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NEWS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

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WO 3-6925

FOR RELEASE: FRIDAY P.M.
November 1, 1968

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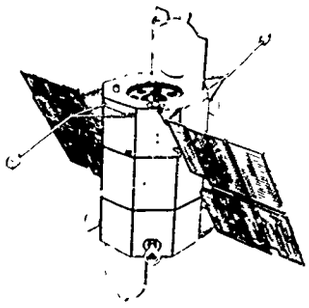

PROJECT: OAO-A2

PRESS KIT

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10/24/68

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OAO SET FOR LAUNCHING

A star-studying observatory, carrying 11 telescopes designed to investigate the past of the universe so astronomers can better determine its future, is scheduled for launching no earlier than Nov. 12 from Cape Kennedy, Fla.

The National Aeronautics and Space Administration's Orbiting Astronomical Observatory (OAO), weighing 4,400 pounds, is the heaviest and most automated unmanned satellite under development in the United States today.

OAO-A2 (OAO-II in orbit) is 10 feet tall and 21 feet wide with its solar arrays unfolded. It contains 328,000 separate parts, nearly three times the amount of the Surveyor spacecraft which successfully landed on the Moon.

-more- 10/24/68

A two-stage Atlas-Centaur rocket will place OAO-A2 into a circular orbit at 480 miles above Earth. The observatory's path will be inclined 35 degrees to the Equator. The time for one revolution will be 100 minutes.

OAO-A2 carries two experiments provided by the Smithsonian Astrophysical Observatory and the University of Wisconsin.

Both experiments will observe extremely young hot stars in the ultraviolet-the blue portion of the spectrum not visible to the human eye or Earth-based observatories. Some of these young stars are only tens of thousands of years old. Our Sun is believed to be middle age, about 5 billion years old.

It took 15 years and about 40 sounding rocket flights to obtain approximately three hours of ultraviolet data from some 150 stars. OAO-A2 can collect twice as much ultraviolet information in one day, and from much fainter stars. Over a six-month period, astronomers hope to study more than 50,000 stars.

In addition to young stars, OAO-A2 will observe instellar gas (dust)--the matter from which stars are formed and several planets in our solar system, Mars, Jupiter, Saturn, Neptune and Uranus. Some young stars in the Andromeda nebula and Magellanic clouds may also be studied.

The Andromeda nebula is a galaxy in the constellation Andromeda which is visible in the northern hemisphere. Magellanic clouds are near-galaxies observable only from the southern hemisphere. They look like patchy clouds.

OAO's computer system can store 256 instructions (commands), more than any previous unmanned satellite. Efficient on-board processing of scientific information on OAO will prevent overloading of ground stations that has occurred with previous scientific spacecraft.

Possibly the most significant feature of OAO-A2 capabilities is the pointing precision required to keep its telescopes aimed at a star so astronomers can receive precise scientific data. It has a high-performance coarse pointing accuracy of 1 minute of arc.

This is equivalent to distinguishing between the right or left eye of a person viewed at a distance of 500 feet. Future OAO's will be capable of 0.1 arc second.

Prior to the Space Age, astronomers could see through only two narrow "windows." Optical telescopes--Mt. Palomar for example--were used to see the visible light of stars while radio telescopes listened and measured radio waves emitted from celestial objects.

With OAO satellites, astronomers will have a new vantage point for seeing in the ultraviolet, infrared, X-rays and gamma rays, most of the necessary ingredients for knowing the solar system's make-up today and what course it might be taking.

Contributions in the visible and ultraviolet, from ground observatories and sounding rockets respectively, have greatly increased man's understanding of the solar system and universe.

Both techniques, however, are inconclusive as to the origin, evolution and present conditions of the universe.

Sounding rocket ultraviolet measurements cannot go beyond third-magnitude stars, the typical visible stars. OAO-A2 experiments can measure much fainter stars,--down to about the ninth magnitude.

A sounding rocket can observe one star for only a few minutes, while the Wisconsin experiment on OAO-A2 can observe a star in some cases for many hours.

Unlike that experiment, which studies one star at a time, the Smithsonian experiment is much like conducting a census of people on Earth.

The Smithsonian will survey and produce pictorial maps of more than 700 stars daily. If OAO-A2 lives for about six months, the experiment will photograph some 25 per cent of the sky.

These stellar maps should be as valuable to astronomers and future astronauts as road maps are to travelers on Earth.

Dr. James E. Kupperian, OAO Project Scientist from NASA's Goddard Space Flight Center, Greenbelt, Md., believes a working OAO system would revolutionize observational astronomy.

OAO-A2 is the second in a series of four observatories planned by NASA. OAO-I was launched into an almost perfect orbit April 8, 1966 but failed due to a malfunction in the power supply system and probable high voltage arcing in the star tracker. Several modifications to the OAO system have been incorportated into the OAO-A2 spacecraft as a result of the first flight.

OAO-B and C, scheduled for flights in late 1969 and late 1970, will carry new experiments and, because of the experiment requirements, will have pointing systems accurate within 0.1 arc second.

OAO-B will carry the Goddard 38-inch aperture telescope. OAO-C will have the Princeton University 32-inch aperture reflecting telescope.

The Orbiting Astronomical Observatory program is directed by NASA's Office of Space Science and Applications. Project management is under Goddard Space Flight Center.

Launch vehicle management is at the Lewis Research Center, Cleveland, and launch operations are under the direction of the Kennedy Space Center, Fla.

Grumman Aircraft Engineering Corp., Bethpage, N. Y., is prime contractor for the OAO spacecraft. Electro-Mechanical Research, Inc., Princeton, N. J., built the Smithsonian experiment and Cook Electric Co., Morton Grove, Ill., made the Wisconsin experiment.

Prime contractor for the Atlas-Centaur launch vehicle is General Dynamics-Convair, San Diego. More than 1,000 major subcontractors and vendors participated in the OAO-A2 effort.

-end-

OAO-A2 FACTS

Spacecraft

Weight:	4,400 pounds (1,000 pounds of scientific experiments)
Shape:	Octagonal cylinder, 7 feet wide, 10 feet long, wing span of 21 feet with solar paddles deployed, resembles a bat in flight
Stabilization-Control:	Six star trackers with a 1-minute arc accuracy; two are required at one time

Experiments

Smithsonian Astrophysical Observatory:	Survey the young, hot ultraviolet stars with four telescopes. A major contribution from this experiment could be detecting new stellar objects;
University of Wisconsin:	Will observe about 15 stars daily, with emphasis on studying one star at a time for extended periods (up to several hours).

