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APOLLO TELESCOPE MOUNT

-- Fact Sheet --

The Apollo Telescope Mount (ATM) is being developed to give space scientists a look at the sun's activity unencumbered by the fogging effects of the earth's atmosphere.

The National Aeronautics and Space Administration plans to launch the first of its manned solar observatories, ATM-A, in 1971. The space agency is joined by the scientific community and industry in developing the highly sophisticated satellite.

Five principal investigators, all experts in astronomy and solar physics, have designed five experiments for the first ATM flight. The eight instruments used in these five ATM experiments will obtain measurements of the sun in the extreme ultrame ultraviolet and X-ray portions of the electromagnetic spectrum which cannot penetrate the earth's atmosphere and obtain pictures of the sun's corona in the white light portion of the spectrum.

Dr. George E. Mueller, NASA Associate Administrator for Manned Space Flight, has said the ATM "provides a new great capability for a variety of solar and stellar scientific experiments" to be performed above the atmosphere, where the sun and stars can be clearly observed without being obscured by the earth's



AAP CLUSTER -- The Apollo Telescope Mount, shown at top, is one of the principal payloads in the first Apollo Applications flights. Other main elements are the Saturn I workshop, bottom, the airlock/multiple docking adapter and Apollo spacecraft.

atmosphere. The first ATM, one of the early Apollo Applications missions, is a forerunner of more advanced manned solar and stellar observatories which will provide an increased data gathering capability for astronomers.

A proposed follow-on manned orbiting observatory will have a new set of experiment hardware of greater sophistication than the first one. Some of the solar and stellar experiments already are under development.

Ground based scientists "see" the sun in only the visible light, and portions of the infrared and radio frequencies of the electromagnetic spectrum. Instruments carried by unmanned spacecraft and balloons have pioneered in the field of spaceborne solar astronomy.

The manned ATM offers opportunities not available with unmanned spacecraft. The scientist-astronaut will perform operations requiring judgment to select targets of scientific interest and to point the telescopes. He will control all ATM experiment operations in acquiring the data, including retrieval of films. These operations can be augmented by radio contact with scientists on the ground who can redirect the observing program based on ground data or verbal descriptions from the astronaut crew.

Where ATM fits into AAP Sequence

The Apollo Telescope Mount will be a part of a cluster of hardware in orbit which includes the orbital workshop and a manned Apollo command and service module (CSM). Saturn IB launch vehicles will place these payloads into an earth orbit of 300 statute miles.

The orbiting cluster will be assembled in the following manner:

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The Saturn I workshop will be placed into space first. A day or so later a manned Apollo spacecraft will be launched and will rendezvous and dock with the workshop which then will be made habitable for a 28-day stay. After this phase of the overall mission has been completed and the first crew has returned to earth, a revisit by another three-man crew will be made. This crew will be conducting medical experiments in the workshop for up to 56 days.

The ATM is planned for the firth flight. In this dual launch, the lunar module (LM) ascent stage/ATM launch will follow a manned command/service module launch. The two vehicles rendezvous and dock. After this operation, the LM ascent stage is manned and the combined vehicles rendezvous with the workshop which has remained in orbit after completion of the earlier portion of its mission.

The new crew reactivates the workshop. During the remainder of the mission the cluster will be inertially stabilized by the control system on the LM/ATM to maintain the axis of the telescope along the sun line. The control system consists of two main control loops. The outer loop utilizes a coarse sun sensor and is stabilized by three large control moment gyroscopes which provide basic cluster orientation and stability.

The inner loop is a fine pointing system driving the experiment package. This system uses a very precise sun sensor to accurately point the experiment instrumentation to crew-selected areas on the sun. Stability on the order of plus or minus 2-1/2 arc seconds is also provided by this vernier or inner loop control system by counteracting disturbances such as crew motions.

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During this flight, which is to last up to eight weeks, the astronauts will observe the dynamic phenomenon on the surface and in the corona of the sun.

