

CORBA Supports 400-inch Telescope Data Analysis

Yoko Hirano, The Objectt Report

Introduction

The SUBARU Telescope, that Japan is very proud of, is the world's largest-class infrared optical reflecting telescope measuring 400 inch in diameter. SUBARU was constructed on the top of Mauna Kea in Big Island of Hawaii. The main observation facility is located at the University of Hawaii at Hilo and is operated by the National Astronomical Observatory, the Ministry of Education of Japan. There are about 50 staff personnel and 20 students on station 24 hours a day collecting and examining data and performing other day-to-day operations.

SUBARU captured the light of stars for the first time in December 1998. Since then, various observation instruments have been added and tests conducted in preparation for full operation in 2000. The light that SUBARU captures is saved as image data, video data, and numerical data. The data is sent to the supercomputer at the main facility through the leased line where it is examined. Researchers in Japan can also access part of the data through the international leased line. The supercomputer at the observation facility is equipped with European and American analytical applications like IRAF*, eclipse*, and MIDAS*.

The SUBARU group at the National Astronomical Observatory headed by Dr. Mizumoto in Japan has been working on the development of the analytical system for the main facility since 1996. An astronomical study depends on the performance of the telescope and the observation devices and then these depend on the analytical system. The development of a flexible and scalable analytical system that satisfies the complex needs of the astronomical observation is crucial. Object-oriented and distributed systems are also keys here. The analytical system must account for contradicting elements such as flexibility and integrity, changeability and persistence, and independence and collaboration. In 1996, it seemed reckless to take on the challenge of applying both the object-orientation in development methodology and the distributed objects in multiple applications integration, especially in the heterogeneous environments dealing with huge and complex data. The SUBARU group succeeded in this challenge in a unique way. The SUBARU group realized the potential in COBRA and implemented it into the large distributed system making full use of the data from 400-inch telescope. The foresight of Dr. Yoshihiko Mizumoto deserves special mention.

This report introduces the project that developed the data analytical platform of the SUBARU telescope using the distributed technology based on CORBA (Fujitsu's INTERSTAGE). This report consists of the following,

1) The problems to be solved and the motivation for development

1. The problems to be solved and the motivation for development.

At the data processing system in Hawaii, several analytical applications are working over Fujitsu supercomputer VPP700 that manages a large amount of the data from SUBARU telescope. AP3000 connects with the archival system, the magnetic data library that has the capacity of about 150 TB with 1.2TB RAID disk and many workstations. (See Diagram 1.)*

The analytical applications lack interoperability and could not manage the stratified data necessary for the astronomical studies where a team usually analyzes the data in their own way. The analytical programs and data that are used include those belong to the respective team and those shared within the community. The data in the older analytical applications are not stratified, so it is hard for researchers to get the data they want quickly. While it is also important whether or not the researchers get image data at the quality they expect, it is difficult to response feedback to the older systems.

