SCIENCE OBSERVATIONS WITH THE IUE USING THE ONE GYRO MODE

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Abstract. The International Ultraviolet Explorer (IUE) is a geosynchronous orbiting telescope launched by the National Aeronautics and Space Administration (NASA) on January 26, 1978, and operated jointly by NASA and the European Space Agency. The science instrument consists of two spectrographs which span the wavelength range of 1150 to 3200 Å and offer two dispersions with resolutions of 6 Å and 0.2 Å. The spacecraft's attitude control system originally included an inertial reference package containing 6 gyroscopes for 3-axis stabilization. The science instrument includes a prime and redundant Field Error Sensor (FES) camera for target aquisition and offset guiding. Since launch, 4 of the 6 gyroscopes have failed. The current attitude control system utilizes the remaining 2 gyros and a Fine Sun Sensor (FSS) for 3-axis stabilization. When the next gyro fails, a new attitude control system will be uplinked which will rely on the remaining gyro and the FSS for general 3-axis stabilzation. In addition to the FSS, the FES cameras will be required to assist in maintaining fine attitude control during target aquisition. This has required thoroughly determining the characteristics of the FES cameras and the spectrograph aperture plate as well as devising new target acquisition procedures. The results of this work are presented.

1. Introduction

The International Ultraviolet Explorer (IUE) satellite was launched on January 26, 1978, by the National Aeronautics and Space Administration (NASA) with an expected 3–5 year lifetime.

It is a collaborative project supported by NASA, the European Space Agency (ESA), and the United Kingdom's Science and Engineering Council (SERC). The satellite, located in synchronous orbit, is operated in real-time from the NASA Goddard Space Flight Center in Greenbelt, Maryland, for 16 hours a day and from the ESA Villafranca del Castillo station near Madrid, Spain, for 8 hours a day. The science instrument consists of a 45-cm diameter f/15 Cassegrain telescope, prime and redundant Fine Error Sensors (FES) for target acquisition and offset guiding, and two echelle spectrographs with SEC Vidicon cameras. The spectrographs cover the spectral range from 1150 to 3350 Å, with low (6 Å) and high (0.2 Å) resolution modes. The satellite continues to function well, recently passing its twelfth anniversary on-station.

Y. Kondo (ed.), Observatories in Earth Orbit and Beyond, 517–520.

2. Attitude Control

The original attitude control mode employed gyros (three prime, three redundant) to sense motion in 3 axes. For slews and target acquisition, the On-Board Computer (OBC) used only the gyro information to maintain pointing by commanding 3 reaction wheels. During exposure integrations on target, the offset guiding information provided by an FES camera was also used in order to provide fine pointing control to a stability of better than 0.5 arcseconds.

By 1982, 2 of the 6 gyros had failed. A new attitude control mode was developed which employed information provided by the Fine Sun Sensor (FSS). The FSS is a solid state, two-dimensional device which can provide pitch and roll information with a resolution of $\sim$ 15 arcseconds. Although the device had not originally been intended for use in attitude control, the interconnections of the IUE design allow the OBC to access and use the sensor information. Various combinations of gyro, FSS, and FES information are used to maintain control while slewing, for acquisition, and for offset guiding during exposures. A prominent change from the previous system was the use of FSS information to monitor roll axis motion. When the fourth gyro failure occurred on August 17, 1985, the two-gyro/FSS mode was implemented on the satellite. This mode has proved to be very effective, with essentially no degradation in the capabilities and efficiency of obtaining science observations.

In anticipation of another gyro failure, a one-gyro/FSS control mode has been developed. This mode makes more extensive use of the pitch information provided by the FSS. By using the remaining gyro to sense yaw motion and the FSS for pitch and roll, the mode fully maintains the current capability to slew around the sky with no noticable degradation. However the 15 arcsecond resolution of the FSS makes this mode unsuitable for the fine control required for target acquisition and exposure integrations. To provide fine pointing control, plans are to utilize the prime and redundant FES cameras. A new element of the one-gyro mode is the ability to bias the FES x and y position values. With the FES in track mode, the OBC normally uses the FES information to command the wheels so that a star maintains a constant position within the FES field of view to $\sim$0.5 arcseconds. By biasing the position values, it will be possible to slowly move a star to any desired position in the FES field of view. This allows the fine control needed for target acquisition and exposures.

