SPACE DEBRIS RELATED ACTIVITIES IN NASDA

Akira Takano
Kichiro Imagawa

Office of Research and Development, NASDA,
2-1-1, Sengen, Tsukuba, 305, Japan.

ABSTRACT

Toward the establishment of international control of debris environment of the outer space and the realization of safe space activities, effort has been conducted in NASDA primarily in the field of mitigation and space station protective bumper development. Other debris related works have been conducted in the field of measurement and data base management including the conceptual study of observation of debris in the GEO ring. This paper summarizes the current activities of NASDA and the continuing effort for the future space safety.

1. INTRODUCTION

In 1995, an inter-department debris working group was created in NASDA to promote debris related works in each corresponding department. The debris mitigation practice has been implemented in the H-I and H-II projects. Reflecting these experiences, a debris mitigation standard was set up in 1996 and the rule has been effected in various projects such as H-IIA, ALOS, and DRTS. The development of bumper for the Japanese experiment module (JEM) of the International Space Station is in the flight model development phase. Preliminary studies have also been conducted on the possible ground observation system and on-board optical observation system.

2. ENVIRONMENT MONITORING AND CHARACTERIZATION

Attention has been centered for the need of dedicated space monitoring system to facilitate improved object reentry estimation as well as gathering upgraded object distribution data.

2.1 Ground Observation Study

As a part basic feasibility study, trial observation of low earth orbit satellites using the MU radar of Kyoto University has been carried out in coordinated use of NASDA tracking and control system. The study has been performed as a joint work of National Astronomical Observatory (NAO), Kyoto University and NASDA (Ref.1,2). An useful data has been obtained to verify the detection and tracking capability of utilizing active phased array radar for the orbital determination of space objects on low earth orbit.

2.2 On-Orbit Observation System

There has been a misunderstanding that the satellite and debris environment in the GEO (Geostationary orbit) region is not so serious compared with the low earth orbit (LEO). But the spatial density of objects in the GEO domain is already increased to about 2 orders of magnitude lower than LEO (10^{-10}/km^3) and the 20% of the object data is reported to be missing. In May and June of 1996, there happened two anomalies of abrupt change of attitude and decrease of solar panel power of geostationary broadcasting satellites BS-3s which is attributed to the impact of micrometeoroid or debris (to be presented in March 1997, Ref.3). In this respect there has been a need for the improved surveillance of objects in the GEO region as proposed in the IADC meeting. In NASDA a consistent study has been carried out on the on-orbit debris observation system

