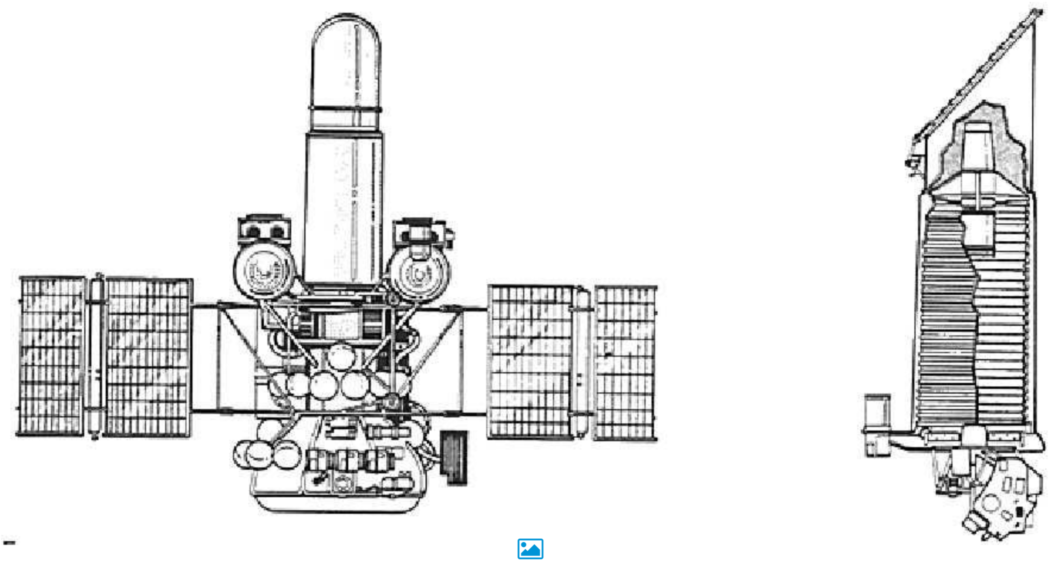
DREW ex machina

Astron: Venera Turned Space Telescope

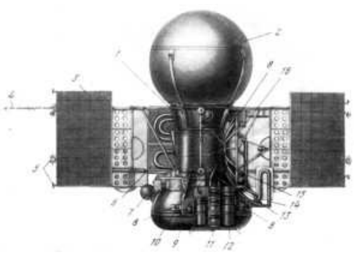
January 7, 2016 Astronomical Instruments, Astronomy, Spaceflight, Unmanned Spaceflight 3 Comments
1980s, Astron, NPO Lavochkin, Scientific Satellites, Soviet Venus Missions, Space observatories



When thinking about the old Soviet space program, people usually remember its long history of crewed space missions or its somewhat checkered lunar and planetary programs or constellations of military and intelligence satellites that outnumbered their western counterparts. Not as well known are the myriad science-related space missions performing many of the same studies as science missions in the West. Among these was a very capable yet little-known space telescope from the 1980s called Astron.

The Astron Spacecraft

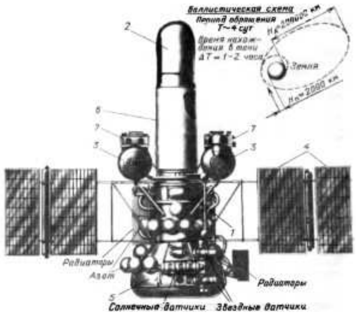
The primary objective of the Soviet Astron mission was to perform astronomical observations of stars, active galaxies and other energetic phenomena in the ultraviolet (UV) region of the spectrum. Since Earth's atmosphere largely blocks UV, astronomical observations at these wavelengths must be conducted from space. Astron's science program was the responsibility of a team at the Crimean Astrophysical Observatory led by Alexander Boyarchuk. Like many other Soviet science missions of the time, there was international participation – in this case, with the French space agency, CNES. The Astron spacecraft itself was the responsibility of NPO Lavochkin which is best known as the builders of the Soviet's lunar and planetary probes since 1966.