Launch Information

Vehicle:	Two stage Atlas-Centaur
Complex:	36B, Cape Kennedy
Azimuth:	60 degrees True
Window:	3:15 to 5:15 a.m. EST (approx.)
Date:	November 12, 1968

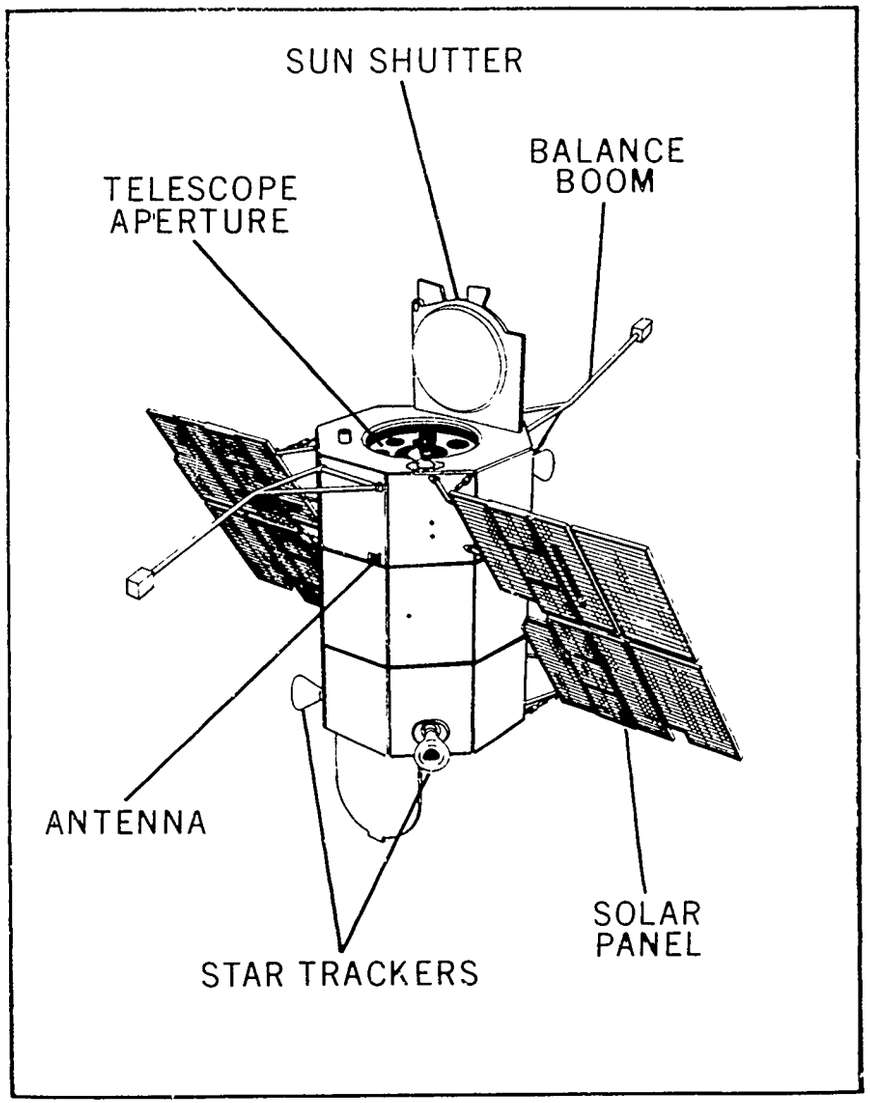
Orbital Elements

Apogee-Perigee:	Circular, 480 statute miles

Period:	100 minutes
Inclination:	35 degrees
OAO-A2 Ground Stations	Rosman, N.C.; Quito, Ecuador; Santiago, Chile; Orroral, Australia; Tananarive, Malagasy
Spacecraft Management	Goddard Space Flight Center Greenbelt, Md.
Launch Vehicle Management	Lewis Research Center, Cleveland
Launch Operations	Kennedy Space Center, Fla.
Prime Contractors	
Spacecraft:	Grumman Aircraft Engineering Corp., Bethpage, N.Y.
Launch Vehicle:	General Dynamics-Convair, San Diego

ORBITING ASTRONOMICAL OBSERVATORY-A2

GROSS WT.	-4,400 LBS.
INSTRUMENT WEIGHT	-1,000 LBS.
INSTRUMENT PAYLOAD	- 11 TELESCOPES
STABILIZATION	-ACTIVE 3-AXIS (6 STAR TRACKERS)
POINTING ACCURACY	-1 ARC MIN.
ORBIT	-CIRCULAR, 480 S. MI. INCLINATION 35°
LAUNCH VEHICLE	- ATLAS/ CENTAUR



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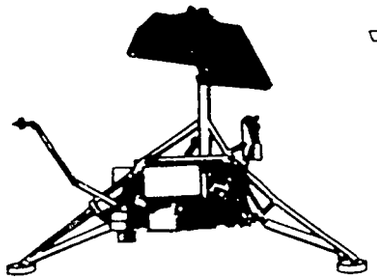
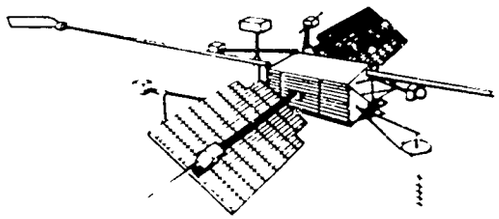
SPACECRAFT COMPLEXITY





SUB-SYSTEM	OAO-A2 PIECE PARTS	SURVEYOR PIECE PARTS	OGO PIECE PARTS
SCIENCE	(VARIED PAYLOADS)	19,300	24,000
COMMUNICATION & DATA HANDLING	118,200	TELECOMMUNICATIONS 23,600	34,200
STABILIZATION & CONTROL	18,700	GUIDANCE & CONTROL 21,300	2,600
POWER	85,500	5,900	33,500
STRUCTURE	15,600	12,500	6,000
TOTAL PARTS	328,000	82,600	100,300

NASA G-69-1711

OAO SCIENTIFIC OBJECTIVES

Since the invention of the telescope in the 17th Century, astronomers have collected substantial amounts of new knowledge from stars.

More recently, astronomers have received stellar information from balloons, aircraft and sounding rockets.

OAO spacecraft will take the astronomers' instruments above the distorting effect of the Earth's atmosphere for detailed observations of the entire electromagnetic spectrum.

Some of the areas which have long interested astronomers, and which OAO-A2 will investigate in great detail for the first time in the ultraviolet:

- Study giant stars with masses more than 100 times as large as our Sun. These stars should blow up with violent explosions, or Supernovae. Why don't they blow up?

- Study stellar temperature of young stars to learn more about their ages.

- Study helium content of stars to determine nuclear processing which has gone on in recent years.

- Study stellar chromosphere (outer edges of stars). Are the chromospheres more active in the giant stars or the dwarfs?

- Study the Red Giant stars, which in their late stages, have burned most of their hydrogen, causing their cores to contract.

- Study various types of stars to see how their chemical composition differs.

- Study the origin, evolution and structure of the more massive, hot stars 1 million years old.

- Discover new classes of objects which might be brighter in the ultraviolet than current theories predict.

- Study interstellar matter, from which stars are born, to determine the amount of absorption between stars and Earth which would provide clues on the amount of dust in space.

- Study stellar hurricanes, which are blowing from stars millions to billions times more intensely than solar wind.

- Study young stars in spiral arms of other galaxies.

- Make observations which will assist in the difficult problem of determining the internal configurations of stars.

- Study the color and distribution of unusual stars.

OAO SPACECRAFT

OAO-A2 is an eight-sided spacecraft 10 feet long and seven feet wide. Eight sets of panels, consisting of two arrays of four panels each covered with more than 109,000 solar cells, give the observatory an over-all width of 21 feet.

The internal structure of the main body includes a four-foot-diameter central tube where the experiments are mounted, surrounded by vertical trusses and horizontal shelves. The bays formed by the trusses and shelves provide space for mounting spacecraft electronics and data handling systems.

