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MSFC ORBITAL SPACECRAFT DEVELOPMENT EMPHASES FOR THIS DECADE

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SUMMARY

Historically, the Marshall Space Flight Center (MSFC) has been responsible for significant accomplishments in the area of developing both manned and unmanned spacecraft. MSFC is presently involved in many of NASA's largest and most prominent programs, with some operational, others being readied for flight, and still others in various stages of design and development. Examples of MSFC programs being designed or developed are Space Station *Freedom* (S.S. *Freedom*), the Advanced X-Ray Astrophysics Facility (AXAF) which includes imaging and spectroscopy facilities, the Laser Atmospheric Wind Sounder (LAWS), and the Lunar Ultraviolet Telescope Experiment (LUTE), with Spacelab and Tethered Satellite System (TSS) as examples of current operational MSFC spacecraft. The information obtained from the Long Duration Exposure Facility (LDEF) will aid the design process and life predictions for these and all future spacecraft. A second LDEF is presently being considered. All of these projects will be briefly described in this paper.

INTRODUCTION

MSFC, with a long reputation as a center of excellence for propulsion research and development, has been responsible for numerous scientifically significant manned and unmanned missions. Many orbital missions of the future are much larger, more complex, and require longer life than those of the past. As a result, the consequences of the space environmental effects on materials and systems are becoming increasingly important. Missions such as LDEF provide information that will benefit these future programs through improved definition of performance degradation and life predictions while in orbit. S.S. *Freedom* is being designed for a 30-year lifetime and will be much larger and provide higher power levels than any previously flown spacecraft. The AXAF will be the next of the great observatories to be placed in orbit above the distorting atmosphere of the Earth. Satellites, such as LAWS, will operate in low-Earth orbit (LEO) in the future to provide information to help us understand the planet on which we live. Some missions, such as LUTE, will require a return to the Moon. There are many other projects under development at MSFC, including numerous payloads. The Marshall Center's role in development of orbital spacecraft will be significant in the upcoming decade.

SPACE STATION FREEDOM

S.S. *Freedom* is to be a permanently manned facility in LEO. The station, as shown in Figure 1, is 353 feet long and will have one habitation module for astronaut living quarters and three laboratory modules for life sciences, microgravity, and crystal growth research. S.S. *Freedom* will be an observation post for Earth and the universe and a facility to assemble, operate, and maintain large spacecraft for future endeavors, including the manned mission to Mars. It also provides for peaceful international cooperation, with other nations working with the United States and NASA to develop an international space station. Japan is providing the Japanese Experiment Module, the European Space Agency is providing the Columbus Laboratory Module, and Canada is providing the Canadian Mobile Servicing System which will allow robotic arms to move payloads and equipment around the station. Assembly of S.S. *Freedom* will begin in 1996, with manned tended capability (MTC) by mid-1997 and permanently manned capability (PMC) by 2000. During the buildup to PMC, there will be many stages of integrated assembly making S.S. *Freedom* a useful space platform and laboratory much earlier.

MSFC is responsible for the design and manufacture of life support systems, composite equipment racks, habitation and laboratory modules, including environmental control and other support systems. The solar arrays, with a length of 112 feet, contain 198,600 solar cells to provide 56 kW of power. The LDEF has proven to be a wealth of information on how these solar arrays should be designed, as well as long-term space environment effects on other materials. For example, anodized aluminum had excellent performance for the 5.8 years exposure and anodized aluminum, tailored to provide passive thermal control, is planned for the micrometeoroid/space debris shielding on S.S. *Freedom.*

ADVANCED X-RAY ASTROPHYSICS FACILITY

AXAF will be a two-part orbiting observatory to study neutron stars, black hole candidates, debris from supernova explosions, quasars, and active galaxies. AXAF will succeed the Einstein X-ray Observatory with significantly improved sensitivity. AXAF-I's mission will consist of high-resolution imaging and grating spectroscopy. AXAF-S will use a cryogenically cooled x-ray spectrometer for high-energy, high-spectral resolution spectroscopy. With both observatories, scientists can obtain images and characterization of the x rays emanating from astronomical objects. AXAF-I will be built by TRW and launched in 1998 from the space shuttle into a high-Earth orbit. AXAF-S will be designed and built by MSFC with a planned launch in 1999 by a Delta II rocket into a low-Earth, Sun-synchronous polar orbit. AXAF-I and -S whose configurations are shown in Figure 2 will operate for 5 and 3 years, respectively. Cleanliness of optics and contamination control are primary concerns due to the grazing incidence optics and the performance requirements.

