Feasibility Study of Nanosatellite based on Commercial Technology

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ABSTRACT

We have begun the feasibility study to build a small satellite in the 3 kg mass range (nanosatellite), funded by NASDA. This scale is challenging target for the nanosatellite development. In this study, we plan to build several key technologies such as small reaction wheel, small electric propulsion, docking mechanism, electrical recharging device and software for three axis attitude control by using image processing. Future space experiment is also proposed.

1. INTRODUCTION

Recently, small satellites of between 50 to 100 kg mass range have been developed and planned for launch by several universities. International projects for smaller satellites organized by graduate students are also begun recently. Potential users of smaller and drastically less cost satellites become to increase in the world.

We have begun to study the feasibility to build a small satellite (so called nanosatellite) in the 3 kg mass range and in the power range less than 30W. This work was initiated as a research program of mission demonstration satellite MDS since October in 1998. Eight proposals were selected and funded by National Space Development Agency of Japan (NASDA). Our research group consists of two universities (Hokkaido Institute of Technology and University of Tokyo), a venture company (Astro Research Company) and an agency (NASDA).

As a background of our study, several movements and activities in space program are there. As everybody knows, recent movements in space activities encourage commercial space use, changing from a few big geostationary satellites to constellation of small satellites as communication infrastructure in space. And venture companies have begun to develop small satellites increasingly. Smaller satellites such as microsatellites and nanosatellites have been developed by universities. Some of them are organized as

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international projects. USSS, University Space Systems Symposium is an example of such university reading projects. Microsatellites and nanosatellites are drastically cheaper than conventional satellites and their development period is usually drastically shorter than conventional ones. Demonstrated technologies of these micro/nano satellites are limited at present, but potential users of these small satellites will go on increasing in the world. Nanosatellites will not only provide us low cost, order-made applications in space activities but also enlighten people on space development in the next century. Our philosophy of development of nanosatellite is to
(a) select and equip minimum necessary functions,
(b) apply commercial component for assembling the nanosatellite.

We select the following functions as key technologies as the first step space experiment according to our philosophy. The objectives of our study are to develop
(1) small reaction wheel,
(2) small electric propulsion,
(3) attitude control software zero momentum stabilization by image processing,
(4) rendezvous docking mechanism for the nanosatellite,
(5) optical navigation in the night,
(6) recharging device.

2. DEVELOPMENT STATUS OF NANO-SATELLITE

This scale of the satellite is a challenging target for nanosatellite development. In this program we propose a space experiment for next generation using a nanosatellite which installs an onboard camera and actuators and develop several actuators as key technologies to realize nanosatellite technology in space. As the first step, we are preparing for demonstrating a motheship daughtership technology.

Daughtership

A daughtership is a radio controlled nano-satellite by a mothership's computer. It is less than 4 kg in weight and 12 watts in power consumption at present design. The daughtership equips a CCD camera, an onboard computer, seven gas jet thrusters, three reaction wheels for zero momentum stabilization, batteries and several sensors. A block diagram in terms of the electrical connection is represented in Fig.1. The daughtership is a radio controlled nano-satellite by a mothership's computer. All commands are sent by a wireless modem from the mothership to the daughtership. The onboard computer connected with the modem by RS-232C or RS-422 serial port translates the command from the mothership and controls each onboard device. The CCD camera captures the mothership and its video image is transmitted to the mothership's smart computer. The smart computer evaluates the relative position between the mothership to the daughtership by image processing and controls the daughtership's attitude and kinetics. Figure 2 shows the present design of the daughtership. Figure 3 is showing the three dimensional arrangement of installed components.

Mothership

A mothership comprises docking ports of daughterships, CCD cameras which observe space experiment and so on. A computer installed in the mothership controls every daughtership kinetics , navigation for rendezvous docking and all sequences of space experiments. The number of loaded daughterships is flexible depending on budget and launch condition. Figure 4 shows the conceptual image for three daughtership experiments.

