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Current Status of ASTRO-F

By

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Abstract: The ASTRO-F is the second infrared astronomy mission of the Institute of Space and Astronautical Science (ISAS). The ASTOR-F is a 70-cm cooled telescope dedicated to infrared sky survey. It will be launched with ISAS's launch vehicle M-V, into a sun-synchronous polar orbit. The current programed launch date is February, 2004. One of the two focal-plane instruments, the Far-Infrared Surveyor (FIS), will survey the entire sky in the wavelength range from 50 to 200 micron with a sensitivity much higher than that of the IRAS survey. The other one, the Infrared Camera (IRC), employs large-format detector arrays and will take very deep images of wide sky regions in the near and mid infrared range. New infrared source catalogs provided by the ASTRO-F will give a valuable base for the further research by large space missions like the HII/L2.
The ASTRO-F project is now in a design-fixing phase. The flight model design will be finalized within this year, based on the results of various tests using a structure model and a thermal model of the satellite, and also electrical protomodels of each component. The flight model fabrication will be completed in 2001. It will be launched at the beginning of 2004, after system tests and refurbishment over two years.

1. OVERVIEW OF THE ASTRO-F MISSION

The ASTRO-F (Murakami 1998) is the second satellite mission for infrared astronomy in Japan. The ASTRO-F was designed as a second-generation survey mission. The previous sky survey by the Infrared Astronomy Satellite (IRAS) (Neugebauer et al. 1984) brought forth a lot of new findings such as the infrared galaxies and Vega phenomenon, and provided huge catalogs of infrared sources. The investigations in various fields in astronomy have very much progressed with the IRAS results as a start. Now, a new survey beyond the sensitivity limits of the IRAS promises further progress.

Figure 1 shows an overview of the ASTRO-F satellite. It is not a flight model, but a structure model which is used to verify the mechanical design of the satellite. It well simulates the launch configuration of the ASTRO-F. A liquid-Helium cryostat which contains the telescope and focal-plane instruments is installed on the spacecraft. The total hight and weight of ASTRO-F are approximately 3.7 m and 960 kg, respectively. The telescope mirror is 70 cm in diameter. The infrared instruments in the focal plane have powerful capability for the survey work owing to

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the advanced technologies now available. The ASTRO-F covers wide wavelength range from K-band to 200 μm. It will perform the all-sky survey at wavelengths $\geq$50 μm using high sensitivity Ge:Ga detector arrays. In the near- and mid-infrared ranges, large-format arrays are employed for a deep sky survey in the selected sky regions. The sensitivity of the ASTRO-F is much higher than that of the IRAS. The angular resolution is also higher than the IRAS.

The scientific targets of the ASTRO-F range from distant galaxies to solar system objects. The key science is a search for the primeval galaxies, tracing the evolution of galaxies to high redshifts z>3, systematic investigation of the star and planet formation process.

The new infrared survey by the ASTRO-F will also provide a valuable guide map for future research with large-aperture space telescopes, such as the FIRST (Pilbratt 1998), NGST (Seery & Smith 1998) and HII/L2, and also for 10-m class ground-based telescopes which have just become available.

