Star Tracks

To boldly go where no space probe has gone before — seeking knowledge of the distances and motions of stars

By DIETRICK E. THOMSEN

Astrometry, the determination of the locations of celestial bodies, is a fundamental, if somewhat unglamorous, part of astronomy. It is probably the oldest astronomical activity, having begun the first time an observer made note of the location a star accurately enough to be able to find it the next night. Accurate astrometry lies at the foundation of the science of mechanics as developed by Kepler, Galileo and Newton.

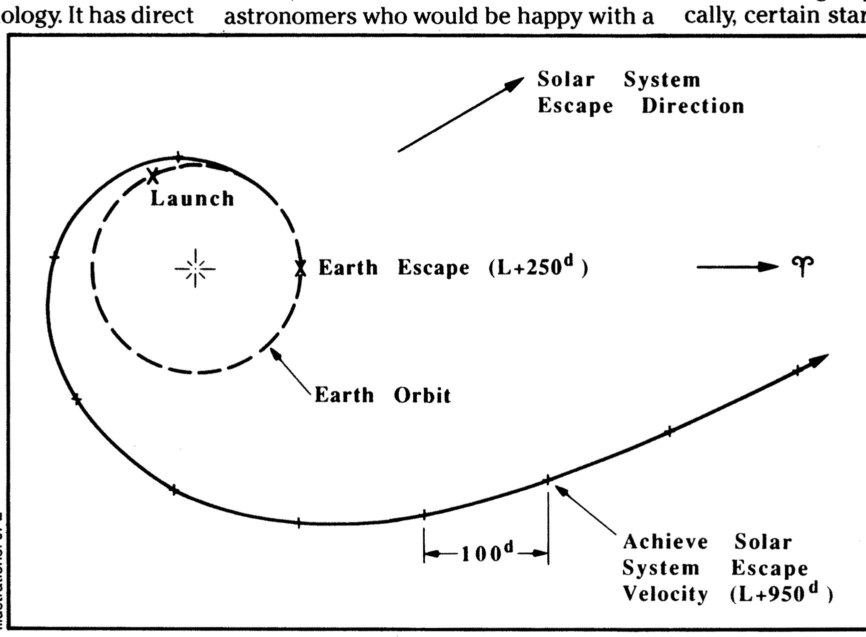
Astrometry is also at the basis of astrophysics and cosmology. It has direct methods of measuring the motions of stars and the distances to them. It gave us our first pictures of where we are in our galaxy and how things are arranged around us. However, astrometric distance measurements, which are done by triangulation, are limited to stars within about 400 light-years of us, because the longest base for the triangle is the diameter of the earth's orbit.

Illustrations: JPL

Now, a group of scientists and engineers at the Jet Propulsion Laboratory (JPL) in Pasadena, Calif., is planning a space mission that will substantially overcome that limitation. Called TAU for Thousand Astronomical Unit project, the proposed flight would take a telescope out to 1,000 astronomical units—1,000 times the mean radius of the earth's orbit, or about 93 billion miles. If it flies, it will surely be one of the great space adventures of the 21st century and, in the absence of an interstellar mission, probably the longest. With a prospective launch date of 2005, TAU would take 50 years to reach its destination.

This lead time raised obvious questions at the session on astrometry at the recent meeting of the American Astronomical Society in Pasadena. "Why are you so enthusiastic?" Aden Meinel of JPL asked himself and other proponents of TAU. "You'll all be dead." He replied that this scenario is in the grand tradition of astrometry: People make observations that come to fruition only with work done at a later epoch. The tradition is handed down the generations. He pointed out that his wife, Marjorie Meinel of JPL, is now working on TAU; back in 1917 her mother was doing astrometry at the Yerkes Observatory in Williams Bay, Wis.