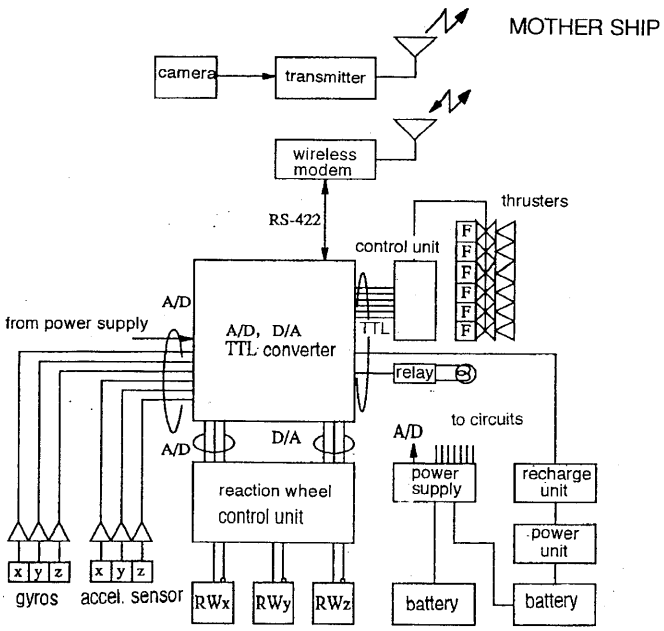

Fig.1 Block diagram of nanosatellite

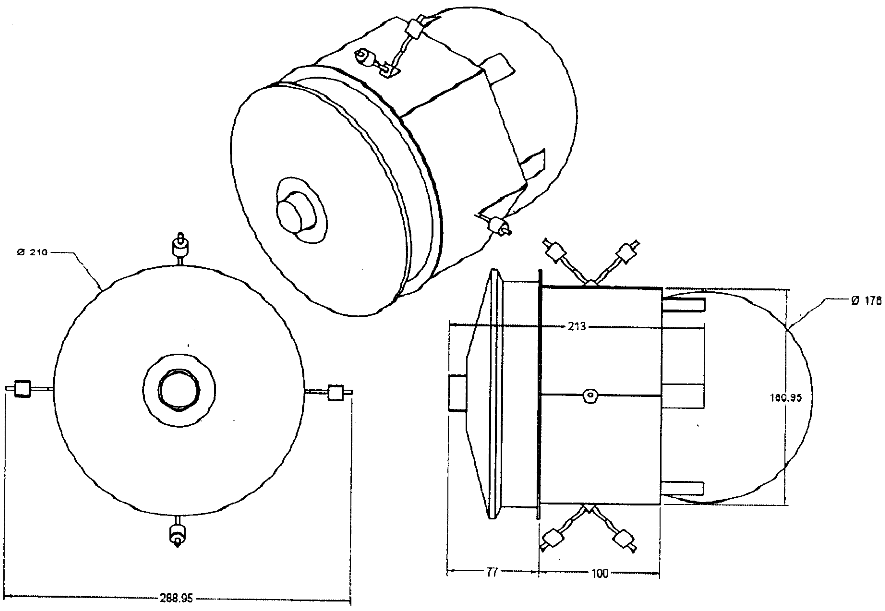

Fig.2 Daughtership (Nasosatellite)