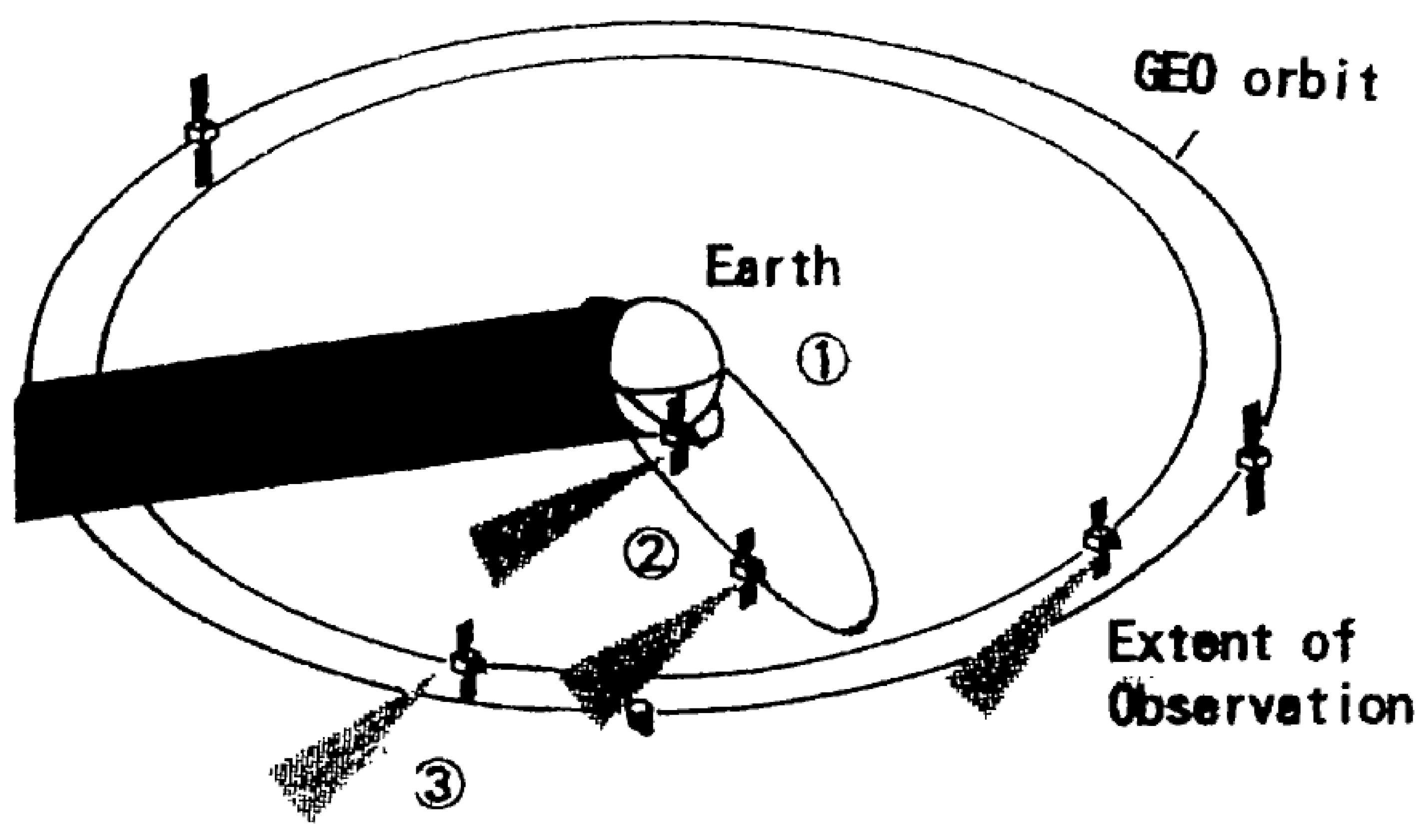

Fig. 1 Candidate Debris Observation Satellite Orbit (Orbit 3 for observation from near GEO orbit)

Proceedings of the Second European Conference on Space Debris, ESOC, Darmstadt, Germany, 17-19 March 1997, (ESA SP-393, May 1997)

for the GEO ring (Ref.4). Fig.1 shows the concept of GEO debris observation from the inner near GEO orbit(Orbit 3). The work is technically supported by the Japan Society for Aeronautical and Space Sciences (JSASS) and is expected to become an international cooperative project.

2.3 Dust Collection Facility

For the orbital altitude of Space Shuttle and Space Station, the high velocity impact of micro meteoroid and debris dust which causes surface material deterioration is of concern. For gathering improved dust environment data, an intact capture device of dust particle (Cosmic Dust Collector :CDC) is to be flown as a part of MFD(Manipulator Flight Demonstration) payload aboard the Space Shuttle in 1997(Fig.2,3,4). The collector unit has been developed using silica aerogel manufactured by KEK (National Laboratory for High Energy Physics) of Japan(Ref.5). The front area of the aerogel unit is 100mm x 100mm and the slab thickness is 20mm. In each of the two CDC units, 4 slabs of aerogels are stacked for collecting dust. The density of the aerogel is 0.03g/cm ^{3} . For the development of the dust collector unit, ground testing using light gas gun(1−5 km/s), electro-thermal gun(1−2 km/s), and plasma gun (3−14km/s) have been conducted to verify dust capturing capability. Another silica aerogel dust collector unit developed by NASA LaRC will also be installed alongside the NASDA units for comparison. The collected dust will be inspected in the post flight analysis.