Still, Aden Meinel admits there are astronomers who would be happy with a mission to 10 or 100 astronomical units, but they want it done while they're alive. However, TAU's proponents apparently feel that if you're going, you might as well go for broke. Meanwhile, there is plenty to do in astrometry while the present generation still lives. Marjorie Meinel reviewed this at the meeting in her advocacy of another project, SNAPS, or Solar Neighborhood Astrometric Parallax Survey.



TAU would take about 9 months to escape earth and nearly three years to escape the solar system, then off toward vernal equinox (denoted by ram's horns).

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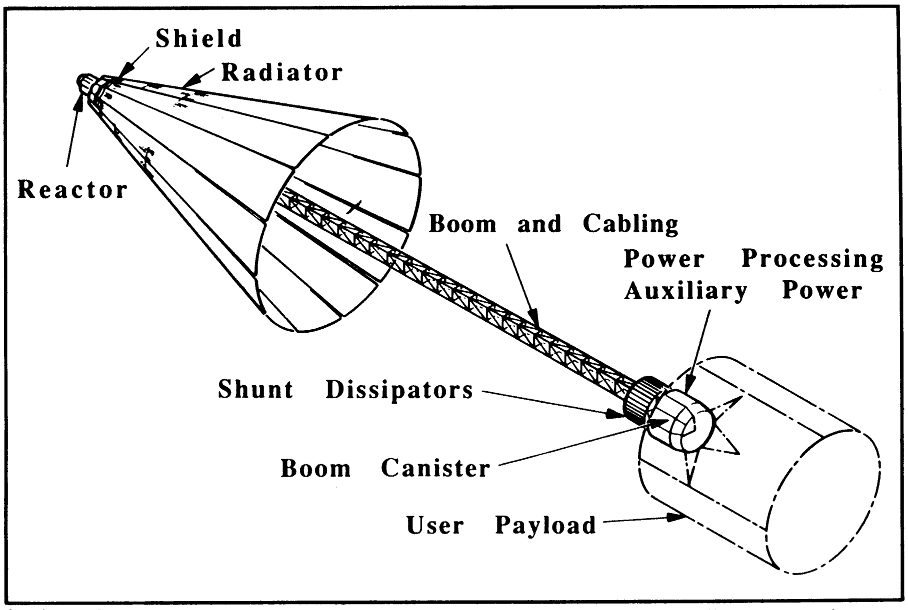
SNAPS, she said, could operate with equipment currently available or likely to be available reasonably soon. Space missions could also be undertaken long before 2055, such as the astrometric Explorer probe that Donald York of the University of Chicago described at the meeting on behalf of a group of nine astronomers from all over the United States.

Parallax is the apparent change in the position of a distant object as the observer changes points of view. Specifically, certain stars seem to change position in the sky when viewed at different times of year, say in June and then in January. This parallax is an angle equal to the vertex angle of a triangle whose base is the earth's orbit or part of it. As astronomers know the dimensions of the earth's orbit, they can calculate the altitude of the triangle, which is the distance to the star. The farther away a star is, the smaller is the parallax angle it shows.

The limit of measurement now is the smallest parallax noticeable to a telescope over the largest possible baseline, the diameter of the earth's orbit. If the base can be extended by sending a telescope out yonder into space, more and more distant stars will show noticeable parallax.

As opposed to the apparent motion of parallax, stars also show a real motion across the sky, which is called proper motion. Over years and even centuries, astrometry charts proper motions. This is particularly the sort of astrometric project that can take generations to accomplish, but it gives astronomers their knowledge of the dynamics of our galaxy.

In addition, some stars show a cyclic wobble in their proper motion that betrays the presence of an unseen companion (or companions) that might in some cases be alien planetary systems. Bar-



In the reference design for the satellite, a long boom keeps the delicate experiments of the payload well separated from the nuclear reactor power source.

nard's star is a particularly famous example of a star with such a wobble, and certain astronomers have followed its motions for decades.