OAO-A2's main body is constructed of riveted or spot-welded aluminum alloy. Extensive use has been made of aluminum honeycomb in locations where high rigidity is needed.

A thin non-structural covering of specially fabricated aluminum coated with Alzak (an aluminum oxide) covers the main body except for the experiment opening. The treated-aluminum-covering is a vital part of the passive thermal control system.

Attitude and Control System

Success of the OAO-A2 mission depends on the ability of the 4,400-pound observatory to point its astronomical instruments at pre-selected objects in space. The OAO attitude control system is one of the most advanced ever developed.

Star Trackers

Six gimbaled star trackers are the heart of the system.

After the observatory separates from the Centaur stage, the spacecraft will go into an automatic "sun bathing" mode stabilizing on the Sun.

The first star tracker will be turned on in orbit No. 25. The remaining five trackers will be turned on during orbits 27 and 28.

The equipment used to sense OAO motions consists of rate gyros to measure initial tumbling rates (after spacecraft separation), solar sensors to establish the direction of the Sun, the six star trackers and one bore-sight star tracker.

The star trackers are designed to acquire selected guide stars, track them continuously and at the same time measure their direction with respect to the spacecraft axes.

The following stars and constellations have been selected as guide stars for OAO-A2's star trackers:

Sirius	Adara	Kaus Australis
Carina	Aried	Orion
Vega	Bellatrix	Alhena
Rigel	Castor	Sagittarius
Achernar	Alioth	Grus
Centaurus	Nath	Sirrah
Capella	Mirzam	Arcturus
Spica	Crux	Fomalhaut
Procyon	Alkaid	Aldebaran
Altair	Vela	
Regulus	Pavo	

To initiate control maneuvers, the spacecraft houses a nitrogen gas jet system -- used primarily for initial stabilization -- a coarse momentum wheel system for star tracker control.

The key to the OAO control system is the star tracker system. It must point the observatory to an accuracy of one minute of arc and maintain this pointing direction within 15 arc-seconds for 50 minutes.

This accuracy is needed to assure that desired "target" stars fall within the field of view of the experiments.

Each star tracker is a small 3.5-inch reflecting telescope mounted in two degree-of-freedom mechanical gimbals.

The incoming target star image is split into two light beams to provide error signals about the two gimbal axes. The beams are modulated by a system of vibrating reeds, detected by a photomultiplier and electrically separated into error signals.

The resulting error signals are then used to drive direct current torquer motors in the gimbal axes. Gimbal angles are measured by variable capacitance transducers with a resolution of about five arc-seconds.

Two trackers are sufficient to provide pointing information under normal operating conditions.

However, six trackers are used to allow for occultation of guide stars by the Earth, to maintain proper reference when the spacecraft shifts guide stars and for redundancy to improve the lifetime of the observatory.

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OAO-A2 SCIENTIFIC EXPERIMENTS

The Smithsonian Astrophysical Observatory and the University of Wisconsin provided the two experiments for the OAO-A2 mission.

Both experiments will measure radiation in the ultraviolet portion of the electro-magnetic spectrum.

While both experiments involve the ultraviolet, their assignments differ. The Smithsonian will map, or survey, 700 stars daily providing astronomers with their first detailed ultraviolet stellar map.

The Wisconsin Experiment Package will study, in great detail, one star at a time to define better the chemical composition, pressure and density of stellar objects. This information could result in revision of present theories of stellar origin and revolution.

The two experiments can complement each other. If Smithsonian should discover a new star or object, Wisconsin could then "zero in" for a close-up look.

If OAO lives for six months, Smithsonian will have charted as many as 50,000 stars and Wisconsin more than 1,000.

Celescope

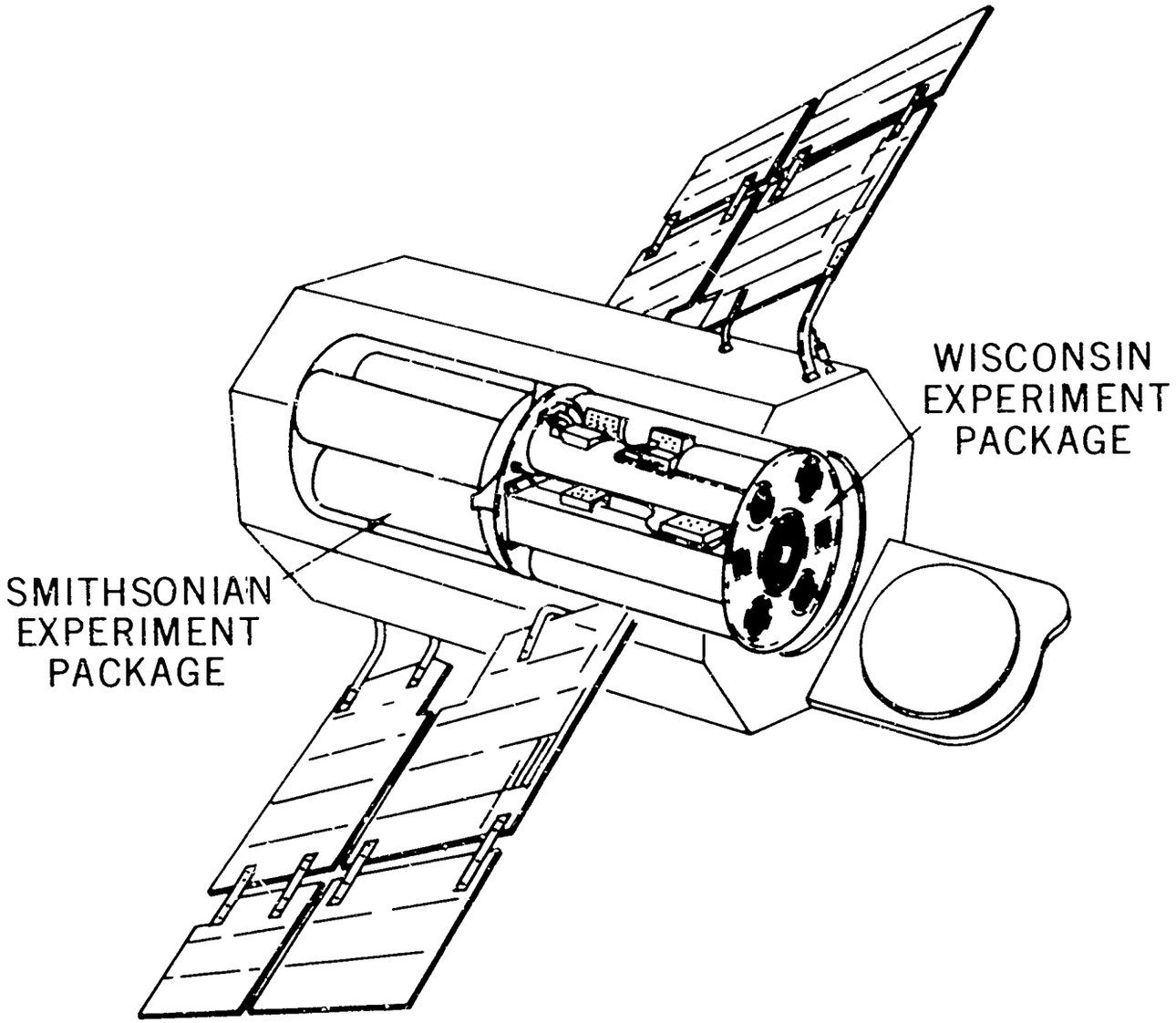
Experimenter: Dr. Fred Whipple
Smithsonian Astrophysical
Observatory, Cambridge, Mass.