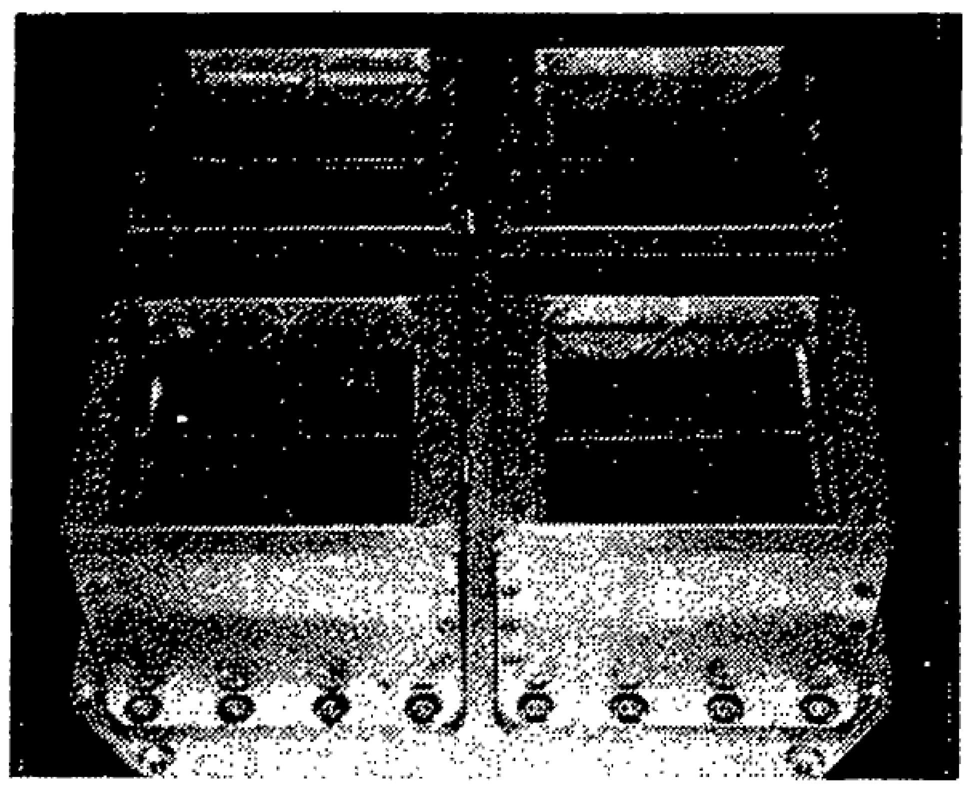

Fig. 3 Cosmic Dust Collectors(Top surface is covered with deposited gold)

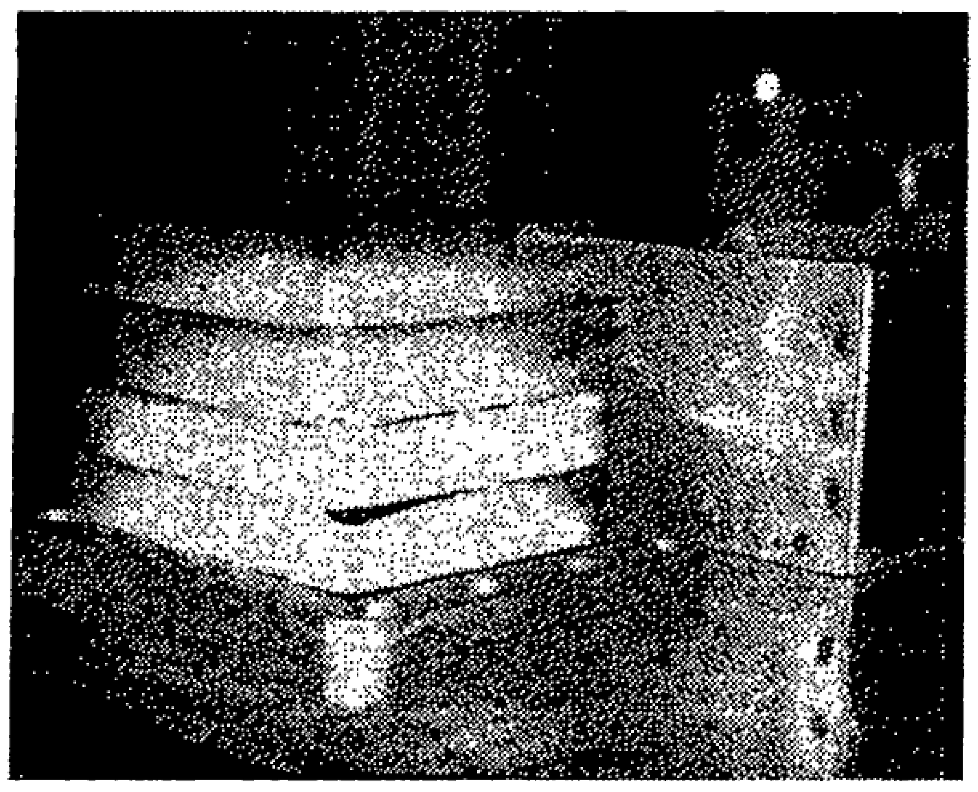

Fig. 4 The stacked layer of silica aerogels before installation into cosmic dust collector housing.

