PREFACE

An opportunity to build a vehicle returning from outer-space called for very wide range of knowledge and considerations in aerodynamics, high temperature gas dynamics and thermophysics, flight mechanics, and thermal protection both in the analysis and design. After the internal approval of one of the interplanetary exploration missions designated as MUSES-C (the third Mu Science and Engineering Satellite), which aims at attempting to collect samples from the surface of an asteroid and to get them back to the Earth, aerodynamicists and reentry researchers in and outside the Institute of Space and Astronautical Science (ISAS) started their works to cope with it in 1994.

One of the major difficulties in designing a reentry capsule for this challenging venture is due to its entry speed: as large as 12km/sec for a direct entry into atmosphere from an interplanetary trajectory. Because of its higher flow enthalpy, atmospheric composition is highly excited, nonequilibrium treatment is essential, and emission from excited species should be included in heating estimates. In addition, the highly heated ablative surface and outgassing from the surface will cause strong interactions in various ways with the external flow, which makes the flow field very complicated. In comparison with the normal reentry from low earth orbit, the question arises whether our existing knowledge and modeling technique can simply be extrapolated to the region of this high enthalpy flow, and whether existing heat shield material can survive in such a high heating environment. An aerodynamicists' university network became very active in order for gaining a better understanding what is going on in the flow around the capsule both on the foreside and rear side. For the flight mechanics of the capsule of this kind, unfavorable instability had been reported in transonic and rarefied regime. For these topics and design considerations, both analytical, ground-based and in-flight test approaches were extensively taken.

Throughout the analysis and design activities, advances in computational analysis tools were available and several new codes were developed for the present application. In comparison with those in the previous works in the U.S. e.g. design activities in the ages of Apollo, Pioneer Venus and Galileo missions, advances in the analysis tools today are amazing. Making maximum use of these analysis capabilities, we conducted our capsule design and they were very helpful in the trade-off, design processes, and uncertainty definitions. On the other hand, ground based test facilities for the reentry application in Japan are very limited particularly for the simulations of hypersonic aerodynamics and for aerodynamic heating. Test results in relatively small facilities in different test conditions must be translated into what may happen in the real flight, and we have to be very careful about this bridging. For example, translation of the thermal response of heat shield material obtained in a test facility into the response in the real flight is one such case. In this context, too, computational tools played an important role. However, in several purposes such as radiation estimates and ground test based validations, it turned out that there is still a room for further improvement both in the flow solvers, models of chemical and thermal kinetics in the highly excited state, and measurement techniques in the testing such as temperature measurement and spectroscopy. As a result, this opportunity was a venture in which we realized the limitation of our understanding and capability.

The final design of the capsule was made from many other design considerations, such as a new descent sub-system and its verification, instrumentation which makes sampling and ground recovery possible, in-orbit thermal characteristics, structural considerations, and so on. We have been working with these design issues one after another. As of 2002, shortly before the launch of the spacecraft, it will be a good time to collect what we have been doing through the analysis and design of the small returning capsule. In the present collection of papers, starting from basic aerodynamic and aerothermodynamic analyses, test facilities built and utilized for this research and development, heat shield characterization and qualification, considerations in flight mechanics, and analyses and experimentations for the various sub-systems of the capsule are summarized. Therefore, this ISAS Report contains almost all that we did on the way to finalizing the design of the capsule.

Particularly for the flow field analysis, contributions by university aerodynamicists were significant. At "ISAS Symposium on Space Flight Mechanics" in December 1994, an announcement of the program and anticipated progress in aerodynamic and thermodynamic analyses needed for the design of the returning capsule were addressed. Since then, we started our talks and exchanges for possible studies. As a result, they provided valuable results that helped design and uncertainty synthesis greatly. These works outside ISAS were primarily done on a volunteer basis. In addition, many graduate students in and outside ISAS were encouraged to find interesting topics in relation to the present mission. Many thesis works were completed or are still on the way, and young researchers became qualified keeping in touch with the topics about the present sample return capsule. As editor of the present collection of papers and as one of those who took care of the design of the flight capsule, I am deeply indebted to each author of the papers included here. Those who read through this report will see the cutting edge of our understanding, analysis technique and design capability. They also see the suggestion and indications to which direction further studies should be conducted.

At the end, we address our sincere appreciation to former Prof. Motoki Hinada of ISAS and Dr. Chul Park currently in Thermosciences Institute. Prof. Hinada had been coordinating ISAS's space vehicle aerodynamics, particularly for the development of launch vehicles, reentry and recovery systems from the very beginning of flight testing era in Japan. Our reentry activities at ISAS today are conducted on the basis he had established. It was a coincidence that Dr. Park stayed at Tohoku University in the very early phase of the present program. We had a number of conversations and mail exchanges. Many topics, such as radiation heating, boundary layer transition, arc-heating test, and so on, were discussed based on his broad experience and knowledge about thermophysics and reentry aerodynamics, which were very helpful for us to streamline our analysis and design processes. Needless to say, there are many more contributors to the design, analysis, qualification, manufacturing, testing, and all the works for flight readiness of the present sample return capsule other than those who appear in this report, we also wish to express our very special thanks to all of them.

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