An Amateur Space Telescope

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CRACKING OPEN a new frontier is everyone's business. The North American West was discovered, explored, and finally settled as much through the efforts of private parties as by government and industry. Homesteaders, prospectors, adventurers — all were pioneers. Today, private citizens are joining the ranks of those who will explore that final frontier, limitless space. Major among these is a group that has sprung up in the idyllic countryside of upper New York state, a land known for finger lakes, vineyards, photography, glassworks, and now, an orbiting amateur observatory.

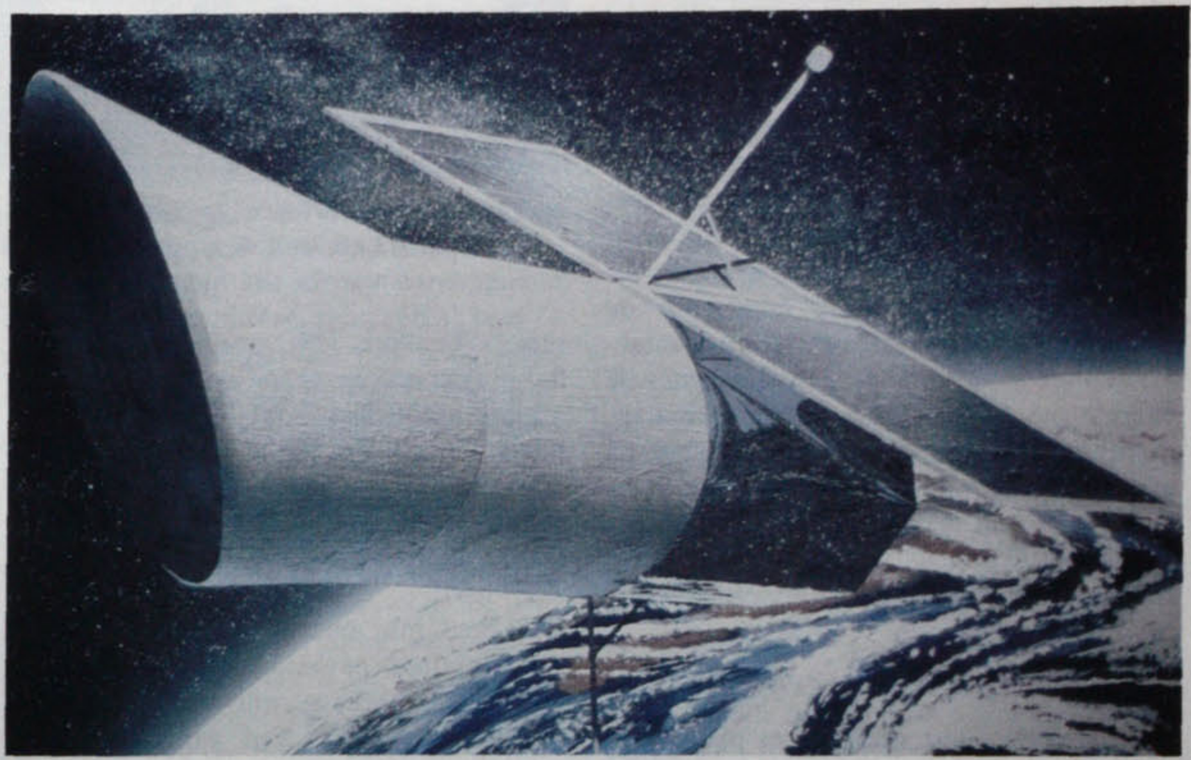
The Independent Space Research Group is an international, nonprofit organization formed in early 1980 by students at Rensselaer Polytechnic Institute in Troy, New York. At present, the ISRG has 250 members in the United States, Canada, and 10 other countries around the globe. The group's first project will be to build an Amateur Space Telescope (AST) and to have it placed in orbit by late 1984. Last year, all optical work was transferred to the University of Rochester, 400 km west of RPI, where a second group of student teams (under faculty advisers) was formed.

Once the AST reaches orbit, anyone with receiving equipment (costing about \$300) will be able to obtain pictures and data directly from the satellite and display them on a standard television set or photographic printer. Armchair astronomers will be able to tune in a show with real stars from their living rooms.