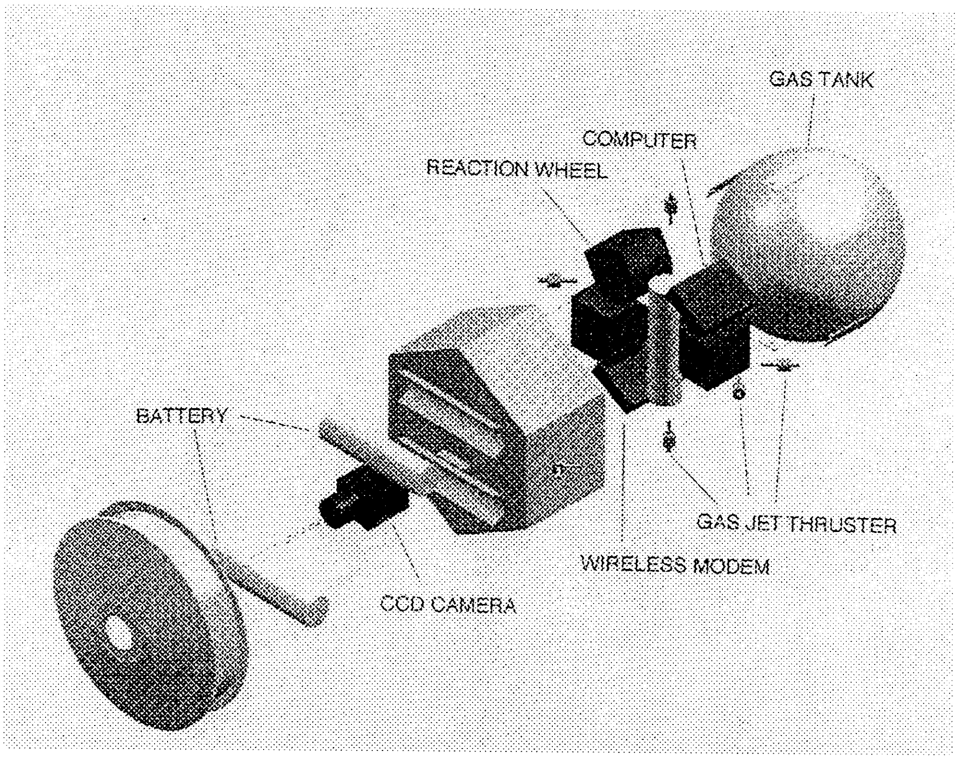

Fig.3 Component arrangement of daughtership

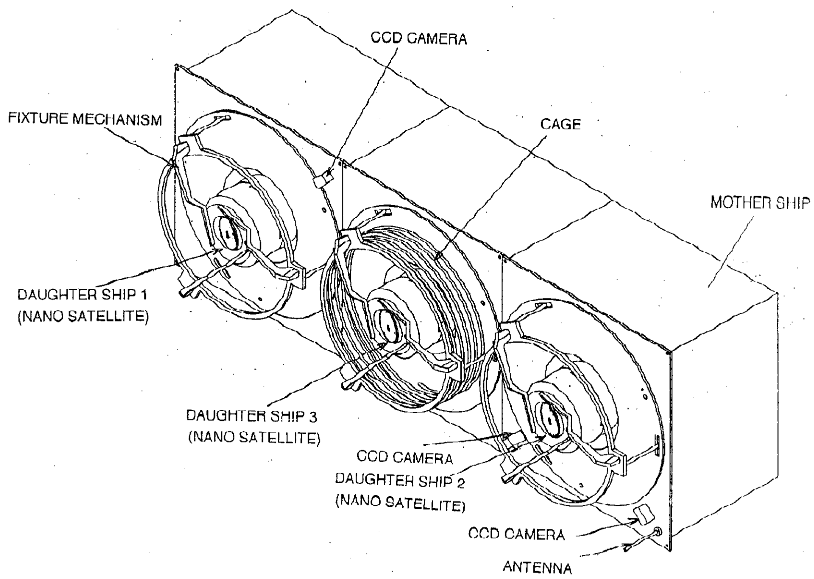

Fig.4 Image of mothership-daughtership experiment in space

Small reaction wheel

Small reaction wheel has been developing in Hokkaido Institute of Technology (HIT). The specification of our target is as follows. The reaction wheel is from 130 to 150 grams in mass range and 2 watts in maximum power consumption. The maximum torque is 30 g cm (3mNm) and the maximum storable angular momentum is 0.015 Nms. Figure 5 represents a photograph of the laboratory model of the reaction wheel.

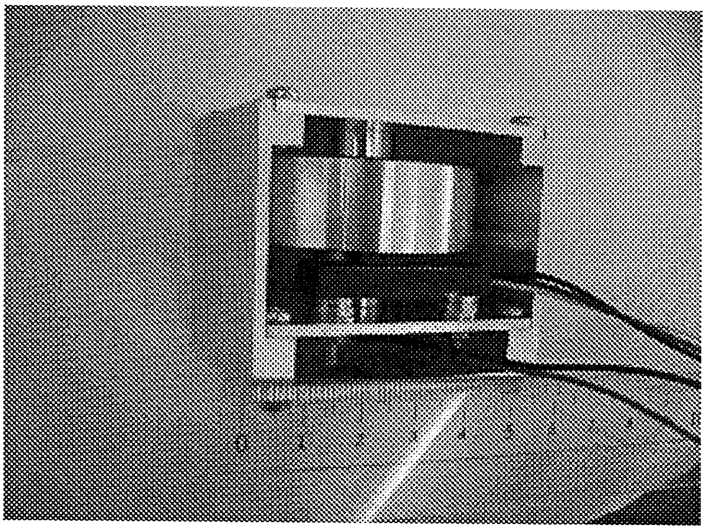

Fig.5 Laboratory model of small reaction wheel

Rendezvous docking mechanism

The mothership installs a docking mechanism required for both ejection and retrieval of the daughtership. At ejection sequence two fixtures release the body of the daughtership, separated by thrusting a cold gas jet installed on the daughtership. At the rendezvous docking sequence the daughtership is navigated by image processing toward the center of the docking port and then captured by two fixtures as shown in Fig.6. First mechanical test and the functional demonstration under the microgravity condition is scheduled at the end of October in 1999.

