NASA'S ASTROMETRIC TELESCOPE FACILITY

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ABSTRACT. NASA is planning an Astrometric Telescope Facility (ATF) for the U.S. Space Station. Space astrometric observations of unprecedented accuracy will yield many important results, including a planetary detection survey. The proposed facility is a dedicated astrometric telescope using the Multichannel Astrometric Photometer (Gatewood et al., 1987). To achieve the goal of sub-milliarcsecond accuracy requires innovative approaches to measuring technique and data analysis.

1. ASTROMETRIC PLANETARY DETECTION

Astronomers generally agree that many stars probably have planetary systems. It is therefore frustrating that no planet has been detected around any star other than our sun. Moreover, study of the origin and evolution of planets is greatly hampered because of absence of data on other planetary systems. The reason for this lack of detections is obvious: the detection of planets close to a bright star is a very difficult problem. A series of workshops sponsored by NASA (e.g., Black and Brunk 1980) starting in 1974 has attempted to identify and study possible approaches to the difficult planetary detection problem. Among the conclusions reached were:

(1) A scientifically important program is to survey approximately 100 stars within about 10 parsecs, using a technique capable of detecting planets with masses as small as those of Uranus and Neptune.

(2) A number of planetary search techniques are viable; the one most suited to the survey described above is the astrometric method.

Astrometric planetary detection is indirect; i.e., one seeks the gravitational effect of the planet on the star's motion, rather than directly sensing the light reflected from the planet's surface. Accurate astrometric measurements made over time will reveal the perturbation in the stellar proper motion caused by the presence of one or more planets.

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The survey will achieve the above-mentioned goal by measuring changes in the relative position of a star to an accuracy of 10 microarcseconds (0.00001 second of arc). It is expected that the survey will disclose many planetary systems. The subsequent study of these planets will provide data of great importance to the understanding of the formation and evolution of stars and planets. A negative result (no detections, or only a very small number) would also profoundly affect theories of star and planetary system formation.

Other uses of the telescope include a variety of astrophysical applications. E.g., the volume of space over which direct parallactic distances can be measured will increase by a factor of a million.

2. UNIQUE ASPECTS OF SUB-MILLIARCSECOND ASTROMETRY

No one, to our knowledge, has previously attempted astrometric measurements with an accuracy below the milliarcsecond level. Observations from space will solve many of the problems that have plagued ground-based astrometricists. Nevertheless, to achieve 10-microarcsecond accuracy requires close attention to a number of important issues. We are interested in the smoothness of the telescope's mapping of the sky into the focal plane at a very small angular scale. Therefore it will be necessary to carefully study how well this mapping can be determined with standard astrometric techniques and the approximately 30 reference stars planned for the ATF.

A reflecting telescope is normally thought of as achromatic. But the image shape is really a convolution of the color-dependent shapes produced by diffraction and coma. There is thus a chromatic aberration that has been called "chromaticity" (Kovalevsky 1984). The ATF design includes a two band-pass detector; a 10-band concept that will nearly completely eliminate the effects of chromaticity is being studied.

Any attempt to directly determine the centroid of star images is vulnerable to errors caused by non-uniform detector response. To overcome this problem, the ATF design has a field lens for each star (target and reference) so that the images are effectively scrambled just as in a photoelectric photometer.

A given star may not be a good astrometric reference at the micro-arcsecond level, for two reasons: (1) as star spots change and rotate around, the photo-center is displaced from the true center of the star; and (2) many stars are actually binaries, such that the photo center of the combined image shifts periodically. The first effect has been estimated, and is not likely to be a significant problem for the ATF. The second effect will be dealt with by judicious selection of the reference stars and by using data reduction techniques that take into account possible periodic motions of the reference stars.