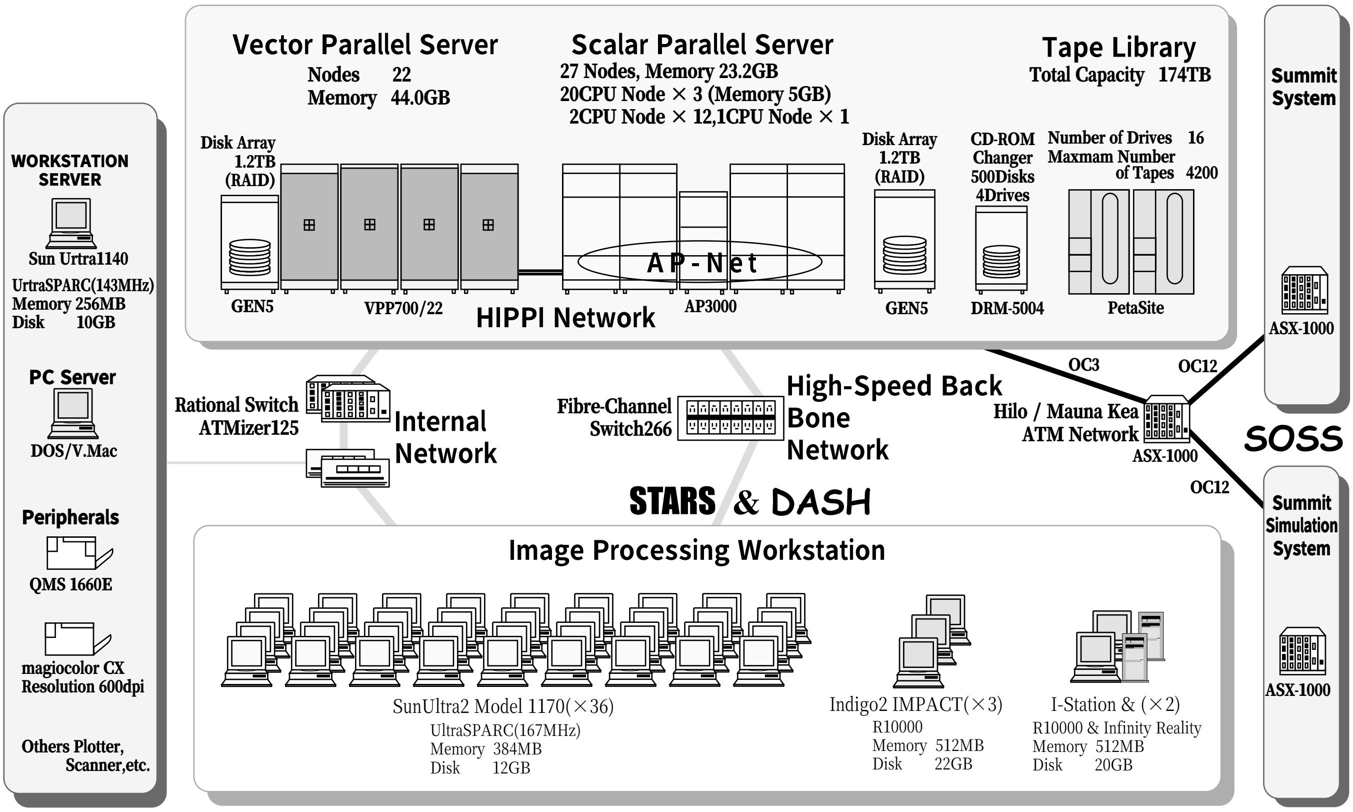
To deal with these problems, the SUBARU group analyzed the problems of IRAF, the analytical software that is most widely used.

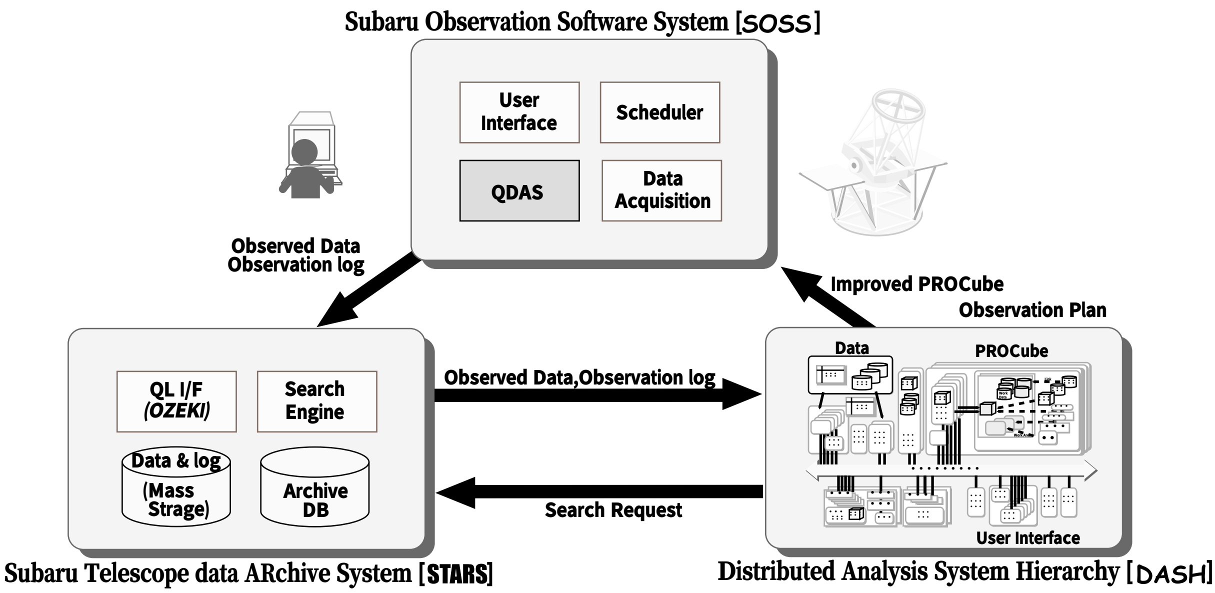
1) The lack of unified management basis for analytical data and related information.
2) The weakness in the management of analytical data and its history.
3) The weakness in the coordination between the subject of the study and analytical processing.
4) The weakness in the cooperation with the observation system.
5) The weakness in the support for latest computing technologies.