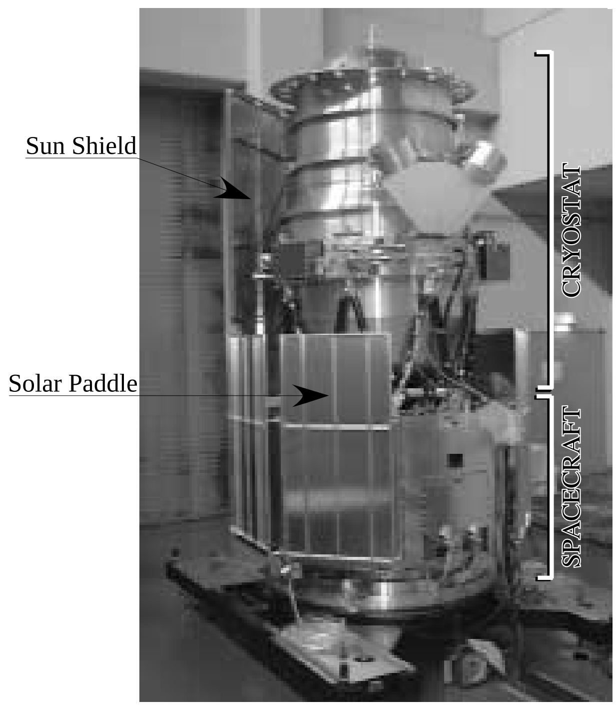

Fig. 1: Mechanical Test Model (MTM) of the ASTRO-F. This model simulates the launch configuration of the ASTOR-F. The cryostat which contains the telescope system and the focal-plane instruments is put on the spacecraft. The total hight is approximately 3.7 m. The solar paddle and the sun shield are also seen (just mass dummies).

2. SCIENCE INSTRUMENTS OF ASTRO-F

2.1 Cryogenic system

The cryostat is a light-weight liquid helium cryostat with mechanical coolers. The cross-sectional view of the cryostat is shown in Figure 2. The outer shell of the cryostat is thermally isolated from the spacecraft and cooled to below 200 K by radiation cooling. The cryostat has two vapor-cooled shields (VCS). The inner shield is cooled by two 2-stage Stirling-Cycle coolers in addition to the evaporated helium gas. This supplemental cooling by the coolers increases the life time of the liquid helium by about a factor of two and stabilizes the temperature of the inner VCS. The temperature of the telescope and the focal-plane instruments, which are cooled by the evaporated helium gas, is approximately 6 K. Only the far-infrared arrays are thermally connected to the helium tank and cooled to 1.8 K. The life time of the liquid helium is approximately 500 days in space in the current design with 170-liter liquid helium. One of the advantages of using mechanical coolers is that the near-infrared observations can be continued even after the liquid helium runs out, as long as the cooler works properly. The life time of the coolers is expected to be 5 years, and is now under verification test.

The ASTRO-F cryogenic system is a good precursor to that of the HII/L2. The radiation cooling of the cryostat outer shell which is thermally isolated from the spacecraft, and the usage of cryocoolers are technique common to the HII/L2 mission. Especially, the Stirling-cycle coolers developed for the ASTRO-F will be a base of the HII/L2 cooling system, added with a J-T cooler or other advanced cooling systems to achieve lower temperatures.

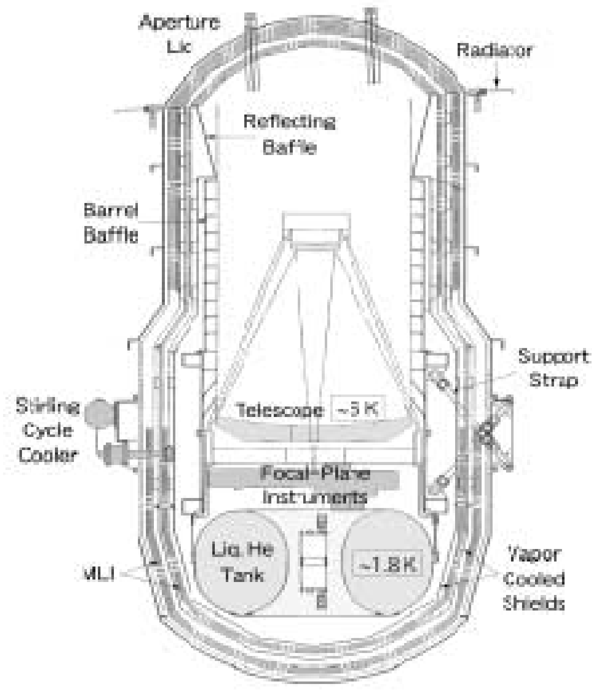

Fig. 2: A cross-sectional view of the cryostat.

2.2 Telescope system

The telescope is a Ritchey-Chretien type, whose effective aperture size is 70 cm and whose system F-number is 6 (Onaka, Sugiyama, & Miura 1998; Kaneda & Onaka 2000). For the mirror material, silicon carbide (SiC) is adopted, because of its large Young's modulus and high thermal conductivity. The SiC mirrors consist of porous core and CVD coat. The porous SiC has a very low density (1.85 g/cm^3) and is easy to machine. The CVD coat is dense and can be polished very accurately. The current weight estimation for the 70-cm primary mirror is 11 kg. The goal of the image quality is diffraction-limited performance at a wavelength of 5 μm, including the aberration of the camera optics at the focal plane.