3. THE ASTROMETRIC TELESCOPE FACILITY (ATF)

The preliminary design is a 1.25-meter f/13 prime focus reflecting telescope (Figure 1). The astrometric measurements are made by moving a

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Ronchi grating in the focal plane (Gatewood et al., 1980). The resulting modulated signals will be read out using a multiple-pickup system which has an individual field lens for each of the reference stars and for the target star. The angular separation of two stars in the direction of the grating motion is measured by determining the number of grating cycles between the stars and adding the phase difference of the corresponding signals.

The ATF is a robust system well suited to the Space Station capabilities and is planned as one of the initial payloads (see Figure 2). With its long lifetime, provision for easy instrument maintenance, and advanced data systems--the Space Station meets the ATF's requirements for a platform with long-term stability. The Ronchi-ruling design makes the instrument insensitive to vibrational and other dynamic disturbances expected on the manned Space Station. Details of the design are described in two NASA documents (Sobeck 1987)

Although the primary motivation for the ATF is the planetary detection program outlined here, it will be capable of many important astrometric observations. We expect that the existence of this astrometric facility in space will revolutionize a number of astrophysical areas where narrow-field astrometry is important.

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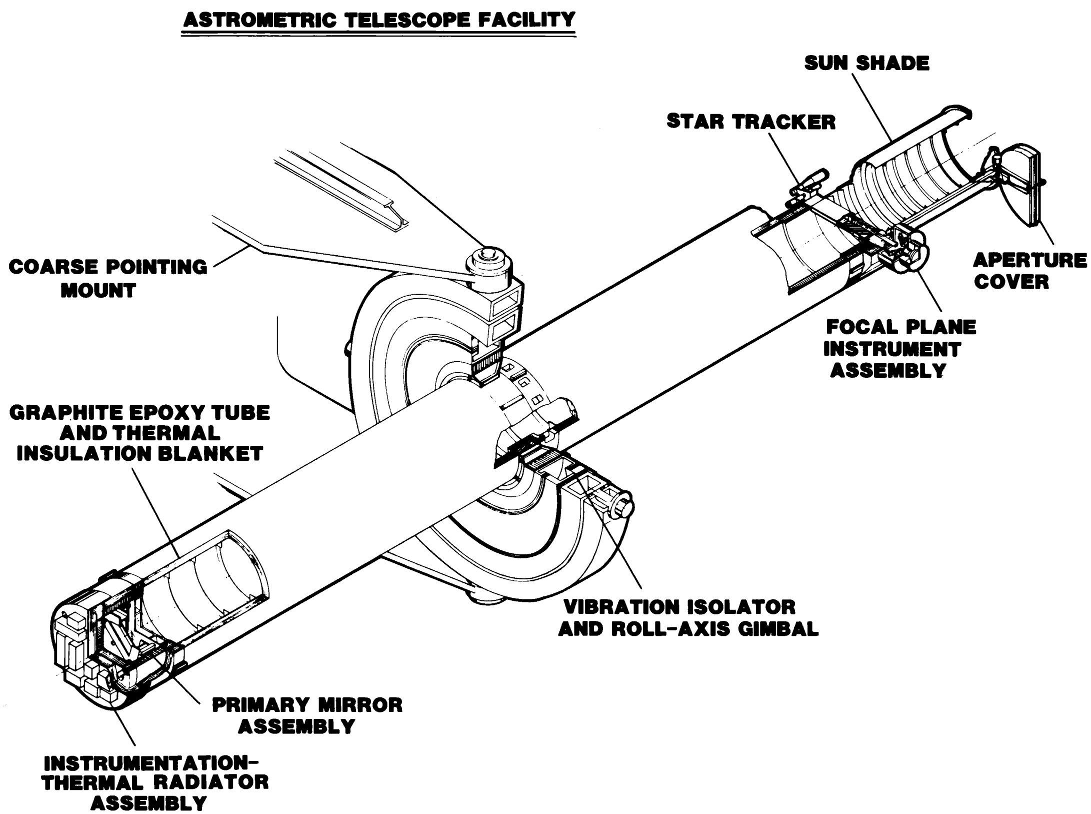

Fig. 1: Preliminary design for the Astrometric Telescope Facility (ATF).