Soviet diagram of the 4V Venera spacecraft. (Nauka)

For the Astron mission, the engineers at Lavochkin decided to use a modified version of the 4V spacecraft bus employed in the highly successful second-generation Venera program since 1975 (see "**Venera 9 and 10 to Venus**") which itself was an adaptation of the bus employed in the earlier (and less successful) M-71 and M-73 Mars missions. The use of a flight-proven spacecraft design improved the chances that the mission could meet its one-year mission goal and was in keeping with typical Soviet aerospace engineering practices of the time of relying on evolutionary upgrades of existing designs when possible.

The baseline 4V Venera bus consisted of a cylindrical core with a toroidal instrument module around its base. The 1.1-meter in diameter cylindrical core of the 4V housed propellant tanks for the KTDU-425A engine used for orbit insertion and course corrections during planetary missions. Solar panels, radiators and various communications antennas were attached to the core's midsection. The 2.35-meter in diameter instrument module contained the spacecraft's computers, avionics, scientific instrument electronics and other sensitive equipment. This toroidal module, whose shape was chosen to minimize the length of required cabling and allow easier access to its systems during construction and testing, was pressurized to provide a laboratory-like environment for its equipment. This approach added to spacecraft mass but it simplified the design and testing of the systems as well as provided for easier thermal control. Various optical sensors were mounted on the exterior of the equipment section to provide inputs to a sophisticated autonomous navigation system.

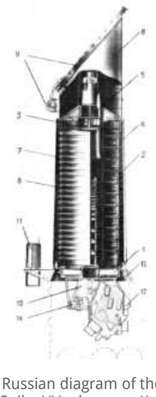


Soviet diagram of the Astron spacecraft and, in the upper right, its intended orbit. Components include 1) support cylinder, 2) Sun shade, 3) accessory containers, 4) solar panels, 5) instrument module, 6) the Spika telescope and 7) the SKR-02M X-ray spectrometer. Click on image to enlarge. (Nauka)

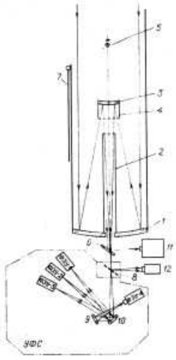
This basic 4V spacecraft design was modified for its new mission with larger solar panels to provide more power and a new arrangement of communication antennas for a mission in Earth orbit. The arrangement of navigational sensors was also changed so that Astron could lock onto Canopus or a number of other bright stars for attitude reference during astronomical observations and communication sessions. The number of tanks holding nitrogen gas for the attitude control system was also increased to lengthen the life of the satellite. The most noticeable change was the shortening of the spacecraft's cylindrical core to accommodate the UV telescope carried by Astron.

Astron's Instruments

The UV telescope, called "Spika" although sometimes referred to as "UFT" (the Russian acronym for "Ultraviolet Telescope"), was the primary scientific instrument of the Astron mission. Based on work done earlier with the OST-1 UV telescope flown on the Salyut 4 space station launched in December 1974, originally it was intended to fly Spika on another Salyut space station. But since the attitude disturbances caused by the presence of a crew were deemed to create too much of a problem, it was decided to design the instrument to fly on an automated spacecraft instead. The 400-kilogram Spika telescope was a Ritchey-Chretien design with an 80-cm diameter primary mirror and a 26-cm secondary. The mirrors were made of a highly stable ceramic called Sitall chosen to maintain its figure over a range of temperatures. Both mirrors were coated with reflective aluminum and a protective layer of magnesium fluoride. The hyperboloid shapes of the mirrors' reflective surfaces gave a good quality image across a fairly large half-degree field of view and had an equivalent focal length of 8 meters. A sunshade at the top of the five-meter long telescope allowed Spika to be safely pointed to within 45° of the Sun. After assembly and testing, a protective cover was closed over the top of the telescope and its interior filled with dry nitrogen for transport and launch.