ATM Experiments

Five authorities in astronomy and solar physics are designing the five major experiments for the first ATM mission. These experiments are being developed under the direction of the NASA-Marshall Space Flight Center.

Eight major solar instruments are employed in conducting this investigation. The devices are designed to provide high spatial and spectral resolution in the ultraviolet, X-ray, white light and hydrogen-alpha (6563A) bands of the spectrum and are particularly concerned with the active regions on the solar disk or in the corona.

The fiarly large telescopes are mounted in a 7-foot diameter cylindrical structure on their unique optical bench structure which is mounted on the ATM structural spar assembly.

The five principal experiments are the High Altitude Observatory (HAO) white light coronagraph, the Naval Research Laboratory (NRL) ultraviolet spectroheliograph and extreme ultraviolet spectrograph, the Harvard College Observatory (HCO) ultraviolet scanning spectrometer, a Goddard Space Flight Center (GSFC) X-ray telescope and an imaging X-ray spectrographic telescope by American Science and Engineering.

Dr. Riccardo Giaconni of American Science and Engineering Co., Cambridge, Mass., is the principal investigator for the X-ray spectrographic telescope. This experiment proposes to obtain X-ray photographs of temporal changes associated with solar activity, including flares, with a spatial resolution of about

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two arc seconds and to simultaneously record spectrally disbursed emissions over the range of two to eight angstroms with a resolution of a fraction of an angstrom.

An electronic flare detector, in addition to the main telescope, will give the astronaut a visual indication of flare buildup. This will allow him to select active regions and photograph the flares in the early X-ray rise periods.

James Milligan is the principal investigator for the Goddard Space Flight Center's X-ray telescope experiment.

This experiment uses a glancing incidence X-ray and extreme ultraviolet telescope with a resolution capable of recording the solar X-ray distribution over the complete solar disk and near corona in the 3 to 100 angstroms wavelength region. The information will be recorded on X-ray sensitive 35 millimeter roll film. There are also two proportional counters to monitor the total solar X-ray flux in the spectral regions of two to eight and eight to 20 angstroms. This data will be pulse height sorted and recorded for use by the astronaut for historical observation to identify possible flare precursor activity changes.

There are two Naval Research Laboratory extreme ultraviolet experiments to be flown on the ATM. J. D. Purcell of the NRL, Washington, D. C., is the principal investigator.

The first of the two instruments, Experiment A, is an extreme ultraviolet spectroheliograph and is designed to photograph images of the total disk in the various wavelengths between 160 and 650 angstroms. The main elements of the extreme ultraviolet spectroheliograph are a concave grating and a film strip camera. Experiment B, an extreme ultraviolet spectrograph, is designed to photographically record line spectrograms of the solar radiation between 1200 and 4400 angstroms from selected small areas on the solar disk and at different levels across the limb of the sun and into the corona.

An additional part of Experiment B is the extreme ultraviolet monitor. Housed in the same case and closely aligned with Experiment B, its purpose is to provide a television representation of the solar image in the extreme ultraviolet, which is used by the astronaut to identify solar ultraviolet features not visible at the longer wavelengths. Experiment B also can be commanded by its astronaut to display a television image of the spectrograph slit in white light.

Dr. Leo Goldberg of the Harvard College Observatory, Cambridge, Mass., is the principal investigator for the HCO ultraviolet scanning spectrometer experiment. This experiment acquires its primary data by photoelectric conversion technique with subsequent periodic data transmission to earth receiving stations. Photographic recording on 70 millimeter film of the spectrometers 30 arc second square slit imaged against a 20 arc minute solar background field in the hydrogen alpha wavelength (6563A) will be used for post mission data correlation. A similar image is available to the astronaut via TV monitor. The instrument spectrally scans 30 arc second square areas of the solar disk in a range of 300 to 1310A, searching the chromosphere, photosphere and corona for quiet sun phenomena, plus perturbations such as plages, flares, filaments and associated active regions. At least 30 arc second spatial and 1.5A spectral resolution is anticipated with a time resolution response of approximately 80

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milliseconds.