2.3 Focal-plane instruments

The focal plane of the telescope is shared by two instruments, the Infrared Camera (IRC) (Matsuhara 1998) and the Far-Infrared Surveyor (FIS) (Kawada 1998). The IRC is a wide-field imaging instrument. It consists of three independent camera systems, each of which covers near infrared (2-5 μm), 7-11 μm and 15-25 μm in the mid infrared, respectively. The filter bands are selected by rotating the filter wheels by commands. The IRC also has a capability of low-dispersion spectroscopy by replacing the filters with a prism or a grism which are also attached to the filter wheels. This spectroscopic capability will be used to classify the detected sources, to get SED of the sources, and to roughly estimate the redshifts. The fields of view are $10' \times 10'$ for all three cameras.

The FIS covers the wavelength range from 50 to 200 μm. The primary purpose of the FIS is the all-sky survey. The survey observations are performed in four filter bands at the same time. The FIS also has a Fourier-transform spectrometer with a resolution of 0.5 cm^{-1}. Imaging spectroscopy is done for selected sources.

3. CURRENT STATUS OF ASTRO-F

The programed date of ASTRO-F launch was August 2003 at the time of the workshop. The launch schedule, however, has recently been delayed by half a year. The M-V rocket of the ISAS failed to place the X-ray astronomy satellite, ASTRO-E, into a stable orbit at the beginning of this year. We need some time to fix this problem of the launch vehicle. The new launch date will be in February, 2004.

The ASTRO-F program is now in a design-fixing phase of the flight model. The design of the flight model will be finalized after various tests with protomodels. A mechanical-environment test using the mechanical test model (MTM, Figure 1), which includes a static load test, a vibration test and a shock test, has been done in February-June period this year at the ISAS. Figure 3 shows the spacecraft part of the MTM. Although components are just mass dummies, a part of the main structure will be used as a flight model. The upper part of the MTM, the cryostat, has actual cooling capability. It can be used to evaluate the performance of the cooling system including the Stirling-cycle coolers (see Figure 5). The mechanical tests were performed when it contained liquid helium. A mechanical test model of the telescope system was installed in the cryostat, together with mass dummies for the IRC and FIS (Figure 4). The mechanical properties of the telescope system were also evaluated at low temperatures.

The electrical interface test was performed in March-June. This test included the prototype model of the the Data Handling Unit (DHU), Data Recorder, Attitude and Orbit Control System (AOCS), IRC and FIS. The data transfer from each component to the data monitoring system on the ground, as well as the onboard data storage capability, have been verified in this test. A detailed evaluation of the protomodel of the AOCS is now under way.

The MTM is now being reconstructed as a Thermal Test Model (TTM). The test of this TTM to verify the thermal design will be performed in November, 2000.

The protomodels of the focal-plane instruments, FIS and IRC, are now under performance tests in Nagoya University and the ISAS, respectively. See Onaka (2000) and Kawada (2000)

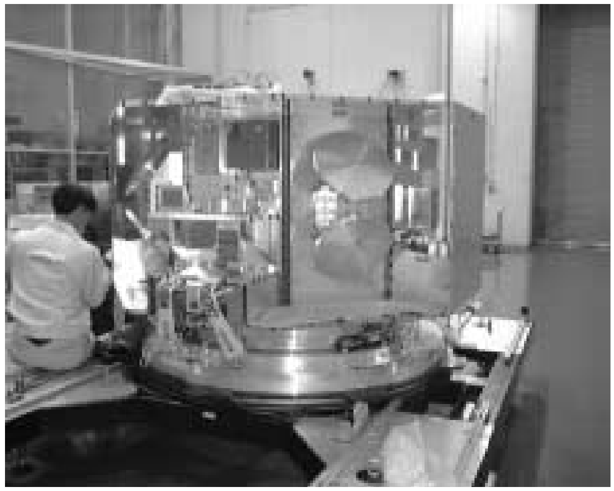

Fig. 3: The spacecraft MTM under integration. The main structure is the same as the flight model. Components integrated on it are just mass dummies.