Celescope (celestial telescope) will measure the brightness of young stars in four spectral bands between 1,000 and 3,000 angstroms (an angstrom is about 254-millionths of an inch).

The entire Smithsonian experiment weighs about 500 pounds.

Celescope will measure with four large-aperture television cameras using broad-band television photometers, significant numbers of O, B, A and F stars in the longer wavelengths and O, B and A stars in the shorter wavelengths.

A special type of celevision tube, called the "uvicon," sensitive only to ultraviolet lights, was developed for Celescope.



PHANTOM VIEW OF OAO-A2 EXPERIMENTS

NASA G-69- 1713

In six months Celescope will have catalogued more than 25 per cent of the sky (about 50,000 stars) down to magnitude 9, or about 12 times fainter than what the human eye can see.

Optical data collected by Celescope will be converted into numerical data by instrumentation aboard OAO-A2 and transmitted back to Earth.

On the ground the data will be analyzed, and with the aid of computers, converted into photographs, new maps and catalogs of the celestial sphere, as it looks in the ultraviolet.

If possible, exposure of the television cameras will be increased to permit ultraviolet observation of other objects, such as bright nebulosites (large class of celestial structures composed of matter in a gaseous or finely divided state), radio sources, planets (including Earth), and perhaps the newly discovered quasars.

Quasars, until 1963, were thought to be faint stars in the Milky Way. They are considered among the most distant celestial objects man has observed. The farthest quasars are now believed to be some 4,000 million light years from the Milky Way.

More than 30 quasars have been identified and several new ones are expected to be discovered.

Celescope will be turned on about the eighth day in orbit. The first three days of stellar pictures will be taken in the Constellation Draco, an area of the sky which is not very crowded with stars.

After Wisconsin has the spacecraft for one week, Celescope will take pictures in a very crowded region in the southern Constellation Scorpius (in the Milky Way).

When the OAO-A2 has reached the plane of the Milky Way, about one month after launching, Celescope will begin photographing 700 stars daily.

Smithsonian plans to publish the first ultraviolet catalogue about six months after launching.

The four, identical high resolution telescopes, with 12.5-inch diameters, four filters and four image-forming uvicon tubes will image sections of the sky about 2.8 degrees in diameter in four spectral ranges.

The Uvicon signals will be quantized into 128 levels, providing an accuracy of about 0.1 magnitude. A complete image requires the transmission of about a half-million bits of information. Between one and four photos are planned per orbit, depending on the length of time OAO is over ground stations.

Normal exposure times will be about one minute.

Wisconsin Experiment Package

Experimenter: Dr. Arthur D. Code
University of Wisconsin,
Madison, Wisc.

The Wisconsin experiment will be the first large scale effort to obtain detailed ultraviolet photometric measurements on stars and nebulae.

Comprised of seven separate photometric systems, it will study selected stars, especially the hot young ones, in the 1,000-3,300-angstrom region for extended periods.

An average of one star per orbit will be studied. If OAO-A2 operates for six months, Wisconsin could study more than 1,000 stars.

In addition to stellar study, Wisconsin hopes to obtain the first ultraviolet information on instellar gas (dust) in the Orion Nebula (Orion Sword). It will measure line emissions which light up in the ultraviolet like a neon sign.

Multiple observations will be made on selected targets over a period of time to check observational consistency and to verify that the energy distribution is not intrinsically variable.

The Wisconsin experiment will be turned on for the first time about five days after launching. Over a two-day checkout period, it will take photometric measurements from six stars including the well known Canopus which has been used as a navigational star for several of NASA's deep space missions.

The Wisconsin experiment might obtain information, within the first few days of operation, on Olber's paradox which concerns cosmology (theory of the creation of the universe).

Olber's paradox states that if the universe were infinite, an individual on Earth could look in any direction, and eventually this line of sight would intersect a star. If this were the case, the entire sky would be as bright as the Sun, and the temperature on Earth would be some 6,000 degrees.

Why, then, is the sky dark at night? Astronomers say this isn't easy to understand unless the assumption is made that the universe is finite.

The experiment, weighing 450 pounds, consists of three separate types of instruments -- four stellar photometers, a nebular photometer and two scanning spectrographs.

The stellar multicolor photometer system, intended primarily for measurement of stars, consists of four eight-inch telescopes, each sending information to a separate three-color filter photometer.

The multicolor filter photometer system, designed primarily to study nebulae, consists of a 16-inch telescope.

The scanning spectrometer system employs two objective grating spectrometers with an aperture of about six by eight times.

In general, the experiment works as follows: The stellar photometer-telescopes and associated mechanisms measure the intensity of incoming ultraviolet light and convert these measurements into electrical signals. By using a rotating filter wheel, measurements at different wavelengths are obtained. The nebular photometer performs similarly.

The spectrometer spreads the star light into a "rainbow" allowing the independent measurement of various wavelengths (colors) without the need for filters.

The experiment optics are protected by a sunshade located at the top of the spacecraft.

During the launch phase the sunshade will be closed over the experiment tube. After orbit is attained, the sunshade will be opened to permit experiment operation.

If the OAO-A2 control system is inadvertently pointed toward the Sun, the shade will close automatically to keep out potentially damaging solar rays.

OAO-I

OAO-I was successfully launched from Cape Kennedy into an almost perfect orbit about 500 miles high Apr. 8, 1966. After several days, the mission was declared a failure due to an electrical malfunction.

Causes of the OAO-I major problems have been attributed to a failure in the power supply system and probable high voltage arcing in the star trackers.

In its 20-orbit lifetime OAO-I successfully performed spacecraft operations in several complex areas, which are required in an OAO system.

The spacecraft performed its sequence of stabilization and control operation, consisting of rate stabilization after separation; coarse and fine solar pointing; roll-search, and coarse pointing wherein the star trackers provide a celestial reference system for spacecraft stabilization.

This stabilization was achieved on several orbits.

The spacecraft command system received, verified, stored, and executed commands accurately.

The first sign of a potential problem occurred about eight minutes after the observatory separated from the Agena rocket. It is believed than an electrical transient occurred, after initial star tracker turn-on, which affected the status of some of the spacecraft subsystems.

A second star tracker experienced an unscheduled turn-on and the stabilization and control mode of roll-search was terminated.

Subsequent to this electrical transient, data indicated that all equipment resumed normal operation except for a loss of some channels of spacecraft status data.

The two major problems that seriously affected the mission operations were the inability to program spacecraft operations reliably because of spurious clock resetting, and the high battery temperature which shortened the battery lifetime.

Battery power was lost after the 20th orbit and no further spacecraft data were received. The experiments were never activated.

Several required modifications have been made to OAO-A2 to insure mission success.

The battery charging system has been redesigned to improve system reliability and redundancy, to simplify logic circuitry, to parallel battery outputs and to provide ground command control of the battery charge control circuits and batteries.

Modifications have been made to the star tracker system to prevent high voltage induced arcing and corona discharge.