Russian diagram of the Spika UV telescope. Key components include 1) the primary mirror, 3) secondary mirror, 5) secondary mirror assembly, 6) telescope housing, 8) Sun shade, 9) telescope cover and drive, 11) field identification camera, 12) UFS spectrometer, 13 & 14) star position sensors. Click on image to enlarge. (Nauka)

Various sensors on the spacecraft and in the telescope worked together to allow pointing accuracy of about two arc seconds and a stability of 0.3 arc seconds thanks to a steerable secondary mirror which could also be moved to adjust the focus of the telescope. Although the size of Spika's primary mirror was the same as that employed by the UV telescope on the American OAO 3 (Orbit Astronomical Observatory 3 also known as Copernicus) launched in 1972, part of OAO's aperture was blocked by internal equipment. Without this limitation, Spika's primary mirror had about 35% larger clear aperture than the UV telescope on OAO 3 making it the largest UV telescope launched into orbit up to that time. During the development of Spika, a total of six copies were constructed for ground testing, flight and as a backup.



The optical layout of the Spika UV telescope with the four-channel UFS spectrometer at the bottom. Click on image to enlarge. (Nauka)

The primary instrument using Spika was a UV spectrometer jointly developed by France and the Soviet Union. Designated "UFS" (the Russian acronym for "Ultraviolet Spectrometer"), this spectrometer used a Rowland design to feed detectors in three spectral channels covering UV wavelengths from 110 to 350 nm. A fourth, "zero-order" channel covered wavelengths of 170 to 600 nm and was vital for ensuring proper pointing of the instrument. Three different entrance diaphragms could be chosen for observations: a 0.04 mm diameter diaphragm to observe bright stars, an offset 0.5 mm diaphragm for dim stars as well as extended sources and a 3 mm diaphragm for the faintest sources. Photon counting photomultiplier tubes were used to measure the incoming UV flux from the spectrometer by scanning in 0.025 nm steps with a time resolution as good as 40 nanoseconds. A French-supplied camera coaligned with Spika provided visible band images to aid in field identification.

Components of the SKR-02M X-ray spectrometer: 1 & 2) spectrometer detector heads and 3) proportional counter electronics. Click on image to enlarge.

The second scientific instrument carried by Astron was an X-ray spectrometer designated SKR-02M. Built by a team lead by Andrei Severny of the Sternberg Astronomical Institute, SKR-02M consisted of a pair of detectors employing proportional counters filled with a xenon-methane gas mixture and sealed with 150-μm thick beryllium foil. The effective area of the two detectors was about 1,700 cm^2 with a 3° square field of view. The detectors were sensitive to X-rays in the 2 to 25 keV range (equivalent to wavelengths of 0.6 and 0.05 nm, respectively) and had a spectral resolution of 2 keV. The spectrometer was capable of taking measurements as fast as once every 2.28 milliseconds allowing for observations of fast-changing energetic events.

The spectral response function of the SKR-02M X-ray spectrometer. Energy units, E, are in keV. (Nauka)

The Astron Mission

The six-meter tall, 3,250-kilogram Astron spacecraft was meant to be placed into a highly elongated 2,000 by 200,000-kilometer orbit around the Earth with a period of about four days using a Proton-D – the same rocket used to launch the 4V Venera missions. This elliptical orbit kept Astron above the Earth's radiation belts (which would affect the UV and X-ray sensors as well as other spacecraft systems) for 90% of the time. This orbit also kept Astron above the brightest portion of the Earth's geocorona whose brightness at key wavelengths, such as the Lyman-α line of hydrogen, limited the sensitivity of UV investigations from lower orbits like those of NASA's OAO 3. The high inclination of the orbit also allowed Astron to be tracked almost continuously from Soviet territory for up to 3½ days at a time. This permitted Astron, which carried no data recorder, to transmit its data in near real time to the ground during up to 200 communications session throughout the year.

Soviet schematic of Astron's elongated Earth orbit.

For its nominal mission, Astron would make observations of specific targets for up to 3 to 4 hours. Astron could also scan a swath across the celestial sphere in 12 minutes making as many as 70,000 measurements to map the UV and X-ray sky at lower sensitivity. Astron's on-board computer was loaded with position information of 600 targets to survey. It could also operate in a mode where if it detected a gamma ray burst or other energetic transient phenomenon, it could quickly slew to make observations of the source with its UV and X-ray instruments. In many ways, Astron was superior to its contemporary, the joint US/UK/ESA International Ultraviolet Explorer (IUE), which had a smaller 45-cm primary and was launched into an elliptical, one-day orbit in 1978.