The SUBARU group decided to introduce CORBA-based solution to solve these problems, capable of sharing various analytical data, tracking of process, using data archive, and building analytical engines with less resources. COBRA was selected because it gives the ability to easily change the systems configuration, to limit effects of a damage, and to balance the load. Also, with COBRA, which supports the multi-vendor environment and interoperability, it is easy to integrate the legacy systems.

The problem was that CORBA was new in Japan when they started the project in 1996. Other researchers believed that it was impossible to develop the observation system with COBRA. However,

Diagram1 : Hardware configuration of SUBARU Supercomputer System





when the SUBARU group attended the ADASS Workshop in 1997, they learned that the European team was also planing to develop a system using the distributed technology. This encouraged SUBARU group's decision to carry out their original plan. The Fujitsu Ltd. that was in charge of the implementation of the system at the National Astronomical Observatory, also offered INTERSTAGE, the ORB system that they developed and therefore reliable for support and tuning of the product.
It was planned that new observatory instruments are going to be added to the capabilities of the SUBARU telescope, so it was necessary to efficiently develop the data processing software for each instrument. It also must be easy to improve the analytical system keeping up with the improvement of the observatory instruments. The development of the CORBA-based object systems was a key to success because it is the foundation of the entire system. The SUBARU group evaluated these factors and decided to develop the system. "CORBA was the only way to make full use of the existing resources to build an integrated research environment capable of providing usability to the researchers," Dr. Mizumoto recalls. Thus SUBARU group started to develop the system that provides scalability, security, reliability, efficiency and ease of operation requirements.

2. The prototype development

The SUBARU group started to develop the prototype by setting goals, examining the specifications and testing ORB. The tasks were as follows:

1) Wrapping CORBA at the task level of IRAF and MIDAS.
2) Ability to replace IDL-defined CUI with GUI.
3) Support for the same operation of multiple display tools wrapped with CORBA.
4) The development of the calculation engine that arranges the individual processing of images taken by a mosaic CCD camera in a row. ORB controls operations and transmission of the data.
5) The evaluation of the different performances between command-driven system and data-driven system over AP3000.
6) The testing of the efficiency of the data server for handling large image data.
7) Implementation on the AP3000-VPP700 system. An evaluation of the efficiency of AP-net, FibreChannel, ATM, Hippi, Ethernet, and the interoperability between the different CORBA products (INTERSTAGE/Orbix).
8) To coordinate with observation records so that easily retrieves astronomical image data and accompanying numerical data and other image data.

9) To develop the tool that generates analytical process from analytical logs.