Dr. Gordon Newkirk, of the National Center for Atmospheric Research, High Altitude Observatory, Boulder, Colo., is the principal investigator for the HAO white light coronagraph. Its purpose is to monitor the brightness, form and polarization of the solar corona between one and one half and six solar radii from the center of the sun.

This instrument consists principally of the three forward (sun direction) external occulting disks, and a modifed Lyot coronagraph optical system, drive mechanisms, electronics and 35 millimeter camera.

Four of the five experiments have instrumentation built by industry. Ball Brothers Research Corp., Boulder, Colo., is manufacturing instruments for the High Altitude Observatory and the Naval Research Laboratory. American Science and Engineering is building the equipment for its experiment and the Harvard College Observatory (HCO) experiment. The Marshall Space Flight Center has the responsibility for manufacturing the Goddard experiment equipment. Perkin-Elmer has been awarded the prime contractor building the HCO Hydrogen-Alpha telescopes and the main ATM pointing telescope.

ATM Operation and Control

The LM ascent stage control and display panel will be the primary experiment work station. From this point the crew will control and monitor the experiments, the pointing control system, the instrumentation and communications and the power system.

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A television system will enable astronauts at the work station to view images of the sun recorded by the telescopes. There are six TV cameras in the experiment package, two TV display monitors, and the associated switches and other equipment on the control console.

Two of the cameras will observe the portions of the disk through hydrogenalpha telescopes, with different bandwidths affording discrimination of detail. A third camera will observe the whole sun in extreme ultraviolet. The fourth camera will be part of the NRL experiment B and will observe the spectrograph 3 x 60 arc second slit superimposed on the solar disk in white light with a narrow field of view. The fifth television camera will be a part of the HCO spectrometer, observing in hydrogen-alpha, the spectrometer slit position superimposed on the solar disk with a narrow field of view. The sixth camera will observe the sun's corona, as seen through the white light coronagraph occulting optics.

Video switches will allow the operators to observe the same experiment or two separate experiments at one time.

The control station displays allow the scientist-astronaut to monitor the solar activity and, in conjunction with investigators on the ground, determine sun features of scientific interest for detailed investigation. This activity not only involves control of which instruments are active and what program is desired, but allows the astronaut to precisely position the instruments on specific regions of solar activity and to traverse them accordingly.

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Film retrieval is an important part of the proposed ATM flight. Astronauts will retrieve and change film. This is done outside the spacecraft in pressurized suits. The film will be stored in the command module for the return trip to earth.

ATM Physical Description

NASA, where possible, is using a maximum amount of available Apollo equipment for the Apollo Telescope Mount mission module. This module is made up of a lunar module ascent stage and a "rack" in place of the descent stage. ATM design engineers estimate the weight of the ATM payload will be nearly 31,000 pounds. The ascent stage is expected to weigh about 11,000 pounds and the rack with its experiment package will be nearly 20,000 pounds.

Control station for the crew will be in the modified lunar module ascent stage. Modifications will be concerned mainly with the controls and displays and expendables for mission duration. Some of the special electronics added to the lunar module will include television monitors to view experiment displays, pointing control instruments, and other devices for experiment control.

The "rack" is an octagonal truss structure approximately 114 inches deep. It supports the ATM experiment package and the LM ascent stage. For the launch phase, the rack attaches to the launch vehicle at the four spacecraft-lunar module-adapter support points.

There is a 102-inch diameter support ring carried at the center of the rack. This ring supports the gimbal bearings required for fine pointing.

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The 82-inch diameter cylindrical experiment package is 135 inches long. An interior cruciform structure extends the length of the experiment package and divides the cylinder into four equal parts. The telescopes of the five ATM experiments are mounted on the cruciform structure.

This cylinder is actively cooled to maintain an internal surface temperature of 50 degrees by a liquid coolant which is circulated in the cylinder's skin.

A solar shield is located around the pointing end of the experiment package in such a way that it does not interfere with movement. This device protects the rack's electronic components from the sun's direct radiation. Temperatures in some 100 "black boxes" on the rack are to be passively controlled. Exhaust deflectors are to be placed beneath the lunar module's reaction control system engines to protect ATM components from exhausts and to protect the precision mirrors from contaminants.