ISRG's members are not the first fans to stop being mere spectators in the sport of spaceflight. Amateur radio operators ("hams") have built and operated their own radio communications satellites since 1961. A dozen of these devices, affectionately known as OSCAR's (for Orbital Satellites Carrying Amateur Radio), have hitched free "piggyback" rides on various NASA and European rockets.

The hams discovered that they could build simple satellites for two percent of the cost to NASA or private industry. The savings are attributed to skilled volunteer labor, off-the-shelf parts, and proven system designs. In addition to the hams and the ISRG, at least four other nonprofit organizations are working on spaceflight endeavors.

Though details continue to be refined, the size, shape, and internal layout of the ISRG's first AST have been firm since 1980. It will measure 50 cm in diameter and 1¼ meters long, weighing in at about 80 kg. The actual telescope will be a 45-cm Ritchey-Chrétien system. Images across a considerable range of wavelengths will be available — from 1900 angstroms in the ultraviolet to 10,000 angstroms in the near infrared — with resolution near the respective diffraction limits of about 0.02 and 0.35 arc second. By applying computer enhancement to the images, these theoretical limits may actually be obtained. The AST will yield resolution as fine as that seen by a visual ground-based observer with a 45-cm telescope under "perfect" conditions. Features as small as 130 km wide will be visible on Mercury, and in the ultraviolet Venus will show atmospheric details only 80 km across. Martian craters 70 km in diameter will be resolved, as will structures in the clouds of Jupiter as small as 700 km. Far Pluto and dark moon Charon will be separate objects to the AST's eye.



In orbit, the Amateur Space Telescope would resemble a scaled-down version of NASA's 2.4-meter Space Telescope. In fact, the AST might actually begin operation before NASA's entry reaches orbit. Painting by William J. Beaty.

Images will be fed to two General Electric CID (charge-injection device) solid-state television cameras, providing both narrow- and wide-field coverage. The cameras can take short exposures repeatedly and integrate them in memory. This time-exposure effect — an electronic version of keeping a shutter open — will allow images of very faint objects to build up for as long as 10 hours. Coupled with noise-cancellation procedures, crisp images of objects down to the 23rd magnitude should be obtainable. The field of view depends upon the number of discrete picture elements (pixels) available at the focal plane. The AST will likely be outfitted with a 256-by-256-pixel array, although a unit with four times the area may prove feasible. The telescope will also carry three photometers to measure the brightness of stars in separate wavelengths and a small ultraviolet spectrograph.

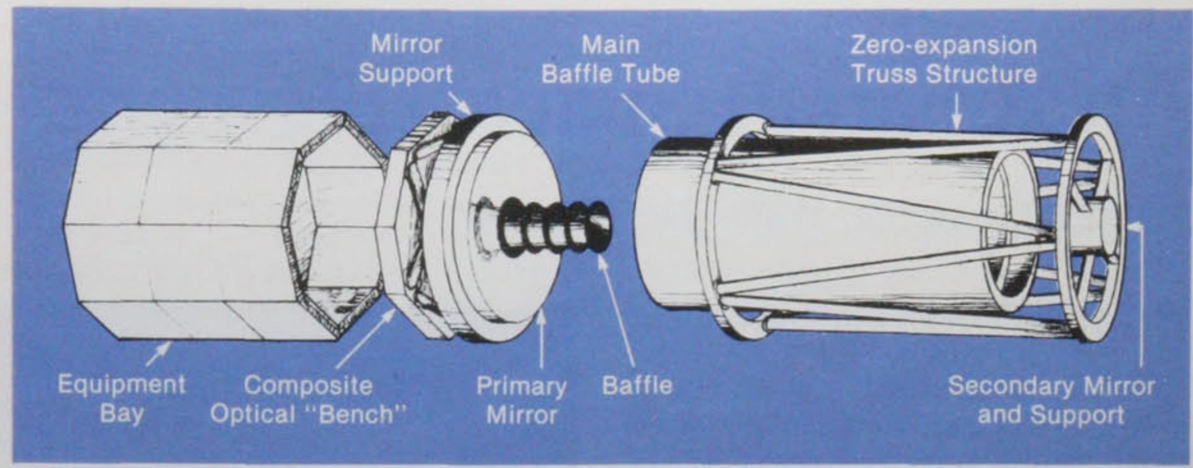
AST has a projected minimum operational life of two years. If a camera and supporting electronics worth \$3,500 depreciate to nothing over two years, then each day's operation costs about \$5. To raise funds to purchase the cameras, the ISRG is seeking "sponsors" to contribute money for a day's, week's, or month's pictures.