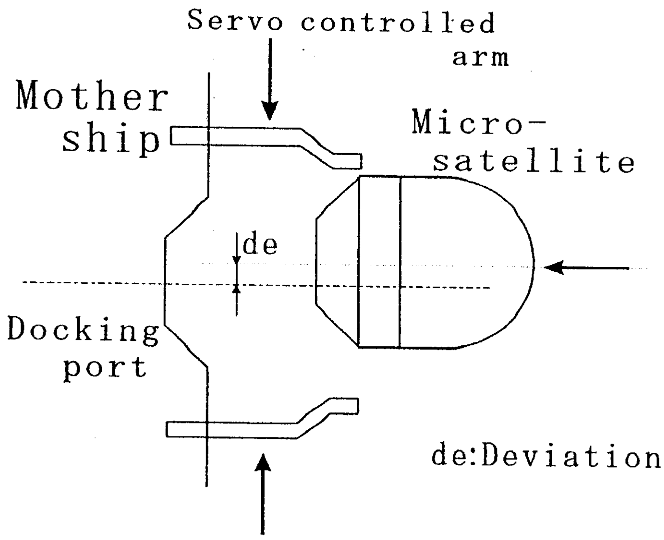

Fig.6 Docking mechanism

Electrical recharging device

An electrical recharging device extends the service life of the nano-satellite, since the daughtership has a limited volume and storable energy is very small. The daughership equips electrodes for electrical recharging attached on the body. The electric current is supplied through the docking equipment when it is stored in the mothership.

3. FUTURE MISSION PLAN AND OUR DREAM

As mentioned these small satellites are so cheep in cost and short in period for development that nanosatellites will spread out space activities for every people. As the first step of the experiment in order to establish future mission design and satellite architecture for next generation technology, we propose the following space experiments:
(1) mothership - daughtership technology experiment,
(2) demonstration of maneuver technology whose attitude information is evaluated by image processing using the onboard camera,
(3) demonstration of optical navigation at night time by using a strobe light,
(4) demonstration of the formation flying between the mothership and the daughtership.

At next step of the space experiment, the nanosatellite will load payload and realize a micro space laboratory that will widely spread out the its potential usefulness opened for every researcher. The micro space laboratory will also enable an international collaboration for Asian countries. Figure 7 shows our dream of utilization of nanosatellites. In near future nanosatellites will controlled from laboratory or private room using mobile telephone as if it is connected to the internet.

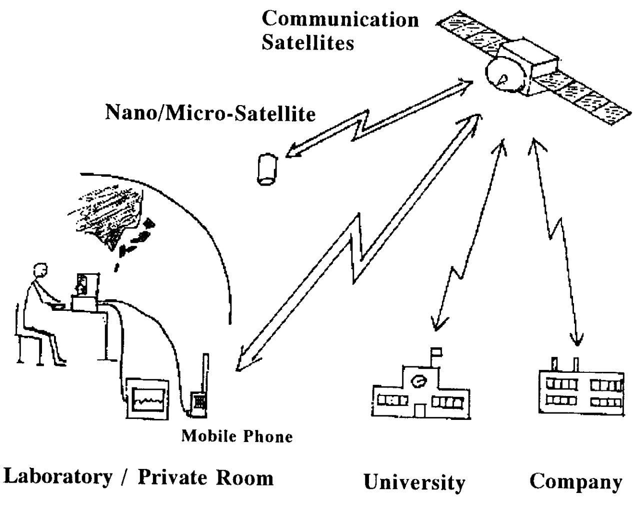

Fig.7 Future utilization of nano/micro-satellites

5. SUMMARY

We have begun the program for developing the nanosatellite which is less than 4 kg in mass range and 12 watts in power level. At the first of space experiment the nanosatellite installs a CCD camera, an onboard computer, seven gas jet thrusters, three reaction wheels, batteries and several sensors. The conceptual design has been almost fixed and some of its breakthrough technology such as a small reaction wheel are begun to build. Our first step technologies will be accomplished within two years and we are waiting for a launch change as fast as possible.