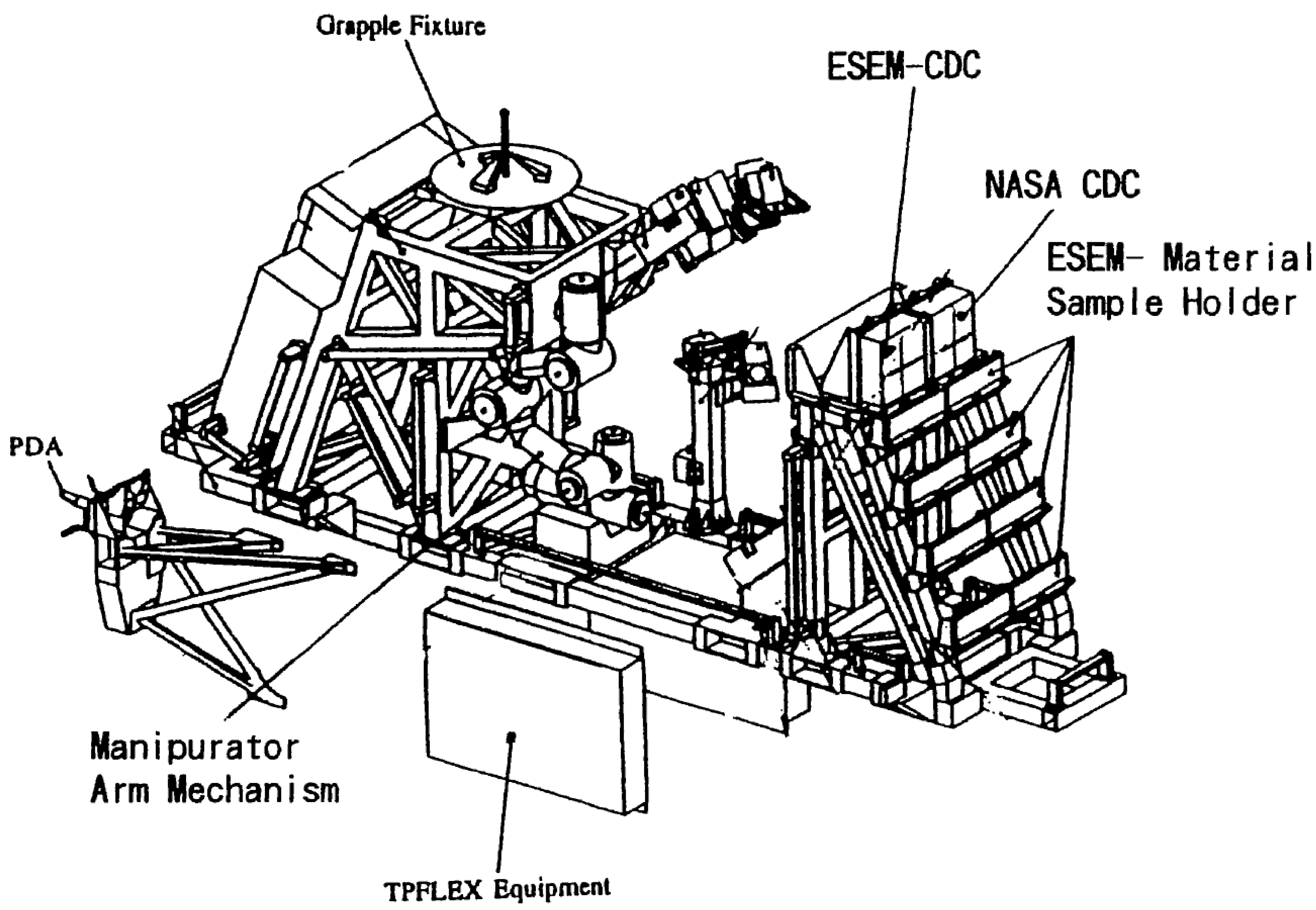

Fig. 2 General view of MFD payload and ESEM(Evaluation of Space Environment and Effects on Materials)

3. DATA BASE AND MODELLING

Catalogued objects data provided by the cooperative work of IADC(Inter-Agency Space Debris Coordination Committee) member agencies (NASA, ESA) is introduced into the NASDA Reliability Information System(RIS). A debris impact rate prediction program equivalent to ENVIRONET of NASA has been facilitated and a quick reference handbook has been issued(Ref.6). The handbook gives the introduction of general concept of analytic method employed currently and some quick look tables of estimated debris impact rate for a series of altitude, orbit inclination, and the period of orbital life and helps preliminary design of spacecrafts.

4. PROTECTIVE BUMPER DEVELOPMENT

For the protection of Japanese Experiment Module (JEM) of International Space Station, from impacting meteoroid and debris, a bumper has been developed. The initial design wall thickness of the pressurized module has been taken as 3.2mm for aluminum alloy 2219-T87. A series of hyper velocity impact testing has been conducted for several bumper models(Fig.5). The results showed the stuffed bumper configuration(Option 3) originally proposed by NASA failed to satisfy the non-penetration requirement(Ref. 6). A heavy bumper(Option 4) revealed excellent no defect performance. Reflecting these results, a final design concept of the bumper configuration and arrangement has come to an conclusion as shown in Fig.7. The pressurized wall thickness shown in the figure was later increased to 4.8mm(equivalent to the US module thickness) for the minimization of catastrophic failure probability through the commonality of structural design.