The equipment bay, a 50-cm-long octagonal prism, forms the main body of the satellite. Inside are five identical shelves (with identical partitions) for mounting hardware. These interchangeable components make structural analyses and manufacturing much simpler, while maximizing the design flexibility. The shelves are fabricated from a honeycomb sandwich of graphite-epoxy and Nomex nylon. Sandwich construction is very efficient in terms of stiffness to weight, and it requires a minimum of skill and tooling to manufacture.

Solar panels will provide up to 60 watts of electricity, to be stored in nickel-cadmium batteries. Once in orbit, the spring-loaded panels should unfurl to a rigid 1.5-meter wingspan. Attitude control of the satellite will be accomplished by a trio of flywheels on mutually perpendicular axes. A fourth flywheel, mounted at an angle, will be used as a backup in case one of the others fails. An RCA 1802 microprocessor, combined with a series of star sensors, will control the flywheels and most other on-board systems and transfer ground commands into actions.

The satellite's communications will be handled by a receiver, with a backup, plus a pair of transmitters each broadcasting with 500 milliwatts of power. One transmitter will serve as an engineering beacon, continually broadcasting telemetry. The other will act as a data beacon for pictures and other astronomical information. All data will be sent in a digital form that includes checksums and other means for detecting and correcting errors.

Because of their OSCAR program, amateur radio operators have experience in controlling satellites from the ground. Therefore, a network of ham stations will operate the AST, coordinated by a similarly equipped ISRG facility. A number of advanced OSCAR satellites are expected to be in geosynchronous and long-period orbits by 1985; these should provide radio links between the AST and ground stations over its horizon.



This exploded-view diagram shows the AST's major components. The Independent Space Research Group, based in Troy, New York, hopes to see its project completed within the next 2½ years. Illustrations were supplied by the ISRG.

PROVING THE CONCEPT

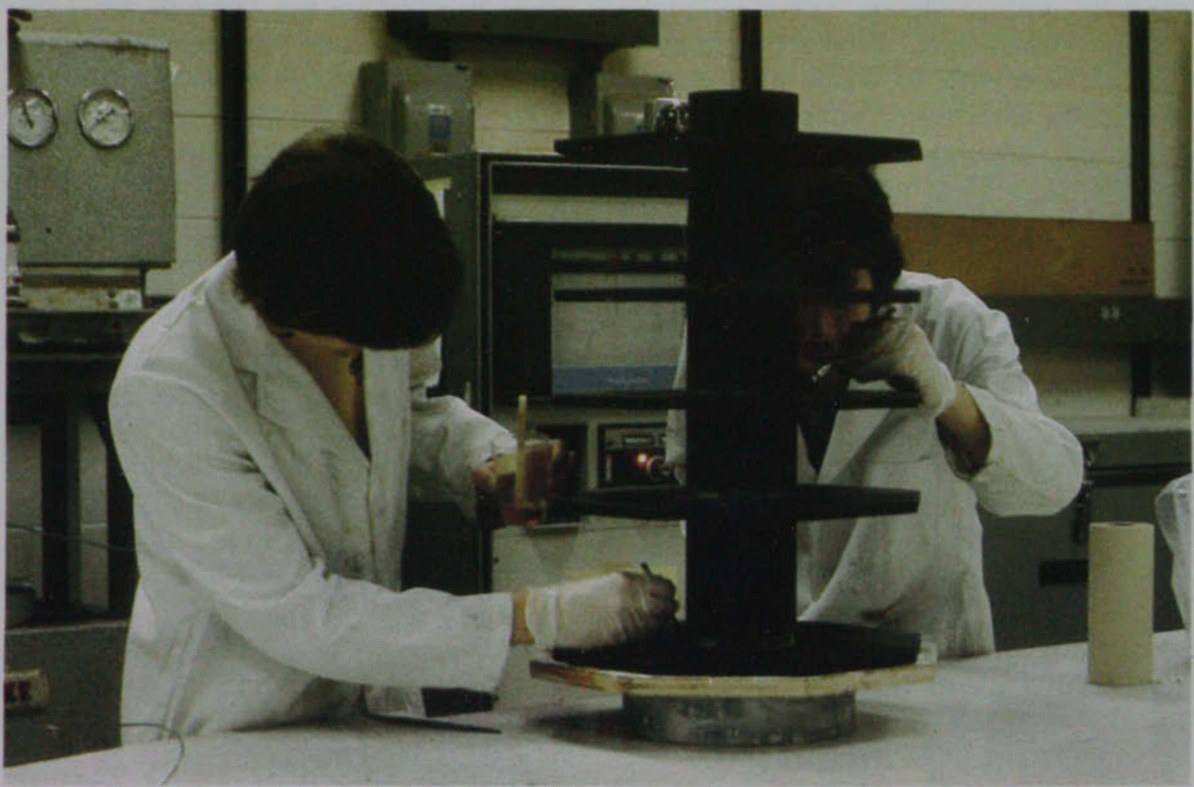
Originally, a test satellite was planned to provide the ISRG with experience in constructing and operating a satellite, to test the attitude-control system proposed for the AST, and to give the ground-based communications network practice in the deployment and control of a device much like the AST. The test satellite would have been the same size and shape as the AST. Yet, even without astronomical optics, it would have cost $30,000 (compared to an estimated $100,000 for the actual AST and its backup).