TETHERED SATELLITE SYSTEM

The TSS, a joint project of the United States and Italy under an agreement signed in 1984, consists of a satellite, a $^{1}/_{10}$th inch diameter tether, and a deployer in the shuttle's cargo bay. This satellite system can demonstrate the feasibility of using a tether to generate electricity, as a propulsion system to power spacecraft, and for studying the Earth's magnetic field and ionosphere.

The conducting tether generated electrical currents using the same principle as a standard electrical generator, converting the mechanical energy of the shuttle's 17,000 mph orbital motion into electrical energy by passing a conductor through the Earth's magnetic field lines. The TSS-1 scientific instruments, mounted in the shuttle cargo bay, the middeck, and on the satellite, allows scientists to examine the electrodynamics of the conducting tether system, as well as clarify the understanding of physical processes in the ionized plasma of LEO.

One possible future application of the tethered satellite would be to use long conductive tethers to generate electricity for S.S. *Freedom* or other orbiting bodies. Conversely, by expending electrical power to reverse the current flow into a tether, the system could be placed in an "electric motor" mode to generate thrust for orbit maintenance. Tethers may also be used to raise or lower spacecraft orbits by releasing a tethered body from a primary spacecraft, thereby transferring momentum and imparting motion to the spacecraft. Another potential application is the creation of artificial gravity by rotating two or more masses on a tether. Downward deployment could place a satellite in regions of the atmosphere that are currently difficult to study since they lie above the range of high-altitude balloons and below the minimum altitude of free-flying satellites. Deploying a tethered satellite towards Earth from the shuttle would also make possible aerodynamic and wind tunnel type testing in the region 50 to 75 nautical miles above the Earth.

The Tethered Satellite (Figure 3) first flew on the space shuttle *Atlantis* in August 1992. The satellite did not fully deploy due to mechanical problems, but the tether did generate 40 V of electricity. In addition, the mission provided data on the dynamics of deployment and retrieval. A possibility for reflight of the experiment on a future shuttle mission is being studied. MSFC was responsible for the U.S. portion of the project, as well as the rapid development, qualification, and application of the electrically conductive paint used on the satellite sphere.

EARTH OBSERVATIONS

The Earth Observing System includes LAWS. This instrument addresses the problem of ozone depletion and pollution. LAWS consists of a carbon dioxide coherent laser system, common transmit and receive optics, and a scanning telescope system for off-track coverage. It will provide real-time measurement of global atmospheric winds, circulation, and climate dynamics. LAWS will be capable of measuring the magnitude of ozone depletion, global warming, and the nature of the threat to the Earth environment, in addition to monitoring man's effects on the atmosphere. LAWS can be flown as either a space station payload or attached to a polar platform. MSFC is presently managing the development of this project.

PAYLOADS

MSFC is also leading the development and flight of several Spacelab and space station payloads. On S.S. *Freedom*, the Material Sciences Glovebox is capable of fluids handling and wet chemistry, particulate generating procedures, and equipment servicing or repair in a clean environment. The internal atmosphere is recycled and filtered to remove dust particles and fluid droplets. Also, a portable glovebox will be available as part of the laboratory support equipment.

A furnace facility is being developed to include a crystal growth furnace, with configurations to include high and low gradients directional solidification processing, vapor crystal growth, and a programmable multizone. Also included are a metals and alloys solidification apparatus, a visibly transparent furnace, a large bore Bridgman furnace, and a high pressure furnace module. These facilities will provide for investigations of the solidification of metals and alloys, crystal growth of electronic and photonic materials, and oxide/glass formation.

Also under development is a electronic still camera laboratory for high-resolution digital imaging systems and processing systems. It is equipped to measure and analyze analog and digital circuit parameters of electronic digital systems and video cameras, as well as perform extensive digital processing of images from video resolution up to 16 million pixel true color resolution. The current design first flew on STS-48, with the downlink from the space shuttle in near real time.

The Optical Properties Monitor Satellite is a multifunction, in-flight laboratory for the study of space environment effects on materials. It is scheduled to fly on the space shuttle in 1997. A very similar project is the LDEF II. LDEF II would be a more compact version of LDEF so as to fit in the current shuttle manifest. It would contain about a dozen experiments with optics, polymers, thermal control coatings, and composites. It would study the space environment, particularly atomic oxygen, and its effects on materials.