3. Operations with the One-Gyro/FSS Mode

Under the present two-gyro/FSS mode, an FES image taken in field camera mode is used to identify the target. The FES field of view is a 15.8 arcminute square image obtained from the reflection of the star field from the aperture plate. The plate contains the apertures of the spectrographs as well as various focus slots and other openings. Once located, the target is brought to a reference point in the FES field of view by performing a small fixed-rate slew. From the reference point, calibrated fixed-rate slews are used to place the target in any one of four spectrograph apertures.

The FES is then "primed" on a convenient field star for offset guiding and the exposure is begun. In the present mode, it is not a concern if the FES briefly loses star presence as the target crosses an aperture or focus slot during the small fixed-rate slews since they are being made under gyro control. It also does not matter if the exact relative positions of the guide star and target star are known prior to target acquisition since any convenient field star can serve as a guide star and the target is placed in an aperture under gyro control.

With the one-gyro/FSS control system, there will be three major differences. The telescope pointing under the remaining gyro and FSS control will not be steady enough for an FES image of the target area in field camera mode without significant blurring and degradation. To overcome this, an FES camera will first be used in a raster scan search pattern to locate any available field star. Once located, the FES will be commanded to hold the position of the star fixed within its field of view. With the telescope pointing now fixed to within ~0.5 arcseconds, the second FES can be used to obtain an image of the target area.

Secondly, since the target star will be moved about the FES field of view by biasing of the FES tracking position, the target cannot temporarily disappear in a focus slot or aperture without loss of fine attitude control. The locations and effective sizes of the aperture plate openings must be known to a high degree of accuracy and the small fixed-rate slews selected to move a target star within the field of view must avoid crossing any of these openings.

Finally, the target cannot be placed in the aperture by biasing of the target position since the FES will lose star presence at the edge of the camera aperture. Instead, the FES will have to be tracking on a selected guide star. The guide star will then be positioned such that the target is centered in the appropriate aperture. This requires not only that the relative positions of the guide and target stars be known to a high degree of accuracy, but that any geometric distortions of the FES cameras, which are magnetically focused image disectors, be taken into account.

Over the last several years extensive studies have been made by IUE Observatory staff members to measure both the locations and effective sizes of the aperture openings and the geometric distortions in the FES cameras. From initial testing of the two-gyro/FSS control mode, it was found that small fixed-rate slews done under gyro control within the FES's field of view were both repeatable and generally accurate to ~0.25 arcseconds.

Thus by performing very slow fixed-rate slews across aperture openings at several angles, both the locations and effective areas of the openings have been determined. Determination of FES geometric distortions required a more extensive series of measurements. Using the FES coordinate system, a grid of points was selected which covered the FES field of view. A target star was then placed at the FES reference point. Next a small fixed-rate slew was calculated and uplinked to the spacecraft to move the target star to a selected grid point. Upon completion of the slew, the FES was commanded to measure the target's position. The difference found by subtracting the predicted geometric position from the found position then constituted the measured geometric distortion for the grid point. As a by-product of these measurements, the surface brightness of the aperture plate with its effective boundary as seen by the FES cameras was also obtained.

The spacing of the measured grid points was varied as a function of the rate of change of the measured distortion. For lookup table purposes, a uniform grid was created with intermediate points being calculated graphically from the measured data to form a smoothly varying distortion pattern. The lookup tables have already been successfully utilized in software which calculates accurate guide star positions in the FES field of view based on information from previous observations.

4. Conclusions

Development of the calibrations of the FES cameras and of the one-gyro/FSS control system is essentially complete. Current efforts by the Observatory staff are to prepare software for the ground system computers which will be needed for the one-gyro/FSS control mode. Experience with the IUE spacecraft and the various attitude control modes being developed to extend its useful mission lifetime may be applicable to other future missions and help prevent premature ending of missions due to problems with gyros and spacecraft inertial reference systems.

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