In addition, the intensive investigations by NASA of the OAO-I program development, test and operations history have resulted in design and program modifications directed toward increasing the reliability and operating efficiency of the OAO system in order to insure the success of the second OAO mission. Such changes were within the schedule of the pacing modifications established by the two design changes required.

-more-

ATLAS-CENTAUR LAUNCH VEHICLE

The Orbiting Astronomical Observatory, weighing 4,436 pounds, is the heaviest payload the Atlas-Centaur (AC-16) has been called on to launch. On the OAO mission, Centaur's task is to place the spacecraft into a circular orbit 480 statute miles above the Earth. After separation, Centaur must be moved into another orbit to avoid confusing the instruments on the spacecraft.

The first seven operational missions for Centaur were launches of Surveyor spacecraft to the Moon. This very successful series of launches has proved the great value high energy upper stages can have in the space program. Centaur, which was developed under the direction of NASA's Lewis Research Center, Cleveland, was the first U.S. vehicle to use the liquid hydrogen-liquid oxygen propellant combination.

AC-16 consists of an Atlas SLV-3C booster combined with a Centaur second stage. The two stages are 10 feet in diameter and are connected with an interstage adapter. Both Atlas and Centaur stages rely on internal pressurization for structural integrity.

The Atlas booster develops 395,000 pounds of thrust at liftoff using two 168,000 thrust booster engines, one 58,000 thrust sustainer engine and two vernier engines developing 670 pounds thrust each.

The Centaur second stage including the nose fairing is 65 feet long. It is powered with two improved RL-10 engines, designated RL-10, A-3-3. The RL-10 was the first operational hydrogen-fueled engine developed for the space program.

Centaur carries insulation panels and a nose fairing which are jettisoned after the vehicle leaves the Earth's atmosphere. The insulation panels, weighing about 1,200 pounds, surround the second stage propellant tanks to prevent the heat of air friction from causing excessive boil-off of liquid hydrogen during flight through the atmosphere. The nose fairing protects the payload from the same heat environment.

Launch Vehicle Characteristics

Liftoff weight including spacecraft:*	319,918 pounds
Liftoff height:	135 feet 4 inches
Launch Complex:	36 B
Launch Azimuth:	60 degrees

	SLV-3C Booster	Centaur Stage
Weight:*	279,906 lbs.	40,012 lbs.
Height:	70 feet	65 feet, 4 inches (with payload fairing)
Thrust:	395,000 lbs. (sea level)	30,000 lbs. (vacuum)
Propellants:	Liquid oxygen and RP-1	Liquid hydrogen and liquid oxygen
Propulsion:	MA-5 system (2-168,000 lb. thrust engines, 1-58,000 lb. sustainer engine and 2-670 lb. thrust vernier engines.)	Two 15,000 pound thrust RL-10 engines. 14 small hydrogen peroxide thrusters.
Velocity:	5335 mph at BECO 6452 mph at SECO	15,745 mph at s/c separation
Guidance:	Pre-programmed autopilot through BECO. Switch to Centaur inertial guidance for sustainer phase.	Inertial guidance

*Measured at two inches of rise.

Several changes had to be made to prepare Centaur for the OAO launch. The major changes were redistribution of the weight of the payload on the forward end of the Centaur tank and a new longer nose fairing to accommodate the large spacecraft.

The new nose fairing is 32 feet long, approximately 10 feet longer than the fairing used for Surveyor. It is of standard fiberglass construction, using 16 explosive bolts and a spring separation system to jettison after its flight through the atmosphere. Nose fairing jettison tests were conducted in the Space Power Chamber at Lewis Research Center to help qualify the new shroud for flight.

The increased length of the launch vehicle and nose fairing and the change in mass distribution made it necessary to move the Atlas displacement gyro package from its usual location in a pod to the nose of the Atlas booster and moving the Atlas rate gyro five feet forward on the Atlas.

FLIGHT SEQUENCE

Atlas Phase

After liftoff, AC-16 will rise vertically for about 15 seconds before beginning its pitch program. Beginning at two seconds after liftoff and continuing until T+20 seconds the vehicle will roll to the desired flight azimuth of 60 degrees. The roll program on AC-16 takes five seconds longer than usual because of the required inclination of the final orbit.

After 153 seconds of flight, the booster engines are shut down (BECO) and jettisoned. The Centaur guidance system then takes over flight control. The Atlas sustainer engine continues to propel the AC-16 vehicle to an altitude of 184 miles. Prior to sustainer engine shut down, the second stage insulation panels are jettisoned.

The Atlas and Centaur stages are then separated by an explosive shaped charge that slices through the interstage adapter. Retro-rockets mounted on the Atlas slow the spent Atlas stage.

Centaur Phase

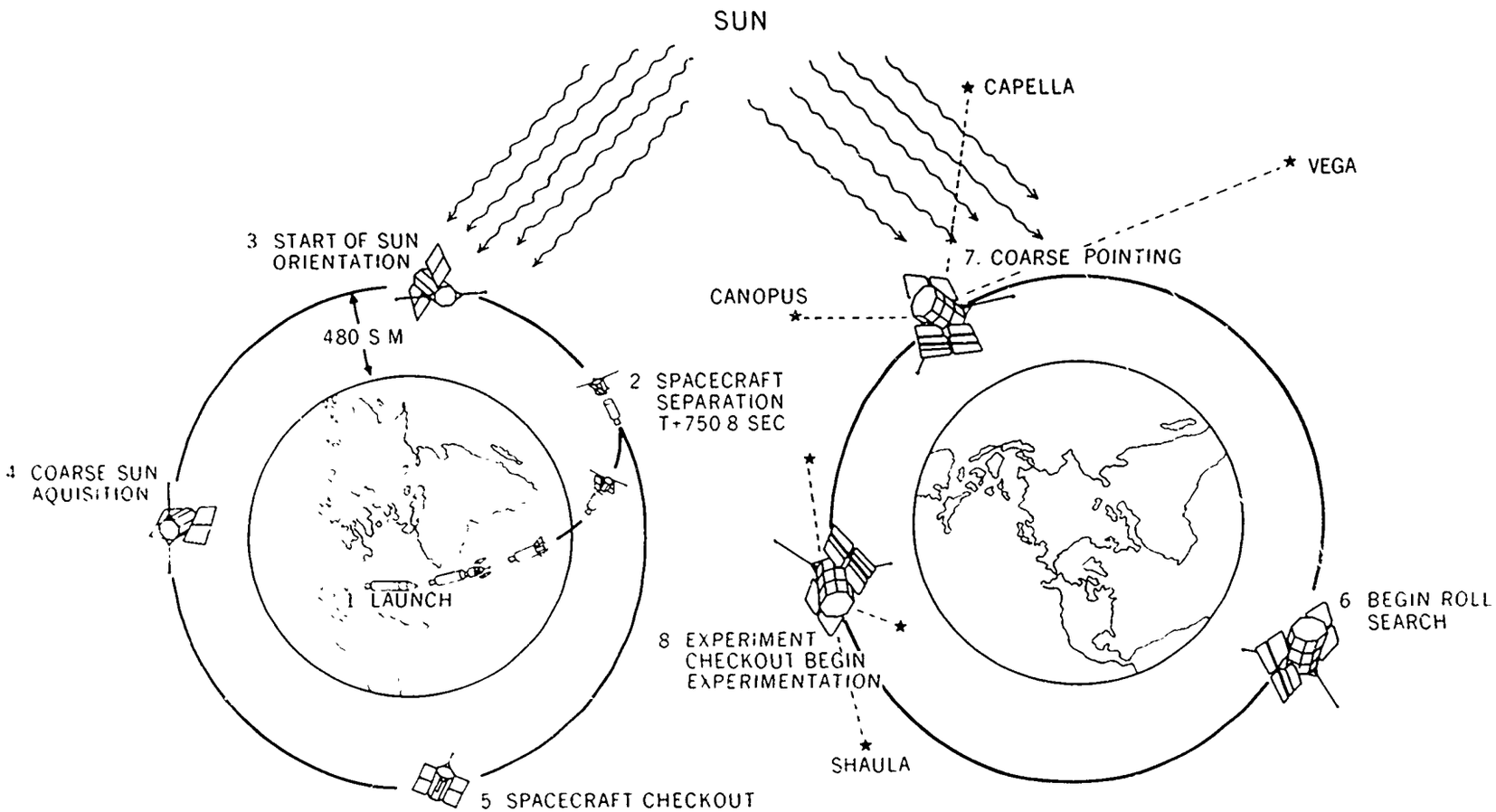
At four minutes five seconds into the flight, the Centaur's two RL-10 engines are ignited for a planned seven minute eight second burn. This will place Centaur and the spacecraft into a near circular orbit at an altitude of approximately 480 miles.