5. MITIGATION PRACTICE

Consistent space debris mitigation practice has been observed for H-I and H-II projects. These include the securing of separation device hardwares, prevention of propellant tank fragmentation of spent upper stages by venting residual liquids and gas, prevention of spontaneous actuation of pyrotechnic devices by automatic unabling in the post mission procedures. A special effort has been made to minimize the orbital life of the spent upper stages for the prevention of environment deterioration.

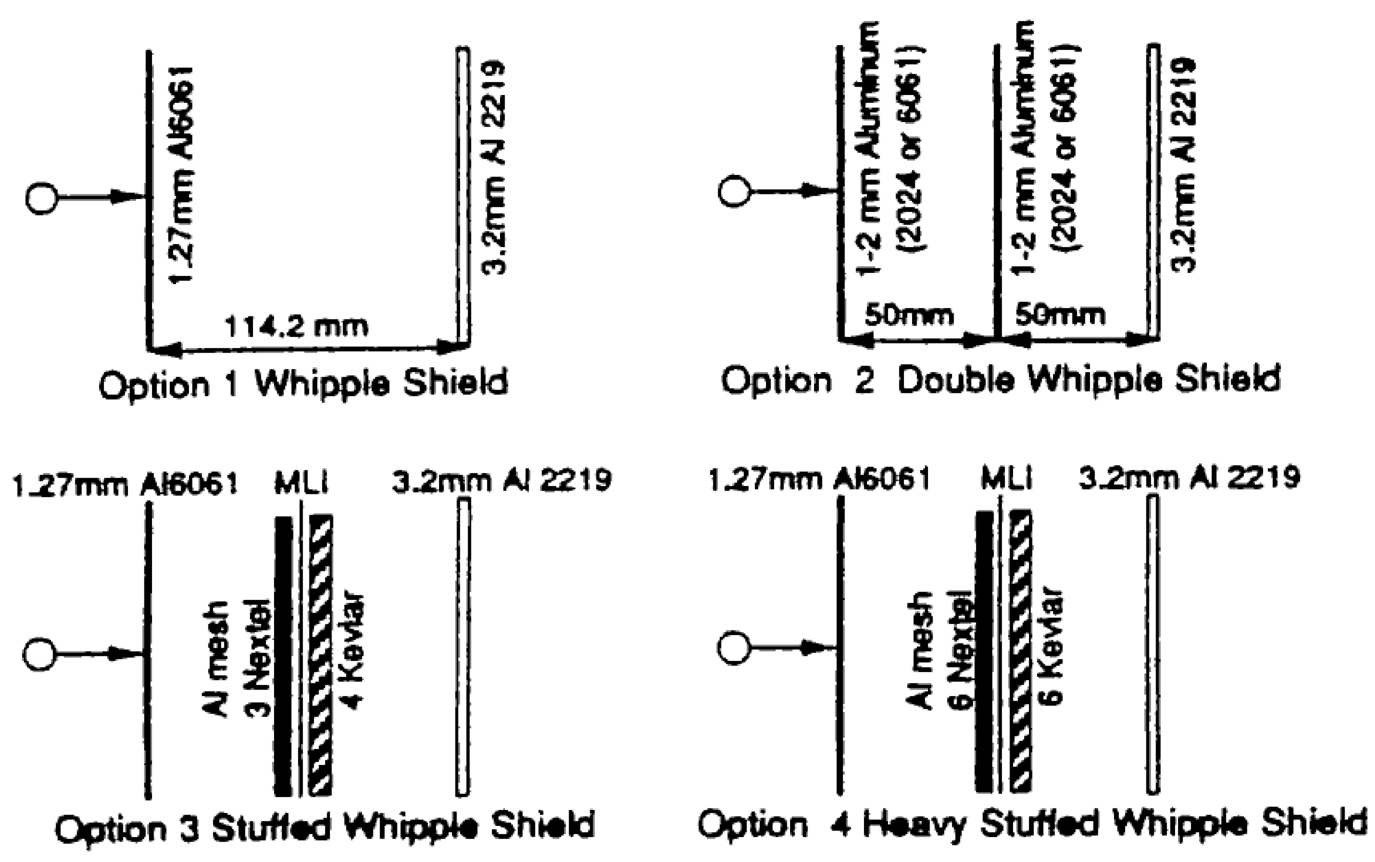

Fig. 5 JEM bumper shield concept.