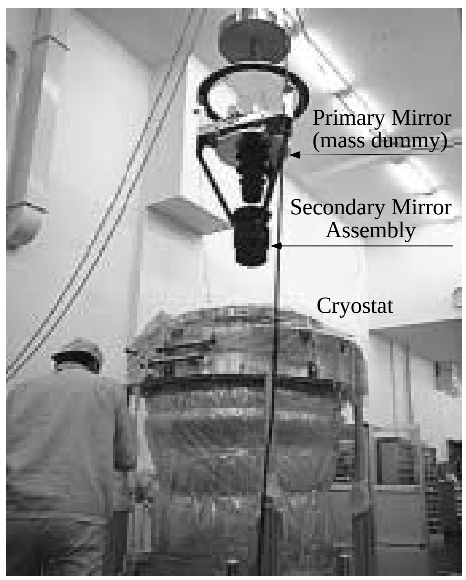

Fig. 4: MTM of the telescope system being installed into the cryostat. The cryostat outer shell has been removed in this photograph. Multi-layer insulators can be seen.

for the detailed status of these instruments. The flight model of the focal-plane instruments will be completed in April, 2001, and integrated with the telescope system and delivered to the cryostat in July, 2001.

The schedule from now to the launch is shown in Figure 6. The performance test of the whole satellite system is planned to be made at the beginning of 2002. After refurbishment and fixing problems, the satellite will be finally integrated at the beginning of 2003. The ASTRO-F will be carried to the Kagoshima Space center, the ISAS's launch cite, at the end of 2003 after an one-year system test. The launch operation will start in January, 2004.

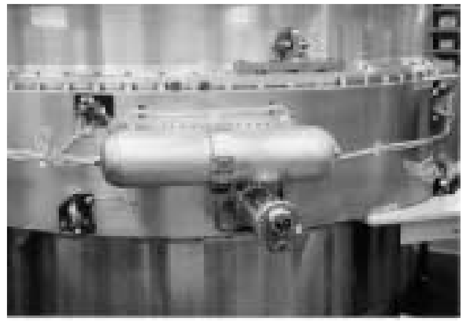

Fig. 5: A Stirling-cycle cooler on the MTM.

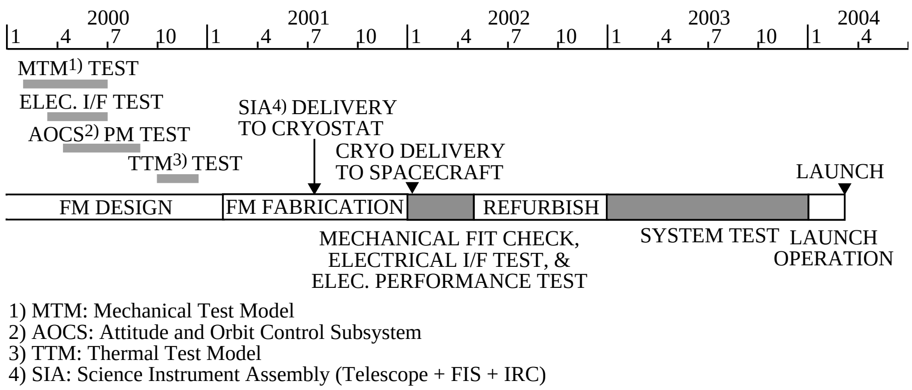

Fig. 6: ASTRO-F development schedule.

REFERENCES

Murakami, H. 1998, SPIE Proc., 3356, 471
Neugebauer, G. et al. 1984, ApJ, 278, L1
Pilbratt, G.L. 1998, SPIE Proc., 3356, 452
Seery, B.D. & Smith E.P. 1998, SPIE Proc., 3356, 2
Onaka, T., Sugiyama Y., & Miura S. 1998, SPIE Proc., 3354, 900
Kaneda, H. & Onaka T. 2000, this volume.
Matsuhara, H. 1998, SPIE Proc., 3354, 915
Onaka, T. 2000, this volume
Kawada, M. 1998, SPIE Proc., 3354, 905
Kawada, M. 2000, this volume