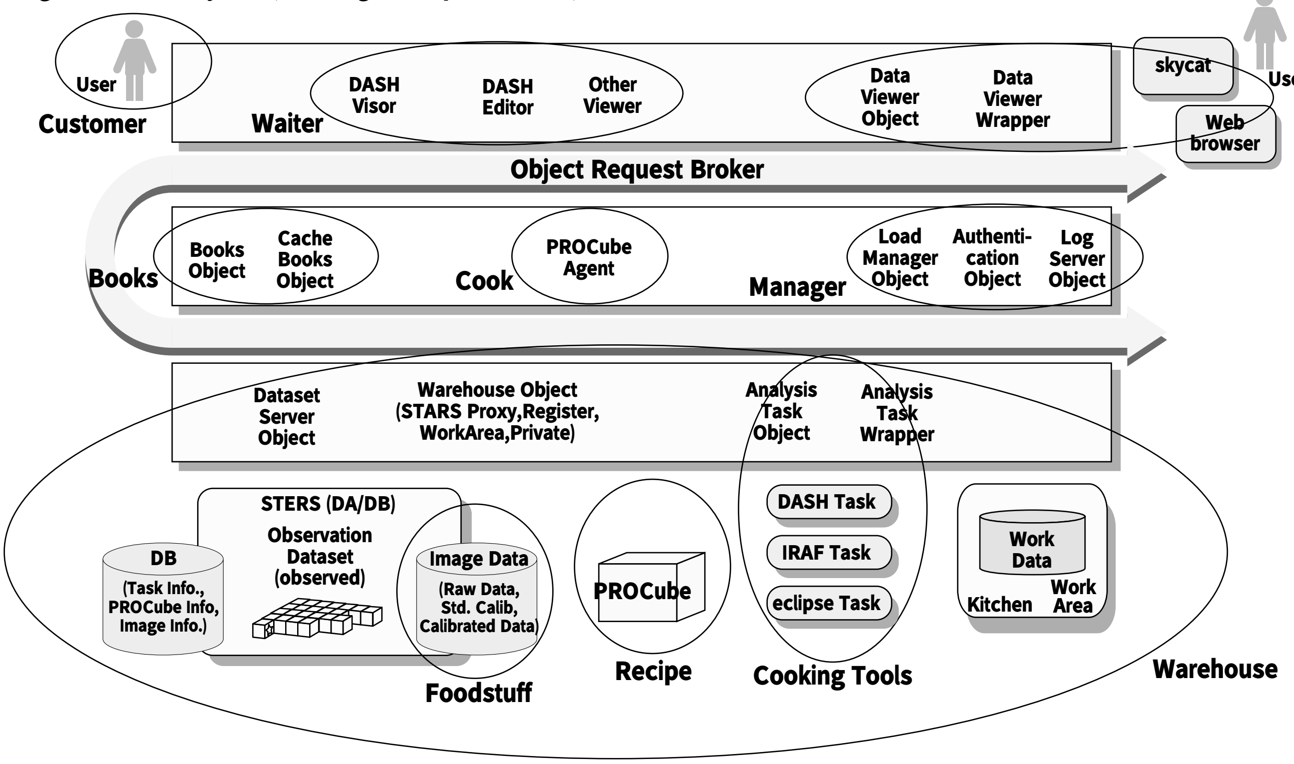
Unfortunately in 1997, 6 months after making plans, four of the five members of the team had to move to Hawaii and other facilities in Japan. That left Dr. Mizumoto alone in Tokyo having to communicate with the other members over long distance. This made it difficult to exchange ideas and caused delays in feedback. Moreover, it was not easy to understand the terminology on both end and develop the user-friendly system.

Therefore, the SUBARU group and the developers hastened to build the prototype and underlying object model. They needed a high-level abstraction of the business model represented by real world objects that makes it easy to communicate with personnel working in distance using different terminologies. So, the "restaurant model" and "recipe model" were introduced.

3. "The restaurant model" and PROCube, the recipe model.

At restaurant model (See Diagram 2), the restaurant represents a whole astronomical data analytical

Diagram2：DASH System (modeling and implementation)



system and the recipe does the analysis. It applies the abstract reference model to the system architecture. The restaurant model has three layers, the upper layer (the presentation layer), the middle layer (the logic layer), and the lower layer (the data layer). The presentation layer is the user interface, where *Waiter* and *Dish* objects represent the order and the data there. At the logic layer, *Book* object describes the location of the resources in the distributed system and *Manager* assigns the orders to the *Kitchen* and decides where to cook considering the state of the system. At the data layer, *Warehouse* manages things in the distributed system at each computer, and there are also *Foodstuff*, *Recipe*, *CookingTools*, *Kitchen* and *Cook* pbjects.

This highly abstract and metaphorical model minimized the interaction with personnel over long distance and made it easier to communicate vendors using specialized terminology. The mutual understanding between the managers, the architects, and the programmers improved when developers analyzed, designed, and reviewed them. The feeling that they have a clear grasp of the entire system, together with easy extraction of the objects made the efficient developing environment.

The restaurant model is equal to the Layers architecture pattern in the software pattern terminology. The pattern divides the application (or a task of the application) into multiple sub-tasks and represents the architecture that handles each task at the different abstraction levels. The advantage of using this explicit software pattern is that it makes it easy to communicate by using common terminology in the software world and the SUBARU group proved it works.

On the other hand, they had to process the huge data acquired at the astronomical data analytical transactions with tens of Gigabytes of the size. With existing applications, they spend a lot of time in the management of recorded data and the process, sacrificing valuable time for study. Moreover, those applications could not track the transactions of the operation. The development group devised PROCube, the object to represent all the information of an analytical procedure. PROCube is equal to a recipe and respond to the "order voucher" at the restaurant model.