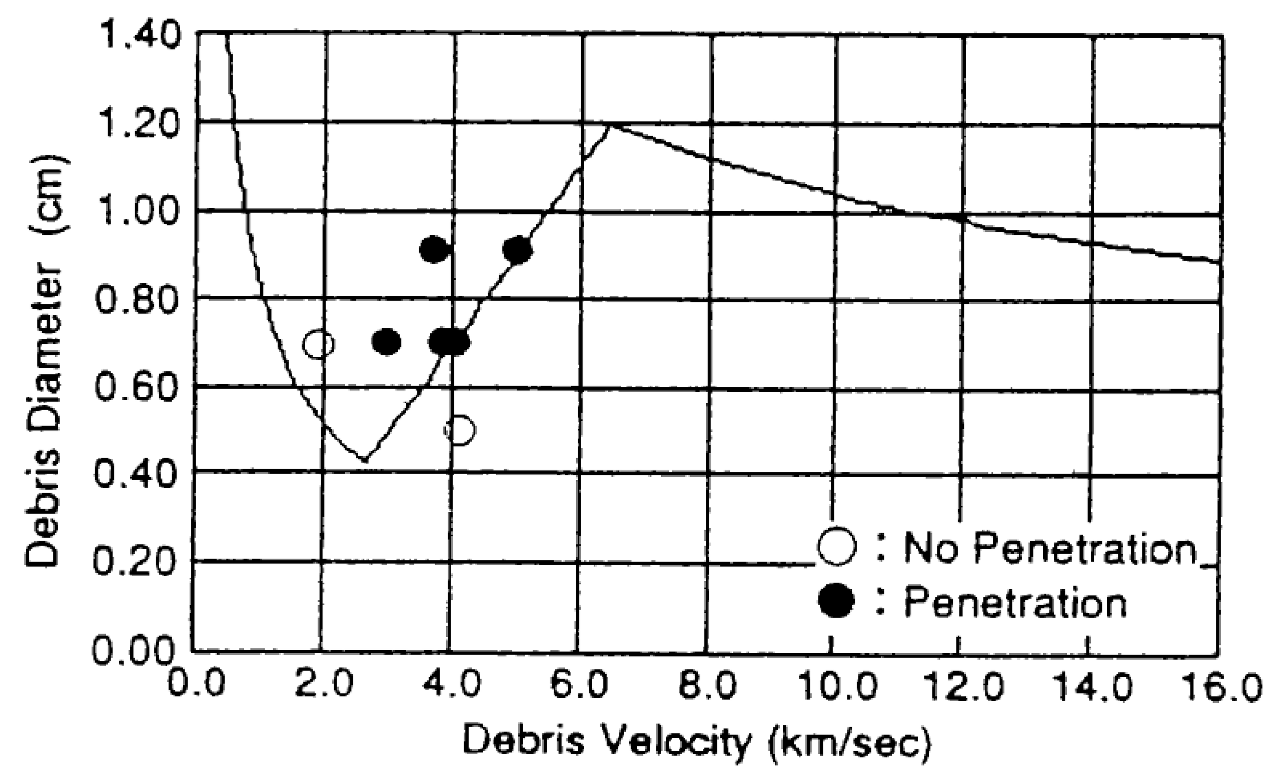

Fig. 6 Hypervelocity impact test data for the Option 3 shield showing some penetration results.