Astron shown being prepared for its launch on March 23, 1983.

The Astro spacecraft, serial number 602L, was launched at 12:45:06 UT on March 23, 1983 on board Proton number 307-01 from pad LC200/39 at the Baikonur Cosomdrome in Soviet Kazakhstan. The Proton successfully placed Astron into an 1,996 by 201,230-kilometer orbit with an inclination of 51.5°. The shape of this orbit would slowly change over time primarily under the influence of the Sun and Moon. Five days after reaching orbit, the protective cover on Spika was opened exposing the instrument to space for the first time. Following a period of in-orbit checks and calibration, Astron started taking UV data on March 29. X-ray data collections with SKR-02M started five days later with initial observations of an X-ray blank part of the sky followed by observations of the Crab Nebula – a bright X-ray source frequently used as a "standard" by X-ray astronomers.

During its first 3½ months of operation, Astron observed a variety of sources in the constellations of Taurus, Leo and Orion and reportedly had secured its first spectra of distant galaxies. Initial X-ray observation were made of known sources and on April 13, 1983 Astron detected its first gamma ray burst. Later on June 30, Astron observed that the X-ray binary known as Hercules X-1 had suddenly stopped emitting X-rays indicating a change in how the neutron star in this system was accreting matter from its companion star.

Plot of the high energy photon flux from the first gamma ray burst detected by Astron on April 13, 1983. Click on image to enlarge.

Over its first year in orbit, Astron continued to make observations of a wide range of sources in the UV and X-ray bands. In total, 70 stars, 22 quasars and galaxies as well as 22 galactic background fields were observed. At the conclusion of its nominal one-year mission, Astron and its instruments were still in good health with plenty of consumables still remaining allowing the hearty spacecraft to continue its mission *far* beyond its design life. By September 1, 1985 it was reported that Astron had made over 300 observations of 200 different objects.

Spectra of Comet Halley from Astron acquired on April 9, 1986: a) spectrum near nucleus, b) previous with scattered solar light removed revealing molecular emissions, c) spectrum ~200,000 km from nucleus, d) IUE spectrum of the nucleus earlier that day. Click on image to enlarge. (Feldman et al.)

In April 1986 Astron observed Comet Halley which complemented those made at close range by the Soviet Vega spacecraft which flew past the nucleus of the comet the previous month allowing the comet's outgassing rate to be modelled more accurately (see "**The Missions to Comet Halley**"). Astron was also used to make UV observations of ozone in Earth's atmosphere and how it was affected by rocket launches presumably for environmental research as well as for military early warning systems (see "**RAMOS: Russian-American Observation Satellites**"). On February 24, 1987 the light from supernova SN 1987a reached Earth – the brightest and nearest supernova observed since the invention of the telescope. Reportedly, Astron was among the first space telescopes to observe SN 1987a with a total of 15 documented sessions over the following 15 months.

A closeup fish-eye view of Astron. Note the sphere's which held nitrogen gas for the spacecraft's attitude control system.

After over six years in orbit, Astron finally exhausted its supply of nitrogen for its attitude control system in June 1989 effectively ending its ability to point its instruments. During this time, Astron responded to a total of 10,000 commands from ground controllers over the course of 628 communications session. The last reported communication session with Astron was held on March 23, 1991 officially ending its mission eight years after launch. Because of the success of the mission, members of the Astron science team received the coveted USSR State Prize. Despite its success, the accomplishments of Astron are still largely unknown to the astronomical community primarily because of the small number of peer-reviewed papers published by the mission's scientists despite Astron's capabilities and the fact that there were no reported issues with the instruments or spacecraft.

An illustration of the Granat spacecraft launched in 1989 following the successful Astron mission. (NASA)

Because of the success of this mission, an additional Astron mission based on this proven design was planned using one of the hulls remaining from the now discontinued second generation Venera missions. On December 1, 1989, Granat (originally to be called "Astron 2") was launched carrying a suite of instruments supplied by the Soviet Union, France and Denmark designed to make astronomical observations in the X-ray and gamma ray region of the spectrum. Despite its relative obscurity, Astron deserves a place in the history of space-based observatories of the late 20th century.