Twelve seconds after main engine start, the nose fairing around the spacecraft is separated. At main engine start plus 15 seconds, Centaur initiates a right yaw maneuver to attain the final orbital inclination of 35 degrees. The original launch azimuth was 60 degrees to avoid the Bermuda area during reentry of the Atlas sustainer engine and tank and the nose fairing.

Separation

Separation of the OAO spacecraft takes place by firing explosive bolts on a V-shaped metal band holding the spacecraft to the adapter. Compressed springs then push the spacecraft away from the launch vehicle at a rate of about 3.2 feet per second.

OAO -A2 MISSION PHASES



ASCENT PROFILE

ROLL SEARCH TO COARSE POINTING

NASA G-69-2064

Retro Maneuver

Five minutes after spacecraft separation, the Centaur stage attitude control thrusters are used to reorient the vehicle. The 50-pound thrust vernier engines are then fired to settle the propellants. The remaining liquid oxygen and liquid hydrogen are vented overboard to provide enough thrust to place the Centaur stage in a slightly different orbit from the spacecraft. The Centaur stage may be visible to the spacecraft for 8-12 days. It will then be out of sight of the spacecraft for 92-138 days and then back in view a period twice as long as the original period during which it was visible to the spacecraft. This cycle will then be repeated at the same intervals.

The final orbital period of the Centaur stage will be only a few seconds longer than that of the spacecraft. The spacecraft period will be approximately 100.29 minutes.

The final Centaur orbit will have an apogee of 504 miles and perigee of 456 miles.

Launch Window

The OAO-A2 launch window opens at approximately 3:17 a.m. EST, Tuesday, Nov. 12 and closes about 2 hours later. In case of delays, the window opens 30 seconds later each day. The window is calculated so that the Sun will be low on the horizon as viewed from the spacecraft at separation.

Atlas-Centaur Flight Sequence

EVENT	NOMINAL TIME MINUTES, SECONDS	ALTITUDE STATUTE MILES	SURFACE RANGE, STATUTE MILES	VELOCITY MPH
Liftoff	0	0	0	0
Booster Engine Cutoff	2'33"	52.3	35.3	5335
Booster Jettison	2'36"	55.9	38.1	5376
Jettison Insulation Panels	3'18"	104.4	80.3	5819
Sustainer Engine Cutoff	3'55"	148.2	123.3	6452
Atlas Separation	3'57"	150.6	125.8	6426
Centaur Engine Start	4'06"	161.9	137.9	6278
Jettison Nose Fairing	4'18"	176	153	6284
Centaur Engine Cutoff	11'26"	483.9	1102	15,740
Spacecraft Separation	12'16"	484	1296	15,745
Start Centaur Reorientation	17'22"	484.1	2486.2	15,743
Start Centaur Retro-thrust	18'57"	483.9	2854.3	15,744

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SPACECRAFT ORBITAL OPERATIONS

Orbital operation of OAO-A2 is divided into four phases. They are "survival" (0-1 days), observatory checkout (2-10 days), initial experiment operation (11-24 days) and extended operations (25 days - observatory lifetime).

Survival

In this phase all procedures are directed toward assuring survival of the spacecraft.

The command memory is programmed automatically to carry the spacecraft to the "sunbathing" attitude with a minimum expenditure of gas, and without aid of ground stations.

Operations personnel will analyze data to determine that spacecraft stabilized, battery charging is safe, thermal conditions are within predictions and the solar array output (power system) is normal.

Observatory Checkout

This checkout, a comprehensive shakedown of the spacecraft, experiments and ground stations will begin on the second day and end on the 11th day (orbits 16 through 139).

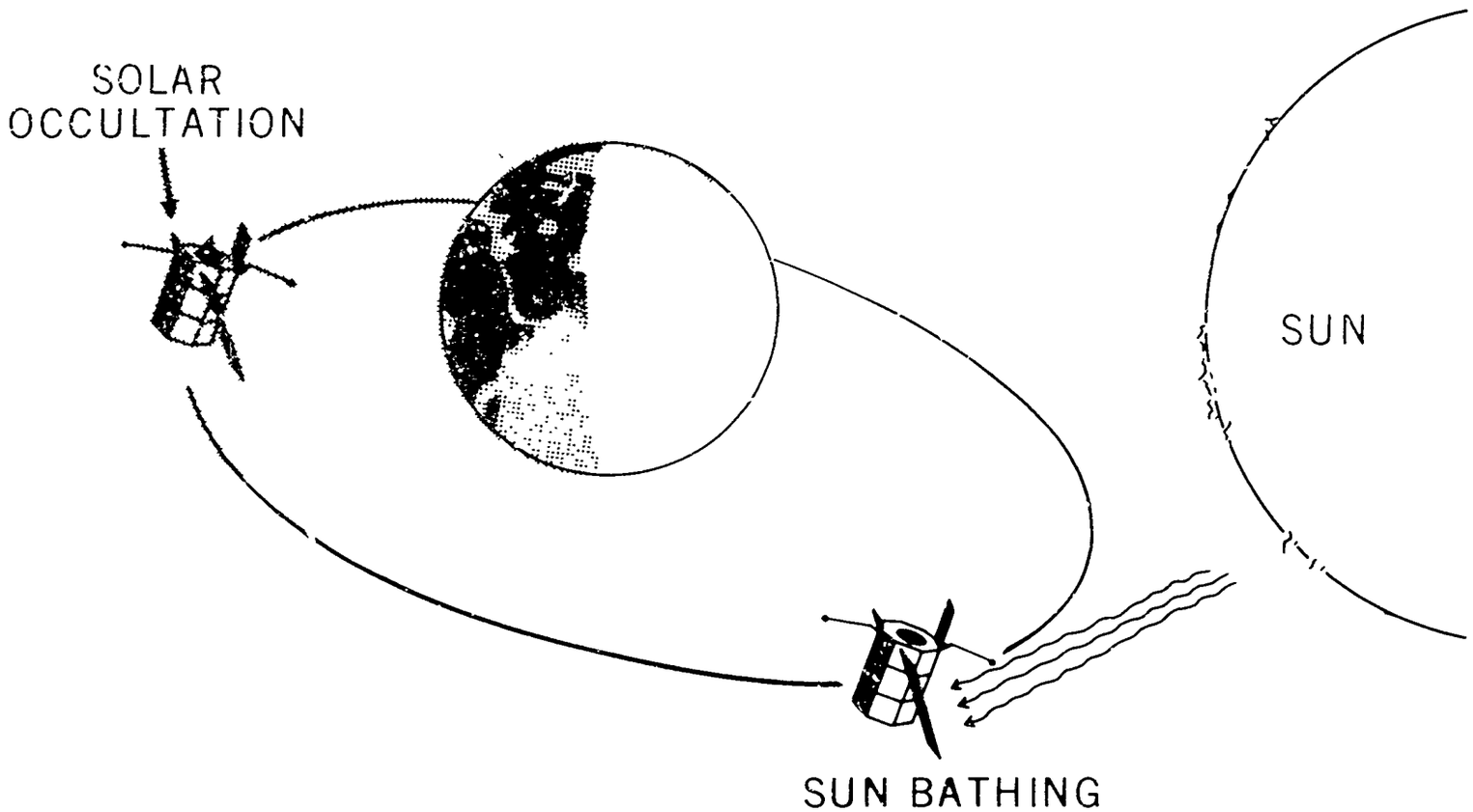
Initial turn-on of all spacecraft subsystems, including experiments, will occur while the observatory is still being automatically controlled in the sunbathing mode.