Fortunately, the simulation and logistics of modern attitude-control systems are so precise that testing was deemed unnecessary. Therefore, this spring the test satellite project was scrapped and replaced with a more useful test flight of critical components aboard the Space Shuttle. A great advantage in sending materials on the shuttle, of course, is that they will be returned to Earth for possible reuse on the AST itself.

Packed into one of the shuttle's small self-contained payload canisters, the AST equipment package will be flown for a thermal, vacuum, and launch-vibration stress test. The canister (also called a "Getaway Special") is worth $10,000 and was donated to the ISRG by the International Space Research Society of Melbourne, Florida. The International Space Corp. contributed another $5,000 to cover hardware development for the test flight. Now 47th in the queue for room in the shuttle's cargo bay, the test package should fly next summer.

As for the AST itself, there are currently no firm policies for launches of small satellites from the shuttle. The ISRG is negotiating with NASA astrophysicists to determine how its observations may augment or complement those to be performed by the 2.4-meter Space Telescope. Such cooperative scheduling may make it possible for the AST to be classified as a NASA payload and thus to be launched for free. Other options include piggyback flights on conventional rockets.

ISRG will have little say in the flight assignment it gets, but it is ready to make the most of what's available. Ideally, the AST would occupy a Sun-synchronous polar orbit, about 500 km high, which possesses special characteristics. In a polar or near-polar orientation, precession induced by the Earth will cause the orbital plane to turn constantly. (If the orbit is circular, the plane will turn like a spinning coin.) With the right combination of altitude and inclination, the orbit will turn at the same rate that the Earth revolves around the Sun — once per year. Moreover, if the AST circles directly above the terminator, the satellite will never enter the Earth's shadow, and the solar panels can then provide full power all the time. This orbit will place the AST in a given ground-based observer's sky at very nearly the same time every day.



Matt Cackett (left) and Andrew Bertolazzi, engineering students at Rensselaer Polytechnic Institute in Troy, New York, work on a prototype of the telescope's equipment-bay structure to be used in stress and vibration tests.

APPLICATIONS OF THE AST

All sciences that depend on the day-to-day accumulation of data count on legions of amateurs. Mineralogists rely on private collectors. Psychologists use students to test behavior theories. And so, too, with astronomers: there simply isn't enough time on big telescopes to allow for the mundane but necessary constant monitoring of the skies. Many amateur observing networks, such as photometric observation of variable stars, quasars, and Seyfert galaxies, could be facilitated by the AST. The ISRG's eye-in-the-sky will regularly observe the planets at high resolution and alert professionals to interesting transient features worthy of closer examination.

The AST will be used for both scientific research and educational projects. Individuals and groups wishing to perform observations should submit proposals to the ISRG, which will then schedule approved projects. There will be no charge for use of the satellite.