Stars that have been closely followed in proper motion or have had their parallax well measured are mostly in the solar neighborhood delineated for the SNAPS project. However, as Marjorie Meinel points out, proper motion and parallax studies are tedious, and those that have been done have usually concerned bright stars or stars that move very fast – Barnard's star is a good example of the latter. She urges a systematic extension of these efforts to faint stars – even to brown dwarfs – and to slow-moving stars.

It is the slow-moving stars, especially those whose motion through space is nearly parallel to the sun's, that may have affected or in the future may affect the development of the solar system. "It is precisely these stars that have grazed the solar system in the past or will do so in the future," she says. "These stars are clearly of much interest to questions concerning the history of the solar system and especially of the Oort zone." The Oort zone is where comets are supposed to come from, and a disturbance there could send a shower of comets into the inner solar system. There has been much discussion recently of the effects of such showers on the earth, particularly in triggering mass extinctions of flora and fauna (SN: 2/14/87, p.100).

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The SNAPS project would coordinate the work of observatories around the world, and particularly that of very modern dedicated equipment. Astrometry has always had dedicated telescopes – usually they have been transit telescopes, instruments that looked only at the zenith meridian of their location, snapping photographs of stars as they crossed the meridian. The meridian makes a good reference for both proper motion and parallax measurements.

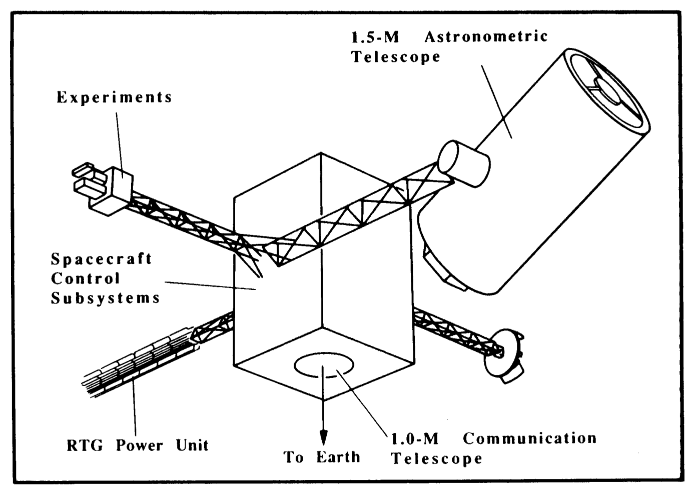
A modern transit instrument originally intended for photometry, but which could be used for intermediate-precision astrometry, is a 1.8-meter telescope at the Steward Observatory of the University of Arizona in Tucson, which was developed by Arizona's John T. McGraw, M. G. M. Cawson and M. J. Keane. This telescope has fully automated data-gathering based on a charge-coupled-device (CCD) photoelectric sensor, rather than the old-fashioned photographic plate.

Also at the Steward Observatory, Robert S. McMillan, Tom Gehrels and J.V. Scotti of the University of Arizona and Brian G. Marsden of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., have converted an old 0.9-meter telescope into a CCD-equipped sky survey telescope called Spacewatch. So far they have been using it for astrometry of asteroids.

Marjorie Meinel calls these examples of instruments that might be used systematically for SNAPS. She would like to see a NASA laboratory designated as a "lead center" for SNAPS, and she wants the International Astronomical Union to involve itself in the international coordination.

The Explorer mission proposed by York and his colleagues would carry a telescope about 1 meter in diameter with a photoelectric sensor and optics specially designed to give a flat field of view on a three- or four-year mission. He rates its capabilities as "orders of magnitude improvement over what's foreseeable in the next few years." It would be capable of measuring parallaxes of objects at kiloparsec distances with 10 percent accuracy. One kiloparsec is 3,260 light-years, roughly 10 times as far as the current practical limit for parallactic distance measurement.