During spacecraft checkout, extreme caution will be taken prior to turning on high voltage subsystems. This permits proper outgasing and reduces the likelihood of "arcing" or "corona."

High voltage systems will be turned on initially only when the spacecraft is under Rate And Position Sensor control. With this automatic control, the spacecraft's attitude remains fixed for extended periods without having to use the star trackers.

The first star tracker high voltage will be turned on in orbit 25. The other five trackers will be turned on in orbits 27 and 28.

OAO-A2 RATE AND POSITION SENSING SYSTEM (RAPS)



NASA G-69-1712

Additional high voltage turn-ons will be the Wisconsin and Smithsonian experiments on orbits 56 and 85 respectively.

Experiment checkout is scheduled for six days (orbits 56-139). Wisconsin will do observations and photometry of six stars in a two-day checkout period (orbits 56-84). Smithsonian experiment will be exercised and analyzed from orbits 85 to 139.

Initial Experiment Operations

This phase will continue from 11th through 24th day. Observatory pointing will be specified by the experimenters during this period.

Extended Operations

Objective of this phase, which begins about 25 days after launch, is to obtain as much astronomical information as possible and to continually improve the operational efficiency of the OAO space-ground systems.

Officials at Goddard will attempt to improve the efficiency of experiment scheduling, ground station operations, and data analysis so a maximum of scientific information can be obtained without endangering spacecraft performance.

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ASTRONOMY BACKGROUND

Birth

The theory of most astronomers is that the first stage in stellar formation is contraction, due to gravitational force, of a very large volume of gas, mainly hydrogen and dust.

During contraction, turbulence may cause the large mass to break up into smaller parts leading eventually to a group of stars or clusters.

Because of the gravitational contraction, the surface temperature of the proto-star (as it is now called) has greatly increased. Its brightness has increased less rapidly because the radius has steadily decreased.

The temperature during the early stages would still be too low for radiation to be detectable in the visible part of the spectrum. However, the proto-star would emit energy in infrared.

Growing Up

In about 15 years the contracting proto-star becomes hot enough (2,200 degrees F.) to become visible. The more massive the proto-star the more rapidly it contracts and becomes visible.

Shortly after the young star becomes visible, depending on its mass, it stabilizes and is called a main sequence star.

The young, bright stars emit most of their energy in ultraviolet. Their chemical composition is about 80 per cent hydrogen, 20 per cent helium, and one part in 1,000 contaminants (carbon, nitrogen and oxygen).

These contaminants provide electrons to the stellar atmosphere, causing the star to heat up because the radiation cannot escape as easily.

At least 90 per cent of the known stars are main sequence stars. They will remain in this category until about 20 per cent of their hydrogen is burned up.

When this happens the hot core of the star, where the thermonuclear reactions have been occurring, is mostly helium. The energy-producing processes in the star's interior have changed and it begins to move away from the main sequence category.

Stars with masses 1.1 to 1.4 times greater than the Sun are generally understood. However, the destiny of the large, massive stars is rather uncertain.

Most of the stars not in the main sequence are red giants (super-giants) and white dwarfs.

Red Giants

These giant stars, ranging in surface temperature from about 5,400 to 7,500 degrees F., are either orange or red in color. They are from a hundred to several thousand times more luminous than main sequence stars of the same spectral class.

The difference in the ratio of brightness increases with decreasing temperature. This means that the brighter stars must have larger radii than those on the main sequence with identical temperatures.

The red giant Capella (Auriga constellation) is as hot as the Sun and its brightness is about the same. However, because the star's diameter is some 12 times greater than the Sun, it emits about 150 times as much light.

The red super-giants, such as Betelgeuse (pronounced beatle juice), have even larger radii than the red giants with the same surface temperatures.

Betelgeuse, in the constellation Orion, has a radius of 180 million miles. It would stretch from the center of the Sun to the Earth, and some 90 million miles beyond.

Astronomers have generally concluded that the temperatures of red giant, and super-giant, stars are several hundred degrees less than main sequence stars of the same spectral class.

White Dwarfs

The white dwarfs are very small and heavy, compared to other stars. They make up about 10 per cent of all the stars in the galaxy. They are very faint, about 10-15 magnitude.

Astronomers need more background on their evolution, so new light can be shed on their past from ultraviolet experiments aboard OAO-A2.

Some scientists believe that white dwarfs are the final evolutionary phase of stars, and that they are the product of an intermediate stage called nova, the Greek word for "new".

White dwarfs are faint blue, white or yellow. Those in the same spectral class as the Sun have a radius like the Earth but a mass about the same as the Sun.

They are very dense and made up of degenerate gas. Although the radii of Earth and the average white dwarf are about the same, a volume of one cubic inch for white dwarfs weighs 30-40 tons.

Several hundred white dwarfs have been noted, but many more will be discovered.

Although they are some 2,500,000 light years from Earth, it is possible that OAO-A2 might discover novae in the galaxy next to ours, Andromeda.

A possible explanation of novae event (stellar blow-up less intense than supernovae) is that during the star's evolution helium and hydrogen are exhausted and the rate of heat being generated from the star decreases. Gas degeneracy then sets in and extends almost to the exterior of the star.

Novae never have been observed in the ultraviolet. Because about 20-30 novae occur in our galaxy annually, OAO-A2 has a 10 per cent chance of making a detailed observation.

Supernovae

The evolution of a star from proto-star, to main sequence, to white dwarf pertains only to those objects about 1.1 to 1.4 the mass of our Sun.

Stars smaller than the Sun may behave the same way, but not the large massive ones several times as large as the Sun.

One theory is that massive stars completely tear themselves up, or disintegrate, into supernovae due to the internal temperature increasing so rapidly that thermonuclear reactions involving helium occur.