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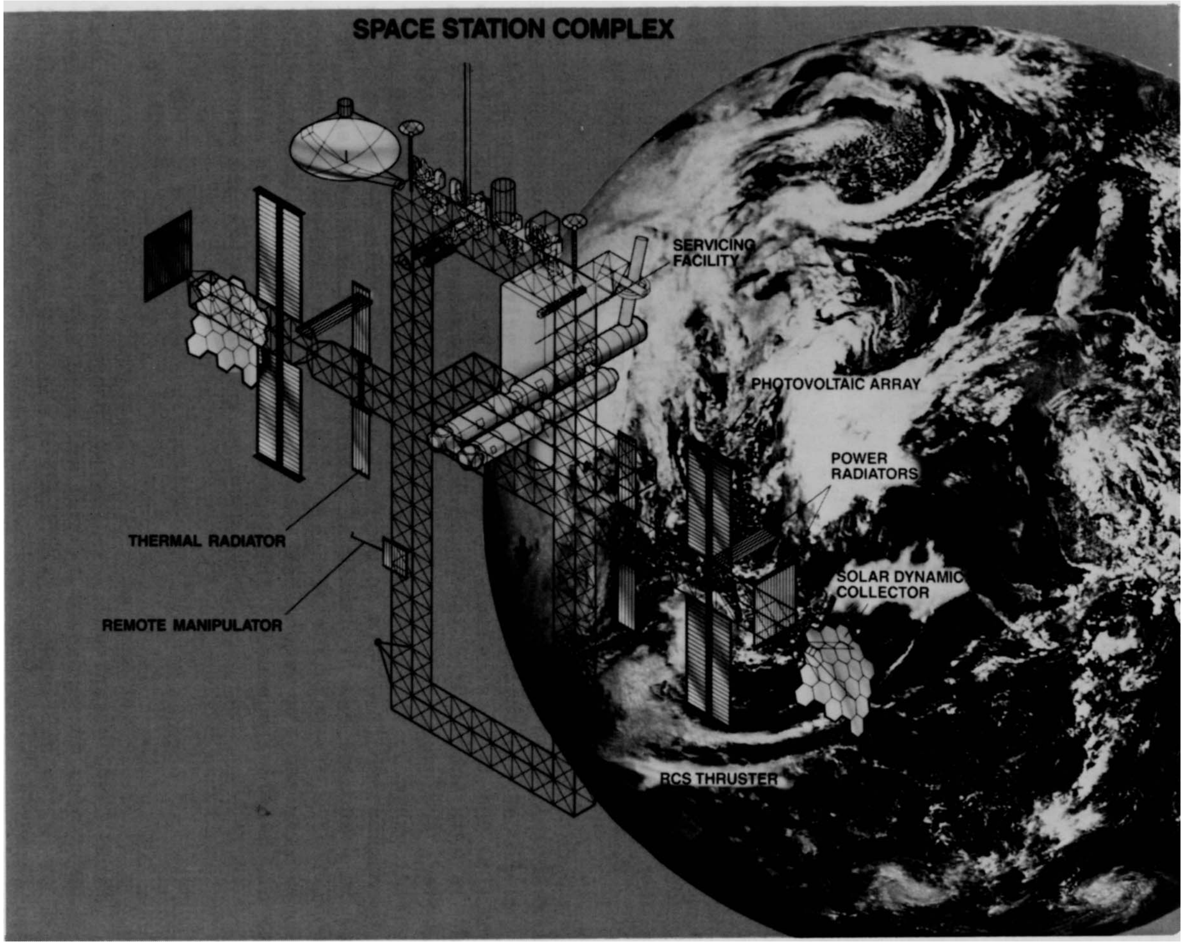

Fig. 2: The ATF mounted on the upper boom of the Space Station (upper right-hand corner, next to the servicing facility).

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