Related Video

Here is a Russian-language documentary on the Astron mission.

Astron: Space observatory - (Обсерватория Астрон) Soviet documentary in russian

Related Reading

"Venera 9 and 10 to Venus", *Drew Ex Machina*, October 22, 2015 [**Post**]

"The Missions to Comet Halley", *Drew Ex Machina*, March 6, 2016 [**Post**]

General References

A.A. Boyarchuk et al., "The ultraviolet telescope aboard the astrophysical space station Astron", *Soviet Astronomical Letters*, Vol. 10, No. 2, March-April 1984

A.A. Boyarchuk, "UV Observations by Astron Satellite", *Dunsink Bicentenary Colloquium*, p. 352, 1986

A.A. Boyarchuk, *Астрофизические исследования на космической станции "Астрон"*, Nauka, 1994

Brian Harvey and Olga Zakutnyaya, *Russian Space Probes: Scientific Discoveries and Future Missions*, Springer-Praxis, 2011

Nicholas L. Johnson, *Soviet Space Programs 1980-1985*, American Astronautical Society, 1987

3 Comments

Bill Keel says:
January 7, 2016 at 4:46 pm
Reply

Great to see this level of detail on Astron. There is a rich history of space astronomy missions pre-Hubble, including poorly known ones from the USSR (and it was also great to see Russia back in the game with Radio astro). You may be interested in the visuals for some talks I've done on "Hubble's Godparents" at https://www.dropbox.com/s/02kn906dwqoygka/godparents.pdf?dl=0 and on 25 years of Soviet space astronomy at https://www.dropbox.com/s/ecuc4voefo57eiv/AstronUSSR25.pdf?dl=0. The Glazar telescope on Mir was especially snakebit…

Bart Hendrickx says:
January 8, 2016 at 11:00 pm
Reply

Interesting article, Andrew.

I can add some information from a piece written on the Novosti Kosmonavtiki forum by an NPO Lavochkin veteran using the pseudonym "Vladimir". He described the origins of Astron and also disclosed new details about the planned successors of Astron :

http://novosti-kosmonavtiki.ru/forum/forum9/topic9863/?PAGEN_1=4
(as I'm writing this, the NK forum seems to have gone offline again, so try again later)

It turns out Astron's Spika telescope had its roots in a Soviet military project dating back to the early 1970s. The success of NASA's OAO-3 Copernicus observatory with its 80 cm Cassegrain telescope inspired Soviet designers to build a similar telescope, not for astronomical purposes, but for use on a new NPO Lavochkin early warning satellite (US-KVI) to detect enemy missile launches. Spika was designed and built jointly by NPO Lavochkin and the Crimean Astrophysical Observatory after design proposals from LOMO in Leningrad and the State Institute of Applied Optics in Kazan were turned down because of their high mass. It was the director of the Crimean Astrophysical Observatory Andrei Severnyy who suggested to fly Spika on an astronomical satellite. This would use the same bus as the US-KVI early warning satellite.

Spika was conceived and developed when NPO Lavochkin was headed by Sergei Kryukin, who had succeeded the deceased Babakin in 1971. When Vyacheslav Kovtunenko replaced Kryukin in late 1977, he decided to shelve US-KVI and the derived astronomical satellite, but a few months later Severnyy managed to convince the Central Committee to reinstate the astronomical satellite. With US-KVI cancelled, it was decided to build the satellite using a bus that contained elements of both the Mars-71 and Venera 4V design. On 8 December 1978 the Ministry of General Machine Building and the Academy of Sciences approved a plan for scientific satellites in the 1981-1990 timeframe that included a UV observatory with the Spika telescope. This same plan was approved by a decree of the Central Committee and the Council of Ministers on 8 May 1980.

The plan called for flying observatories using the M71/4V design (code-named 1A) in 1982-1983 and several new-generation observatories using the Phobos design (code-named 2A) later in the decade (1985, 1987, 1988, 1989). The first 1A was launched as Astron in 1983 and the second one eventually went up as Granat in 1989 (although there were significant design differences between the two). Besides that, there were proposals for 4V-based satellites with a 30-m radio telescope as well as an infrared telescope (drawings included in Vladimir's post), but these never left the drawing board.