In recent years, consideration of science outposts on the Moon and subsequent mission to Mars has increased. The LUTE is part of the planned lunar base of the Space Exploration Initiative (SEI). Because the Moon has no atmosphere, it is an excellent place for telescopic observations. Also part of SEI is the Laser Power Beaming Experiment. This would transfer energy from Earth to Moon, Earth to orbit, or orbit to orbit using phased laser light. Photovoltaic cells would convert the light into electricity. Efficient energy transfer is achieved since very little attenuation of the laser beam would occur due to atmospheric interference.

CONCLUSION

There are many other space-based hardware projects being planned at MSFC, such as space platforms and other Earth-orbiting systems. There are also smaller projects that are in various stages of development here. Whatever the size spacecraft or length of stay in the space environment, it is essential to have a data base of knowledge about atomic oxygen, thermal vacuum, micrometeoroids, space debris, ultraviolet and particle radiation. We will continue to study the environment and its effects on materials in order to develop and build qualified space hardware.

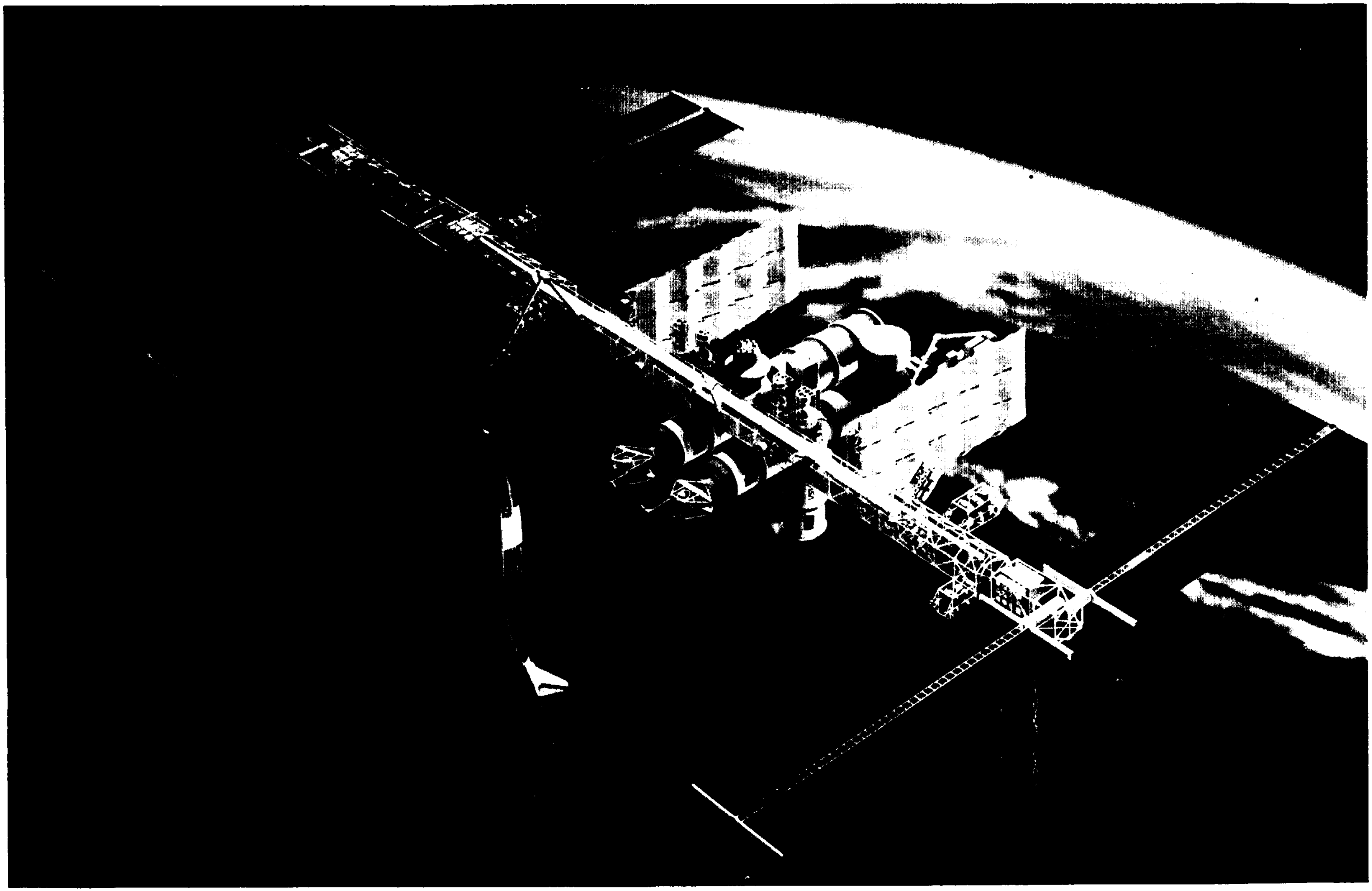

Figure 1. S.S. *Freedom* concept.

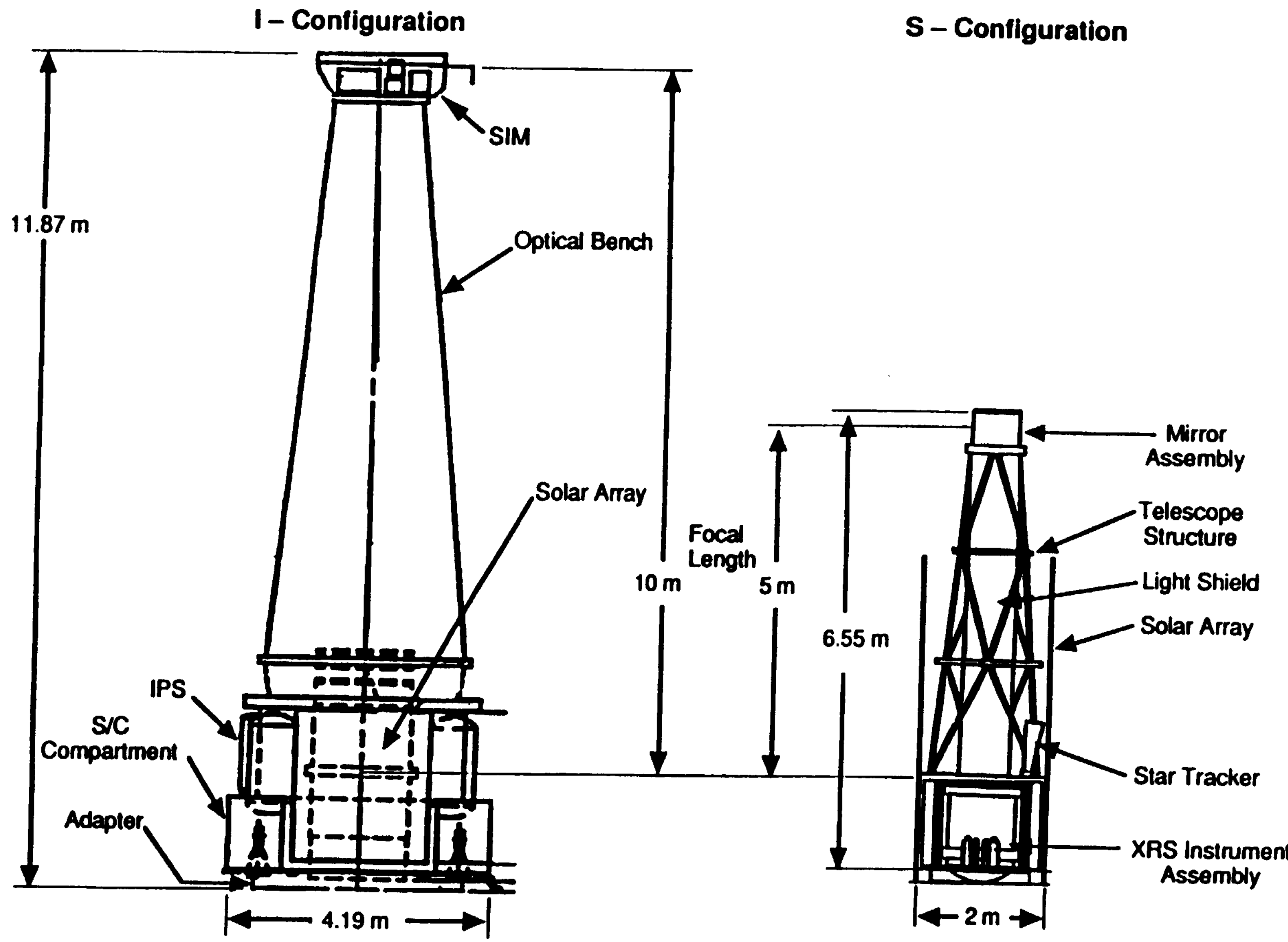

Figure 2. Configurations of the AXAF imaging and spectroscopy spcecrafts.