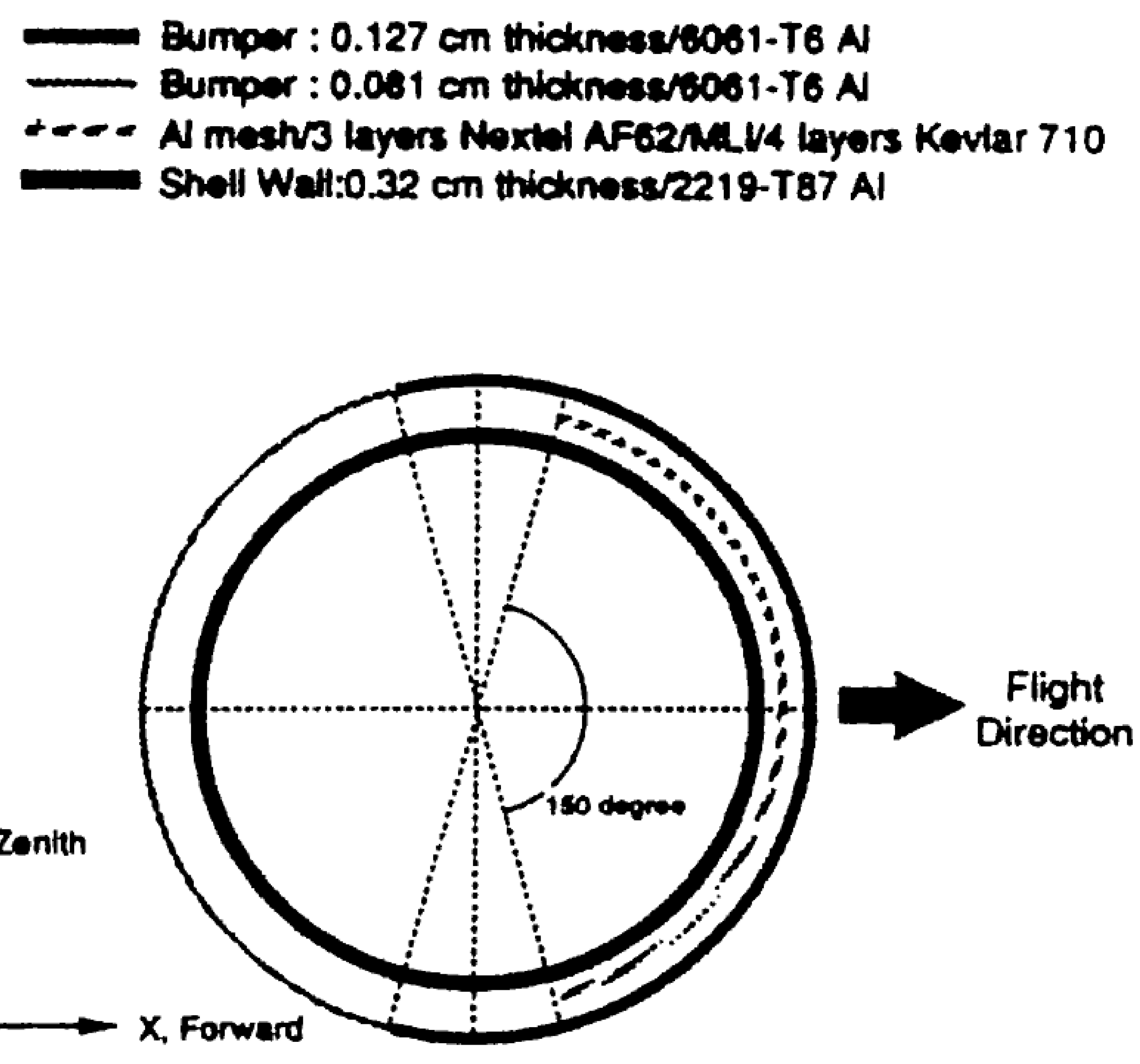

Fig. 7 Shield design arrangement for JEM.