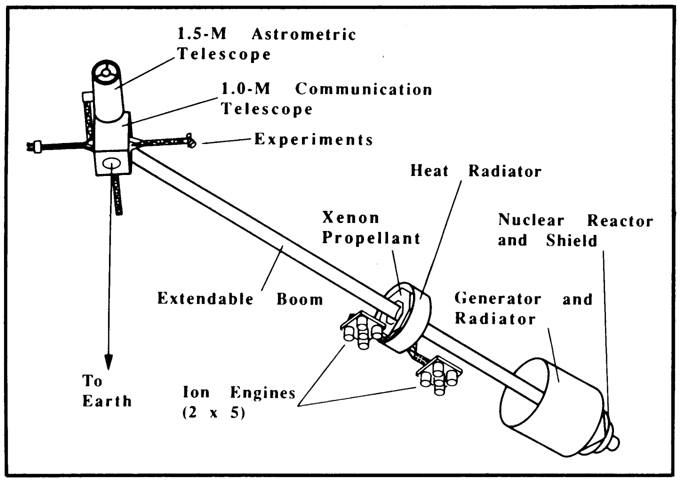
York stresses that the Explorer could measure the three-dimensional motions of the globular clusters of stars that inhabit the edges of our galaxy. These globular clusters contain the oldest stars known in our galaxy, and they are especially interesting to astronomers studying stellar and galactic evolution.



The payload, which would fly free after the acceleration period was over, would be centered on a large telescope used to beam communications to and from earth by lightwave signals. The 1.5-meter telescope for observing stars is only slightly larger than the communications instrument.

TAU would extend even these capabilities enormously again. TAU would be able to measure parallaxes of all the stars in our galaxy (distances to more than 30,000 parsecs or 100,000 light-years) and of other nearby galaxies – the Magellanic clouds, the local group galaxies – to approximately a ten-millionth of a second.

To establish the base of the triangle, TAU would work with another telescope in low earth-orbit. Simultaneous measurement by the two telescopes would determine the parallax without waiting for the earth to go around in its orbit, and without having to subtract the amount of the star's proper motion that occurs while



During propulsion, TAU's xenon-ion engines would sit on the boom halfway between the payload and the nuclear reactor that provides their power. Engines use electric forces to ionize xenon atoms and expel the ions. Reaction to the expulsion of the ions thrusts the rocket forward.

the earth is going around between the measurements.

TAU would also provide infrared measurements with an ultracold telescope and so without the interference due to sources of heat in and around the telescope. It would observe far beyond the sources of the zodiacal light, which interferes with earth- and near-earth-based observations of faint objects, particularly in the infrared. It would be able to measure the parallaxes of infrared objects where that cannot be done now – in heavily obscured regions and in the center of our galaxy.

TAU would provide the first view of the solar system from the outside. On its way it would make closer observations of the Oort cloud. It could study the heliopause, the ultimate outer limit of the solar system, the boundary where the solar wind peters out and the sun ceases to dominate the physics of space.

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The mission would require advanced space engineering to become even more advanced than it is now, as K. T. Nock of the Jet Propulsion Laboratory pointed out at the meeting. TAU would use an ion-propulsion engine, one that gets its thrust from ionization of the fuel, not from combustion, to drive a 5-ton spacecraft. Ionic engines have been under development for more than a quarter of a century. TAU would require a 490-kilowatt engine that expelled ions with a velocity of 196 kilometers per second. Present technology can give 5.1 kilowatts and an ion velocity of 35.6 km per sec. The fuel would be the rather exotic solid xenon. The power source would be a 1-megawatt nuclear reactor. The thrust would last 10 years, by present standards an extremely long acceleration period.

Communication with TAU would be by light waves, not radio. This would require a system capable of transmitting 20,000 bits of information per second from a distance of 1,000 astronomical units. To accomplish this would require improvements of 100 to 200 times in laser efficiency and transmitted laser power.

Nevertheless, TAU proponents think the technology will be ready by 2005. So far, the planning has been supported out of the discretionary fund available to the director of JPL. To encourage support and to work up a program that can be formally presented to funding agencies, the Meinels are organizing a workshop of interested scientists to take place in the autumn of 1987. □