The intensity of a supernova is several billion times greater than a hydrogen bomb explosion on Earth.

A supernova is a massive star which becomes extremely bright in a relatively short time by a factor of several hundred millions. The bright phase -- brighter than any of the planets in our solar system except the Sun and Moon -- may last a year or two.

Some astronomers believe that the bright star mentioned in Biblical history by the three wise men some 2,000 years ago was a supernova.

About 50 supernovae have been officially recorded -- three in our galaxy, in the years 1054, 1572 and 1604. One supernova occurs per galaxy in every 50-300 years.

No supernovae have occurred in our galaxy since the invention of the telescope in the 17th Century.

The Chinese and Japanese recorded one of the better known supernovae in the Milky Way in 1054. The remains of the event is the Crab nebula in the constellation Taurus.

Draper's Classification

Most stars can be divided into seven main groups by the letters O, B, A, F, G, K and M. A few stars have spectra that fall into special categories, R-N and S.

This sequence is called the Draper (or Harvard) classification, after the American astronomer Henry Draper (1837-1882), who made important contributions to stellar spectroscopy.

Each class is further sub-divided to permit finer gradations by adding a numeral from 0 to 9. Thus, B0 is the first member of Class B spectra and B9 is the last.

Class	Main Spectral Lines
O	Ionized helium, nitrogen, oxygen and silicon; hydrogen weak.
B	Neutral hydrogen and helium; ionized oxygen and silicon; ionized helium absent.
A	Hydrogen strong, ionized magnesium and silicon; ionized calcium, iron and titanium begin to appear; helium absent.
F	Ionized calcium (Ca II) strong; some ionized and neutral metal atoms (iron, manganese, chromium, etc.); hydrogen weak.
G	Ionized calcium strong; neutral metal atoms increasing and ionized forms decreasing; molecular bands of CH and CN appear.
K	Neutral metal atoms (including calcium) strong; molecular bands stronger; hydrogen very weak or absent.
M	Neutral metal atoms very strong; TiO bands appear.
R-N	Similar to K and M, but molecular bands of CH, CN and C_2 strong; TiO absent.
S	Neutral metal atoms strong; oxide (ZrO, LaO and YO) bands strong.

Stellar Temperature

Most stars have surface temperatures between 5,000-72,000 F. degrees and fall within the Draper classification.

Ultraviolet data from OAO-A2 will more precisely pinpoint stellar temperatures of young stars. This will provide accurate estimates of their helium content so astronomers can learn more of the nuclear processing which has gone on in the recent past.

The color index (see next page) for the hottest stars (O and B) is negative. These stars are very bright and are blue or blue-white in color.

The F stars are white and the G stars, like the Sun (G2), are yellow.

Cooler stars (K and M) have positive color indexes. Their colors are orange and red.

Spectral Class and Surface Temperature of Main-Sequence Stars

Spectral Class	Temperature (F.)	Color Index
O5	72,000	-
BO	52,000	Minus 0.32
B5	30,000	Minus 0.16
AO	17,800	0.00
A5	15,500	Plus 0.15
FO	13,500	Plus 0.30
F5	12,000	Plus 0.44
GO	10,900	Plus 0.60
G5	10,200	Plus 0.68
KO	9,100	Plus 0.82
K5	7,800	Plus 1.18
MO	6,700	Plus 1.45

Their Ages

Ultraviolet measurements from OAO-A2 will pinpoint the age of stars more accurately than is possible through visible observations from ground-based observatories.

Telescopes on OAO-A2 will determine the mass of stars, and the rate that the mass is being converted into energy. These two ingredients are required for determining age.

Stars are said to be "zero age" when they reach the main sequence. Their actual age is somewhat greater.

The Sun in our solar system is estimated to be "middle age," about 5 billion years old. It has burned up about five per cent of its hydrogen.

Assuming the Sun continues to release energy at the same rate, it will be about 10-billion years old before it departs from the main sequence and changes its character.

During the same period, stars with solar masses 10 times more than the Sun will depart from the main sequence in about 10 million years. The greater the stellar mass, the shorter life expectancy it has.

Pet Stars

Three pet stars which the Wisconsin experimenters are anxious to study are Betelgeuse, Gamma Velorum and Sigma Orionis.

Betelgeuse (M-type star) is very large (1,000 times greater mass than the Sun), very cool and is rapidly losing mass. The Wisconsin experiment probably won't be able to see the actual star, just the outer shell (chromosphere).

Gamma Velorum, W-R star (named after two astronomers, Wolf and Rayet, is shooting out materials at a very high velocity, some 3-million miles per hour. It is possible that these materials may be a source for X-ray stars. Several thousand volt protons are being cast off by Gamma Velorum.

Sigma Orionis E (early B-type star), some 1,500 light years from Earth, has a peculiar chemical composition which intrigues astronomers.

It has more helium than usual, but the exact amount is not known. Astronomers would like to know if Sigma Orionis E was helium rich to begin with or could it have come from evolutionary means.

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Dr. Nancy G. Roman	Chief of Astronomy, OSSA
C. Dixon Ashworth	Program Manager, Astronomical Observatories
T. B. Norris	Atlas-Centaur Program Manager
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Dr. James E. Kupperian, Jr.	OAO Project Scientist
Kennedy Space Center	
Dr. Kurt H. Debus	Director
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Prime Contractors

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Nicholas S. Snider	OAO Program Director Grumman Aircraft Engineering Corp., Bethpage, N. Y.

Industry Team

Prime Contractors	Responsibility
Grumman Aircraft Engineering Corp., Bethpage, N.Y.	OAO-A2 spacecraft
General Dynamics-Convair San Diego	Atlas-Centaur Launch Vehicle
Experiments	
Cook Electric Co. Morton Grove, Ill.	University of Wisconsin Experiment
Electro-Mechanical Research Inc., Princeton, N.J.	Celescope (Smithsonian Experiment)

Major Spacecraft Subcontractors

Company	Responsibility
AVCO Corp. Electronics Division, Cincinnati	Command Receiver
Bendix Corp. Electric Power Division Eatontown, N. J.	Power Regulation and Control Units
Bendix Corp. Navigation & Control Division Teterboro, N. J.	Reaction Wheels
Dalmo Victor Co. Belmont, Calif.	Magnetic Unloading System
Dorne & Margolin, Inc. Bohemia, N. Y.	Diplexer and Hybrid Junction
General Electric Co. Space Systems Operations Valley Forge, Pa.	Stabilization and Control System

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Gulton Industries Alkaline Battery Division Metuchen, N. J.	Batteries
Gulton Industries Engineered Magnetics Division Hawthorne, Calif.	Voltage Inverter-Regulator Converter
Hazeltine Electronics Division Little Neck, N. Y.	Command Control Junction Box
Hughes Aircraft Co. Culver City, Calif.	Solid State Transmitters
IBM, Federal Systems Division Owego, N. Y.	Primary Processor and Data Storage
ITT Federal Laboratories San Fernando, Calif.	Boresight Star Tracker
Kollsman Instrument Corp. Syossett, N. Y.	Star Trackers
Textron Electronics Inc. Spectrolab Division Sylmar, Calif.	Solar Cell Arrays
Radiation Inc. Melbourne, Fla.	Experiment and Spacecraft Data Handling Equipment

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