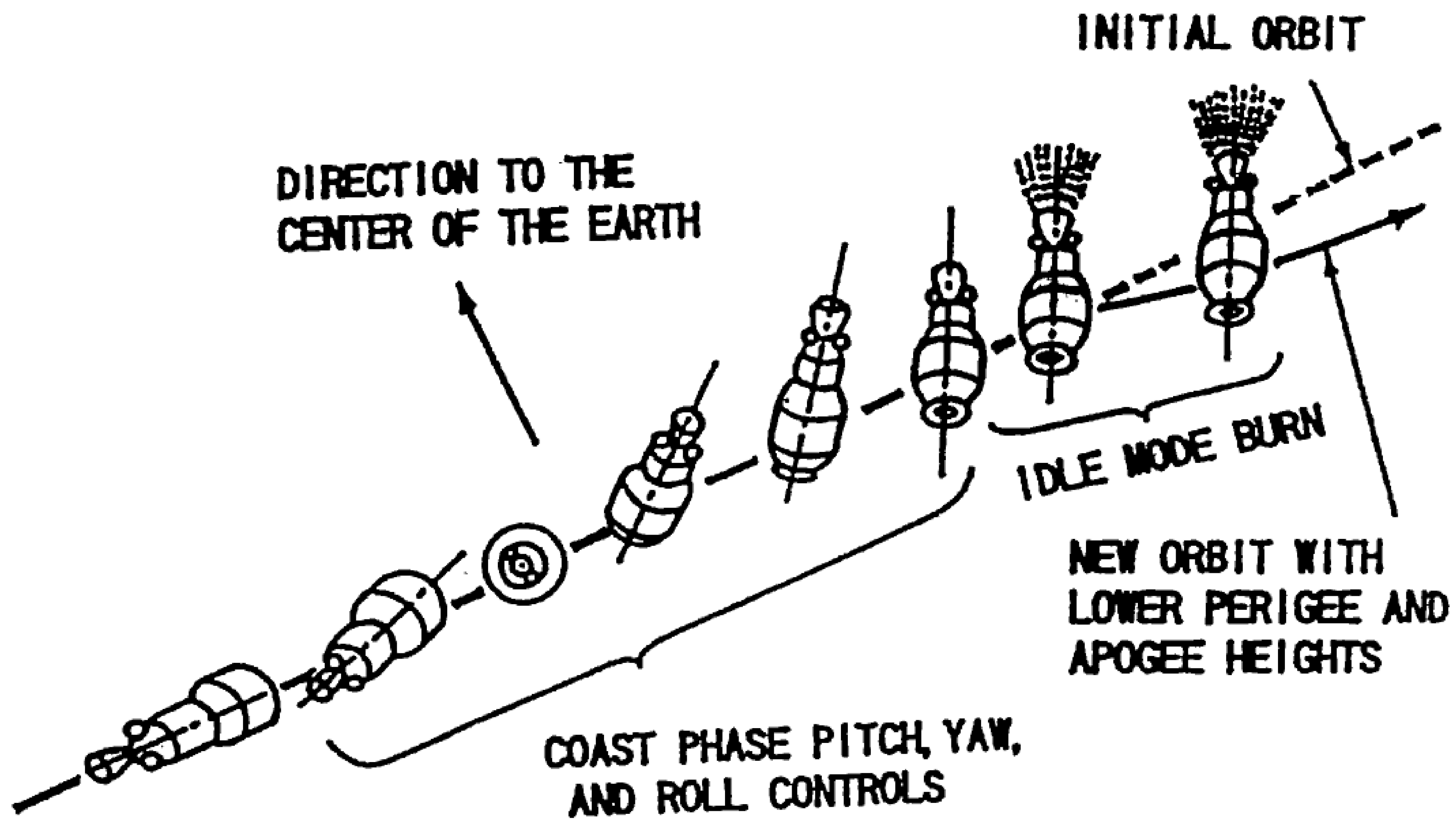

Fig. 8 Schematic of attitude control for the post mission perigee lowering maneuver of H-II.

An efficient numerical analysis tool has been facilitated to investigate the effect of lunar and solar perturbations on the orbital life of object on a highly elliptic obit like geostationary transfer orbit. In the actual flight of H-II, a quasi-retrograde firing of the mission terminated second stage of the H-II utilizing the characteristic low thrust firing mode (named "Idle Mode Burn") of the engine(LE-5A) has been successfully performed(Ref.8). Fig.8 shows the concept of retrograde firing and attitude control. By this scheme, the perigee height of the second stage of test flight #2 was lowered by about 100km utilizing the residual propellant of about 1.7% of total loading. Similar procedures will be observed in the following launching and in the future launch vehicle development of H-IIA. To consolidate these practices, NASDA space debris mitigation standard has been formulated (Ref.9). In this standard, an emphasis is placed on the post mission disposal of satellites and launch vehicle and an formulated evaluation sheet is provided. Further effort will be dedicated toward the international harmonization of the deorbit altitude distance for the GEO satellites.

6. CONCLUSION

Recent debris related activities in NASDA have been outlined. The study on the on-orbit debris observation from near GEO orbit presumes the international cooperation in the development of optical observation system and provision of data acquisition station. Any suggestion from international partner is greatly appreciated.

7. REFERENCES

1. Tajima,T., Konno,H., Mori.S., Sato,T., Orbit Analysis for the Feasibility Study of the Space Debris Observation System, Second European Conference on Space Debris. 1997.
2. Sato,T. Kayama, H. Furusawa, A. Kimura, I., MU Radar Measurement of Orbital Debris, J. Spacecraft, vol.. 28, No.6, 1991.
3. Toyoda,H., Hirabayashi, H., Analysis of Space Debris or Micro Meteoroid Impact to GEO Satellite, in Japanese, to be presented at the IEICE General Conference, Mar. 1997.
4. Takano,A., Tajima,T., et.al., A Progress of Study on the In-Orbit Debris Observation System in NASDA and JSASS, IAA−96−IAA−6.4.1, 1996.
5. Kitazawa,Y., Fujiwara, A.,Imagawa,K., Okada, Y., Hypervelocity Impact Tests on MFD/ ESEM Dust Collector., in Japanese, Shock Wave Symposium, 1997.
6. Takano,A., A Handbook of Space Debris Collision Rate Estimation, GAF-95- 025, NASDA, 1995.
7. Shiraki,K., Terda, F., Harada, M., Space Station Station JEM Design for Micro Meteoroid and Orbital Debris Protection, Proc. Conference on Spacecraft Structures, Materials & Mchanical Testing, 1996.
8. Takano,A., Tajima,T., Kanoh,Y., Recent Efforts toward the Minimization of GTO Objects and its Practices in NASDA. IAA−95−IAA.6.5.03, 1995.
9. Space Debris Mitigation Standard, NASDA−STD−18, 1996.