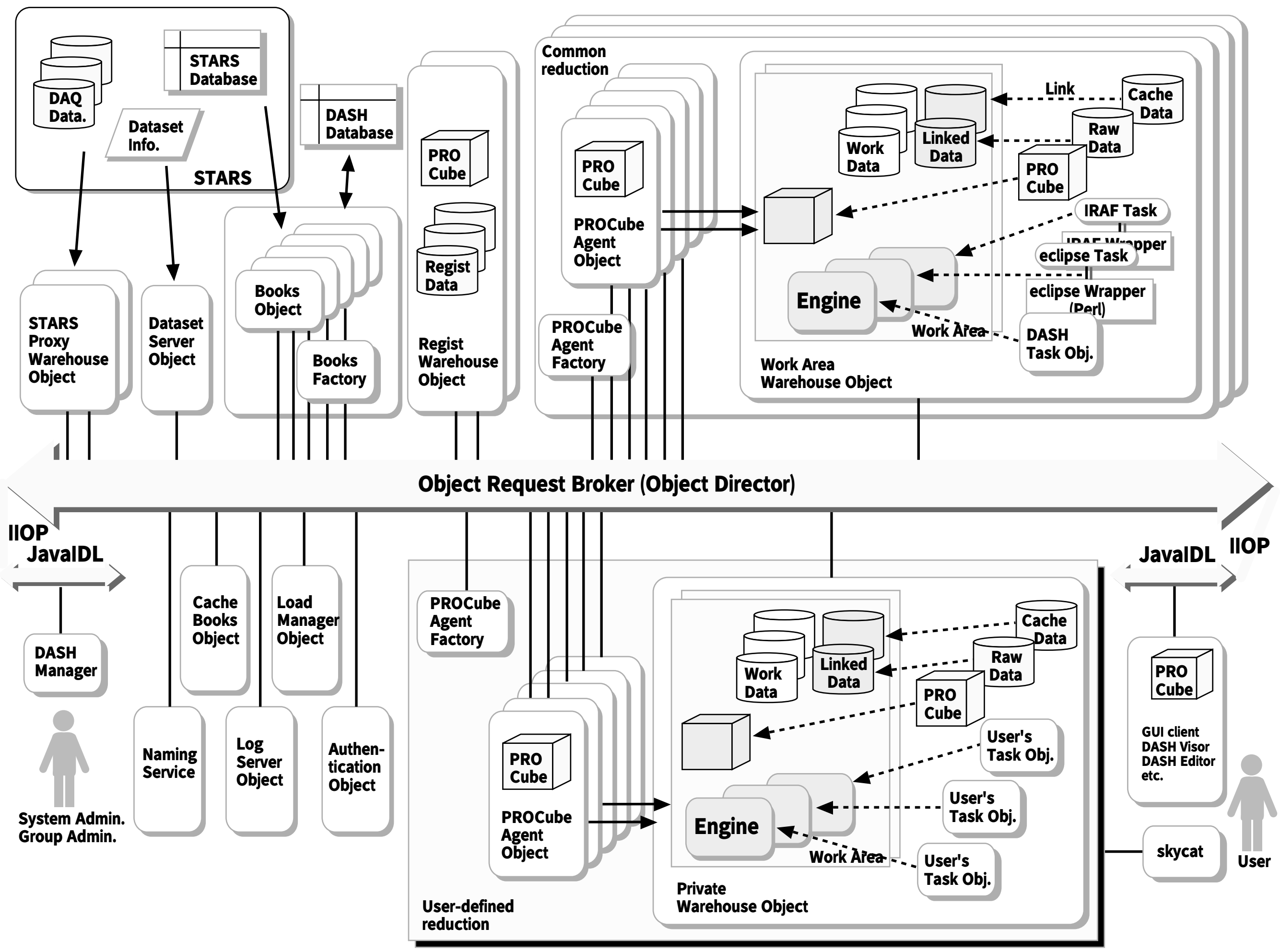
At PROCube, the raw data that comes from the telescope will be processed a series of transactions. The basic structure is a 3-dimensional flow chart. X-axis represent types of data, Y-axis does numbers of data, and Z-axis analytical transactions. At the bottom surface, the raw data received from targeted celestial body and various reference data are arranged. The processed data is arranged at the top. At each transaction, the input is placed in lower stage and the output in upper stage. The management information (Header) and the transaction history (Log) are also recorded and it packages the whole transaction in one object.

Multiple PROCubes are working on the CORBA-based platform and the computers for transaction is chosen automatically.

4. DASH (Distributed Analysis System Hierarchy)

After the analysis of the entire business process, and building of the restaurant model and PROCube, they developed the prototype the whole distributed system as DASH (Distributed Analysis System Hierarchy) system (See Diagram 3). The DASH project was carried out under the CDE 3-year plan that includes setting of targets, analysis, design, implementation, and review of the prototype.