One application of the AST was suggested by a news item in this magazine. The December, 1981, issue (page 545) reports that a possible moon may accompany the asteroid 9 Metis, based on a slight bulge appearing on a photographic plate taken in China. (See also page 164 of this issue.) If the presumed secondary is real, its apparent separation of 1.2 arc seconds from Metis represents an orbital radius of 1,100 km at the asteroid's distance. The AST would have no trouble determining the real situation; in fact, it could search for main-belt asteroid pairs as little as 300 km apart.

FUTURE PROSPECTS

What lies ahead for the ambitious ISRG members? Current discussions revolve around what capabilities would be desirable in a second AST, and three possibilities are now being explored:

- A diffraction-limited ultraviolet telescope of 1-meter aperture or greater.
- A Schmidt telescope optimized for an ultraviolet survey of the entire sky, comparable to the visible-light National Geographic Society-Palomar Observatory Sky Survey. Both wide-field coverage and high resolution would be required, a task better suited to photographic film than television. Recoverable film packages might be considered.
- A compact multiple-mirror telescope. Its weight- and volume-to-aperture ratios make it a more reasonable payload than a comparable single-mirror device. But an MMT design would require great mechanical and structural complexity, making it a potential but unlikely candidate for the second AST.

Farther into the future, a successful ISRG may wish to try other kinds of missions. These might include an amateur lunar orbiter (seed funding has already been donated by the International Space Corp.); a solar-dedicated telescope; and a number of other instruments for research at infrared, radio, and X-ray wavelengths.

Response to the AST concept from the aerospace community has been excellent. The donation of funds ($6,000 from the Inter-Space Society), materials (such as an aluminum "egg-crate" base for the solar panels), expertise, and information have all been gratefully received. Three optical companies have offered assistance in manufacturing the telescope, and a division of Hercules, Inc., is donating the graphite-epoxy composite to be used for the equipment-bay structure.

Not everything comes free, of course, and the ISRG is actively seeking new members. Individuals can obtain membership for as little as $10, which includes a vote in the organization's activities and a subscription to its bimonthly newsletter. Inquiries should be addressed to the Independent Space Research Group, P. O. Box 1246, Troy, N. Y. 12180.

News Notes

FIRST QUASAR YIELDS ANOTHER SECRET

"Are quasars the luminous nuclei of galaxies?" asked Susan Wyckoff and Peter A. Wehinger in the March, 1981, issue of this magazine, page 200. Their affirmative answer is supported by new work on 3C 273, the first quasar known.

Detecting the galaxy in which a quasar may be embedded is a difficult task, for the overwhelming brightness of the quasar drowns out any surrounding nebulosity. To overcome the limited dynamic range and nonlinearity of photographic emulsions, a group at Lowell Observatory used a charge-coupled device (CCD) on the Perkins 1.8-meter telescope. A coronagraphic camera blocked the light from the quasar itself.

A series of exposures ranging up to five minutes unambiguously revealed the nebulosity, as is evident in the accompanying false-color picture. The Lowell work confirms the earlier photographic detection of nebulosity around 3C 273 by Wyckoff and her co-workers, leading J. A. Tyson, W. A. Baum, and T. Kreidl to conclude that the surface brightness of the nebulosity decreases outward from the center in a manner expected for the brightest elliptical galaxies in clusters. Specifically, the profile could be matched to that of NGC 4889, a giant elliptical in Coma Berenices. And there is evidence that 3C 273 is, in fact, a member of a sparse cluster.

Writing in the June 1, 1982, *Astrophysical Journal Letters*, they say, "Of course we cannot rule out the possibility that this nebulosity could be the superposition of two less luminous galaxies (one at intermediate distance where it is gravitationally imaging the nucleus of the distant one), but we prefer the hypothesis that it is a single luminous galaxy with the quasar in its nucleus."

NEW AWARD

The American Astronomical Society will administer an award named after Henri Chrétien (1879-1956), a French professor of optics whose name is best remembered in conjunction with the Ritchey-Chrétien telescope design. This year up to $20,000 will be made available to cover costs associated with conducting research in observational astronomy.

Astronomers throughout the world are

Nebulosity surrounding 3C 273 is evident after light from the quasar was blocked off (black oval with cross) and scattered light removed electronically. The darkest blue contours represent a surface brightness in visible light of magnitude 25.5 per square arc second, some 100,000 times fainter than 3C 273, if its light were spread over the same area. Brightness increments are 0.5 magnitude. North is up, the width one arc minute. Courtesy J. Tyson, Bell Laboratories.