2x10^{-4}$deg/sec	
battery & solar array	power storage : 150wh- generating power : 250w-	
thermal control	necessary radiation capacity : 120w- necessary area for radiation : 0.32m^2	
propulsion	thrust : 1N ISP : 200sec	

Table 7. Weight and Power Distribution of 50kg Class Satellite

subsystem	50kg class satellite		500kg class satellite*		developing technology for 50kg class satellite
	weight(kg)	power(W)	weight(kg)	power(W)	
communication	0.7	-----------	17.4	23.0	Light Antenna
ICU(data handling)**	2.8	21.0	16.7	23.0	MCM,MMCM,HIC
AOCS	2.1	8.7	64.3	79.6	Micro Gyro, Micro RW,CCD Sensor
battery & solar array	2.8	-----------	90.5	49.0	Li Ion Battery, Inflatable Paddle, High Efficient Solar Sell
propulsion	1.0	-----------	17.1	-----------	Micro Thruster
thermal control	0.5	10.0	13.1	23.6	
structure	1.3	-----------	65.0	-----------	Integration of Structure
harness	0.3	-----------	35.0	26.5	
bus total	11.5	39.7	319.1	224.7	
propellant	2.0	-----------	16	-----------	
mission	36.5	60.0	140	262.0	
satellite total	50	99.7	500.1	488.7	

(*) refer to the result of conceptual study of "Optical Inter-orbit Communication Engineering Test Satellite (OICETS)"

(**) In case of 500kg class satellite the value is the weight and power for only data handling.

Nano Sat for Monitoring Mother Satellite

We have made the study of nano sat (-10kg class satellite) as mission of service on orbit. Nano sat for monitoring mother satellite separates from mother satellite and monitors a trouble point in mother satellite when accident happens. We call this nano sat Eye-Ball. The technical requirement of Eye-Ball is to make the satellite as small and light as passable in order to attach it to mother satellite. Therefore the system of Eye-Ball is made to be very simple and not to have excessive function like solar array, wheel and so on.

The mission requirements of Eye-Ball are as follows.

weight : -4kg
size : diameter 20cm globular shape
life time: 1-2days

As a result of the system study, Table 7.1 shows weight and power distribution of Eye-Ball. We have compared the requirement of subsystem level with Hyper-Sat technology we surveyed, and know most requirements are satisfied with the technology we surveyed, especially advanced commercial technology. But one of the problems in the feasibility of Eye-Ball is to develop the micro thruster which fit Eye-Ball.

Table 7.1 Weight and Power Distribution of Eye-Ball

subsystem	weight(g)	power(w)	developing technique
mission sensor	150	1.0	micro image sensor
AOCS(sensor)	50	0.2	micro gyro, micro accelermeter
propuslsion	300	2.5	1mN class microthruster
data handling	300	3.0	ICU, MCM
communication	300	2.5	MMIC
battery	900	1.8	Li/$SOCl_2$ battery
structure	800	----------------	CFRP, integration of structure
propellant	1200	----------------	
total	4000	11.0	

Conclusion

In Project Hyper-Sat we have surveyed the advanced technology which can be applied to space technology in the future, and studied the satellite system of assumed missions which is difficult to be realized in the present space technology. Consequently the prospects for realization of the advanced satellite like 50kg class satellite on low earth orbit, Eye-Ball and so on are bright. The candidate for developing technology were extracted from the result of the survey and the study. We make extracted technology useful in making the developing scenario.

The goal of the present year in Project Hyper-Sat is to make 3 scenarios, Development Scenario of Space Technology, Satellite Development Scenario, and Satellite Missions Scenario. We not only survey the advanced space technology and study the satellite system, but also analyze satellite cost, value the risk of satellite, and survey the future needs of satellite and the advanced technology trend for the purpose of making scenarios. We also study the interface technology of rocket and tracking to cope with simultaneous launch of many miniaturized satellites.

We aim at the launch of the satellite in Project Hyper-Sat in early 21th century on basis of the scenarios.

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Biography

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