Diagram3：DASH system components



At Phase C (the first year, 1997), they defined and implemented PROCube and all the necessary elements for analytical processing like, archives, GUI clients and the reference data are integrated on the CORBA middleware.

During Phase D (the second year, 1998), they achieved the collaboration between PROCubes and observational dataset, database, observational data archive. They also examined the possibility of using persistent objects and agents.

At the last Phase E (the third year, 1999), they completed the analytical engine and tested the system. The new integrated analytical engine for the parallel and distributed processing was developed with existing engines (IRAF, Eclipse) being wrapped and collaborating together.

They are currently working on the Phase E, the last stage of 3-year plan. Not all the targets of the original plan have been achieved with no trouble. Targets have been reviewed and rearranged every 6 months. There is a data I/O bottleneck during the astronomical image data processing and the data transmission was a big problem. The transmission of huge image data on CORBA integrating parallel distributed processors was, and still is the most important subject to consider. Now they have completed ¿version of the system and almost finished with testing and the review.

After completing the 3-year plan, the following functions will be realized.

1) Data transaction on one single system.

2) Applications integration between those implemented with different languages.

3) Seamless and easy-to-use user interface

4) Reuse of the existing software.

5) Wrapping of legacy applications

6) Collaborate Java, CORBA, Web and C++ with customized GUI

The GUI clients implemented with Java send requests to the INTERSTAGE server through IIOP transmission using Java IDL, a standard package of Java 2 1.2.2. All the servers are working on INTERSTAGE from Fujitsu Ltd.

5. The advantage of the CORBA-based system and the development cost.

The new research environment by the DASH system works in the following ways:

a. The unified management of data and the analytical process: To manage both static information (inter-relationship between the analytical engine, acquired data, reference data, and processed data) and dynamic information (the analytical process history and process procedures of the analysis).

b. The realization of a target-oriented analytical processing: To make it possible to gather the necessary information focused on the targeted celestial body corresponding to the SUBARU telescope archive.
c. The Collaboration with the observation system: It is possible to select the acquired data by connecting with SUBARU data archive and also retrieve and display the related data (such as the observation history). Automatic generation of the reference data necessary for the first processing is made possible and also the feedback of the review of each observatory results.
d. Catching up with the latest computing technologies: By adopting CORBA, a seamless, heterogeneous, distributed environment supporting scalability, load balancing, fault tolerance, scalability will be realized.
The cost of DASH development is as follows:
About 25 man-month for systems design and for testing of ORB in 1996. That includes requirements analysis, the functional analysis, object analysis, and technical research (including the test on CORBA), and building of the program.
About 80 man-month for developing the prototype at Phase C in 1997. They developed 2 prototypes in every 6 months to examine required systems functions, the ORB functionalities and performance. The same size of the resource was introduced in the Phase D and E. The members of the group were always less than 10, so it was easy to exchange ideas and information and they could carry out the plan efficiently. In the software world, it is said that the more members the group has, the less efficient it is. So, even though the members of SUBARU group dispersed, they were able to achieve highly efficient management of the project.

Conclusion.

The bold project succeeded to build exceptionally large distributed systems with exceptionally small numbers of staff. As Dr. Mizumoto recalls, the style of the project management depended more on a sort of artisan spirit and is quite different from American and European counterparts, usually applying process- and procedure- oriented management. The development staff of the ORB vendor, Fujitsu also contributed to the success by developing a unique metaphorical models and also tuning their original middleware product to handle unprecedented huge and complex data.
The SUBARU group is now carrying out the final stage of the 3- year plan that started with the motto, "lead the world in 3 years". They are also planing to extend the cooperation with other systems of National Astronomical Observatory and to add new functions.

As the technologies such as Java, CORBA, XML are growing, the development group will apply these to improve the system the component oriented system and now is looking for the new idea for completing the plan on the third year. 2000 will be a memorable year for the Dr. Mizumoto's team.

Page 1:
IRAF (Image Reduction and Analysis System), see http://iraf.noao.edu
MIDAS (The Munich Image Data Analysis System), see www.eso.org/observing/software.html
Page 2
VPP700 Vector Parallel Server: 44.0GB of main memory, 22 vector CPU generates 48.4Gflops, 1.2TB of disk array
AP3000 Scaler Parallel Server: 23.3GB of main memory, 27 nodes, MT library with the capacity 150TB and 1.2TB RAID disk