In 1983 plans were drawn up for the first 2A Phobos-class observatory (supposed to be called Astron-2), which was to be outfitted with a 10-m radio telescope (drawing included in Vladimir's post). However, the 2A/Phobos platform was soon found to have virtually the same limitations for astronomical observations as the 1A platform (the main disadvantage being its limited pointing capability) and by the mid-1980s it was decided to build a new generation of observatories using the bus of the 72X6 early warning satellite, which had much better pointing accuracy. This new generation became known as Spektr, but it would never fly either, at least not in the configuration envisaged in the 1980s.

One correction : you write that the Lomonosov astronometric satellite was also based on the Venera design, but this was supposed to have used the same design as NPO Lavochkin's big Araks (11F664) optical reconnaissance satellites. Vladimir writes that Lomonosov had its roots in a Soviet-era military project called Krugozor that was intended to detect artificial satellites against a background of stars. One of the requirements was to accurately determine the position of stars, which is how Lomonosov came into being. After the end of the Cold War, Krugozor was cancelled, but Lomonosov survived for several more years as a purely scientific project. Although Lomonosov used the Araks bus, it had a different telescope (a 1m telescope of the Vavilov State Optical Institute instead of the 1.5m LOMO telescope flown on Araks).

You also write that the Spika telescope was originally supposed to have flown on a Salyut space station, but is there really any evidence for that? This seems rather unlikely given its origins in an NPO Lavochkin early warning project.

Bart Hendrickx

Andrew LePage says: Reply

January 10, 2016 at 4:43 am

Bart,

Thank you so much for all the additional information on the Astron mission! I especially appreciate the details on the origin of the Spika telescope and the transition to the 4V-based bus.

> The success of NASA's OAO-3 Copernicus observatory with its 80 cm Cassegrain telescope inspired Soviet designers to build a similar telescope, not for astronomical purposes, but for use on a new NPO Lavochkin early warning satellite (US-KVI) to detect enemy missile launches.

The fact that the original mission for the UV telescope that would become Spika was for an early warning satellite certainly explains the report of Astron performing observations of the Earth and the effect on the atmosphere of missile launches. The Russian interest in using the UV band for early warning continued far beyond the 1980s. Between 1994 and 2004, I was on the American science team for the Joint US-RF RAMOS (Russian American Observation Satellites) whose objectives included gathering data to support early warning system development. Our Russian partners included a UV camera in the satellites' instrument payload in part to support research into using this band for early warning. More details can be found here:

http://www.drewexmachina.com/2014/06/21/ramos-the-russian-american-observation-satellites/

To address your two corrections:

> you write that the Lomonosov astronometric satellite was also based on the Venera design, but this was supposed to have used the same design as NPO Lavochkin's big Araks (11F664) optical reconnaissance satellites

I based my claim about Lomonosov on a statement made on page 235 of Brian Harvey's book "Russian Planetary Exploration" (2007 Springer-Praxis) which, after a discussion of the 4V-based Astron and Granat, stated "The third was Lomonosov, a star mapper…". Since this confirmed my recollection of events quarter century ago, it seemed reasonable to repeat the claim. The evidence you present casts doubt on Harvey's claim (as well as my memory!).

> You also write that the Spika telescope was originally supposed to have flown on a Salyut space station, but is there really any evidence for that?

I based my claim on a statement made on page 376 of "Russian Space Probes: Scientific Discoveries and Future Missions" by Brian Harvey and Olga Zakutnyaya (2011 Springer-Praxis) which said "This was Astron, originally intended to be manned and using an adaptation of the OST telescope taken from Salyut." It could have been that among the many options considered for a UV telescope, in addition to the US-KVI and 4V-based options, was placing it on another Salyut space station (instruments with dual scientific and intelligence objectives were certainly included on many early Salyut flights). Then again, Harvey and Zakutnyaya may have been incorrect on this and confused what would become Spika with another UV instrument proposed for a crewed spacecraft. It would be nice to see some documentation on this one way or the other.

Once again, thank you so much for your comment. As always, it was most helpful.

Drew LePage

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7 + 7 =

Post Comment