A gimbal system attaches the experiment package to the support ring on the rack. The gimbal system allows the cylinder to be moved plus or minus two degrees in pitch and yaw and plus or minus 95 degrees in roll and is used for fine pointing control.

The ATM experiment package is mounted in the launch condition so it extends from the engine bay of the lunar module ascent stage to the forward bulkhead of the S-IVB stage.

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Large control moment gyros, being built by the Bendix Corp., will serve as stabilization actuators for the complete AAP cluster. Three of the 400 pound gyros will be used for each flight ATM. The devices have 22 inch wheels which revolve at high speeds, 8000 revoluations per minute, in pointing and controlling the attitude of the cluster.

Fine pointing of the experiment package will be achieved by a closed loop torque system operating the fine gimbals under the control of a fine sun sensor package and rate gyro package.

ATM power will be provided by a combination of solar cells and rechargeable batteries. Four solar cell arrays measuring some 1200 square feet in total area are being planned. Electric power generated by the solar cells will be routed through a distributor to each of the 18 power modules. There is a battery, a battery charger, a regulator and sensing and control circuitry in each power module.

ATM Manufacturing and Testing

ATM hardware is taking shape in the Marshall Center's manufacturing shops and the many testing areas are gearing up for extensive testing in 1968.

An ATM mockup has been at the Center for some time and is being used in engineering design exercises. There also is a neutral buoyancy test article at the Center for underwater tests.

Propulsion and Vehicle Engineering Laboratory is working on the design of the rack which will be built in the Manufacturing Engineering Laboratory. Vacuum chamber tests are underway in the Propulsion and Vehicle Engineering Laboratory. Two tests have been conducted in a 12-foot diameter chamber. These include a test of a quarter section of the ATM experiment cannister, using mockup versions of the Naval Research Laboratory and American Science and Engineering experiments, and of the fine sun sensor. There has also been a thermal deflection test.

ATM vibration testing will take place on newly-installed equipment in the Propulsion and Vehicle Engineering Laboratory. The prototype and flight models will be tested here.

Test Laboratory will do a vacuum development testing on a one quarter segment of the ATM rack this year. The lab will also do component qualification testing of the ATM control moment gyro in a thermal-vacuum chamber later this year.

The deployment mechanism of the ATM and workshop solar panels will undergo extensive testing in the Test Laboratory. A test fixture designed by Astrionics Laboratory will be provided to permit testing these panels under simulated low gravity conditions.

Quality and Reliability Assurance Laboratory has developed a nondestructive test system for locating bond defects in ATM honeycomb solar cell modules. The automated system was adapted by modifying an existing Sperry ultrasonic automatic scanning and recording system. A maximum of five modules may be tested.

Astrionics Laboratory, lead laboratory for the ATM, is testing components of the control moment gyro. Another important development in Astrionics is a device to simulate ATM stabilization conditions.

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ATM Project Management

Engineers and scientists at the NASA-Marshall Space Flight Center have the job of engineering the Apollo Telescope Mount, directing the development of the experiments, and integrating the entire system for the NASA Office of Manned Space Flight.

The ATM program at MSFC is under the direction of Leland Belew, director of the Saturn/Apollo Applications Office in Industrial Operations. Rein Ise is the ATM project manager and William Keathley is the ATM experiments manager.

Under the Marshall Center's lead laboratory concept, Astrionics Laboratory, under the direction of Dr. Walter Haeussermann, is charged with the ATM technical program. William Horton is assistant laboratory director for ATM. Arthur White is technical experiments manager. Gene Cagle is engineering manager, and Norman Gilino is systems engineer.

Dr. Ernst Stuhlinger, director of the Space Sciences Laboratory, is the chief scientist for the ATM project. Scientists in the Space Sciences Laboratory and engineers in the Astrionics Laboratory have been assigned to work with the principal investigators in developing the solar experiments.

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