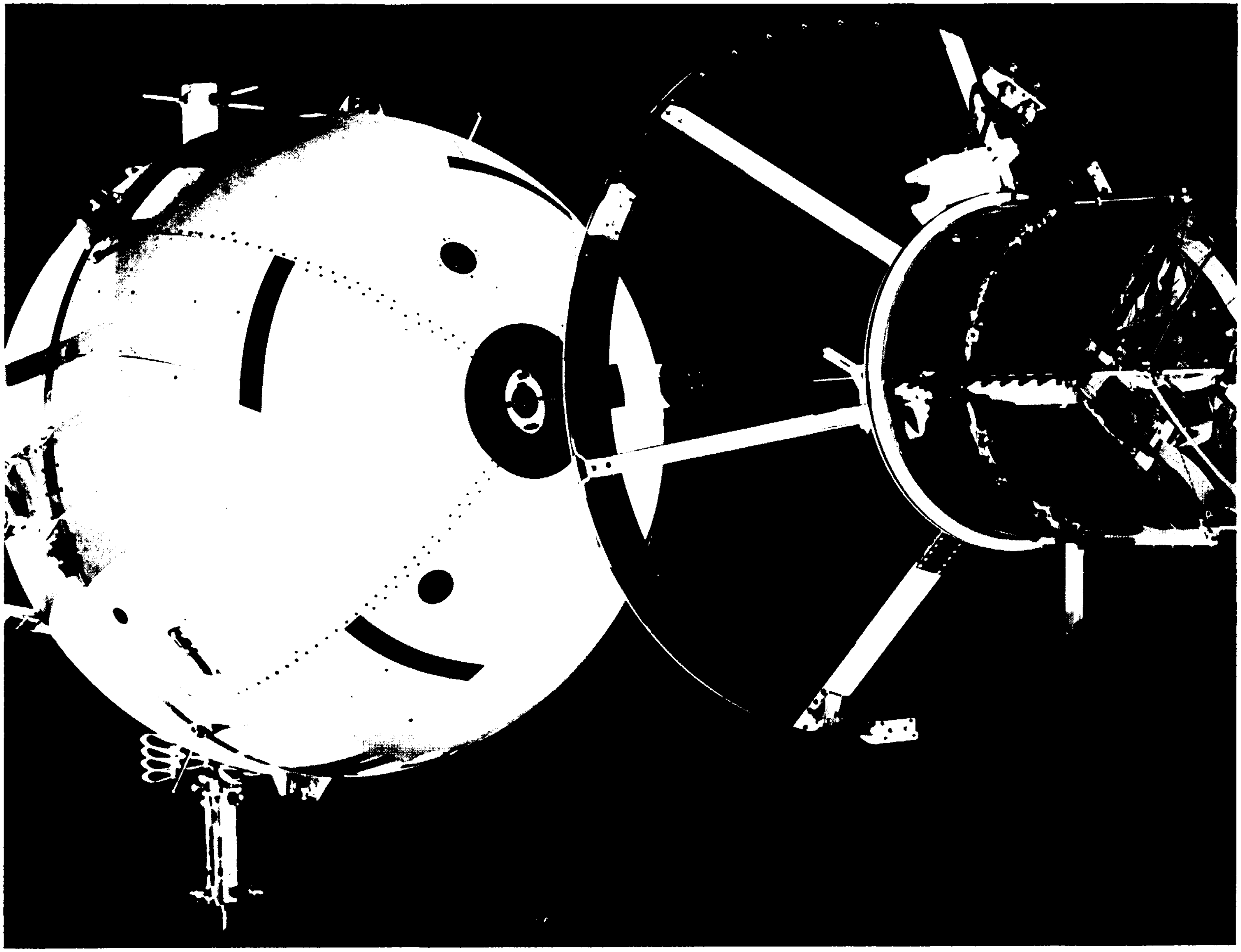

Figure 3. Tethered Satellite during deployment.