A REPORT ON A SPACECRAFT TEST OF THE ONE-GYRO SYSTEM

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I. Introduction

The IUE inertial reference system contains six gyroscopes intended for use in attitude control. Currently, IUE uses the two remaining functional gyros to point and slew. In order to prepare for the failure of one of these devices, the Observatory staff is developing an operating system, consisting of software for the On Board and ground computers, requiring only one gyro, the Fine Sun Sensor (FSS), and both of the Fine Error Sensors (FESs) to control the satellite. This report summarizes the results of a spacecraft engineering test, conducted on March 18, 1991, of an advanced version of this system.

In the test configuration, the OBC receives data from gyro #4, which is most sensitive to pitch motion; this situation represents a "worst case" scenario for maintaining yaw control, and also describes the failure mode presently believed to be most likely. Both FESs are active (FES #1 was powered up on March 14). The spacecraft is initially pointed at a star field containing at least two stars of 9 th magnitude or brighter, and at a beta of 67 degrees. A modified two-gyro system is loaded into the backup 4 K memory; this software controls the satellite while the full one-gyro system is loaded into the 8 K memory, and enhances spacecraft safety during the test. When the one-gyro system load is complete and verified, IUE's operation is transferred to this system.

II. Results

a) FES Telemetry Modes

Since the one-gyro system is designed to use both FESs, it must be able to transmit, simultaneously display, and correctly process telemetry from the two devices. The operations staff may choose to assign all 8 samples/minor frame of available FES data to one of the FESs, or they may receive 7 samples/mf from one FES and 1 sample/mf from the other device. After the activation of FES #1 and during the spacecraft test, all of the possible FES telemetry modes were tested; all modes function as expected. In particular, the ground system can properly collect and reconstruct data for an FES image or star position measurement using one FES while the OBC holds the spacecraft steady with the other instrument. This success verifies the feasibility of an important part of the system.

b) Stability of the One-gyro Attitude Control Modes

Just before, during, and just after a minimum-time maneuver between widely separated targets, the spacecraft uses a default control mode, holding pitch and roll on the FSS and yaw on the gyro. In this mode, IUE oscillates in yaw by more than 30" and in pitch by approximately 7"; this motion is also seen in simulator testing of the one-gyro system. These oscillations are not damped out on reasonable time scale. Spacecraft analysts are investigating this motion, and there is a very good chance that it is possible to significantly reduce the amplitude of the oscillation. The important point is that the FES can still locate stars at least as faint as 8.5 magnitude by stepping through the field ("search and track"), and can maintain the acquisition of such stars with only very brief, and apparently not very critical, losses of star presence. Once a star is acquired, the oscillations are stopped by switching to other control modes.

The tracking modes intended for normal science operations place (fixed-rate slews and exposures) the pitch and yaw axes under FES control, with the gyro usually assigned to one of these axes, and the roll on the FSS. The test shows that the performance of these modes is very satisfactory. The OBC can use either FES individually to reliably maintain fine pointing, or the computer can use data from both FESs (usually primed on different stars) simultaneously. Stars have characteristic position variations of a few FES units when many of these control modes are used, a result not substantially different from the two-gyro system's performance, although modes using Kalman-filitered FES data are somewhat less stable. The spacecraft may be slightly steadier when the gyro is applied to pitch control; this enhanced stability probably results because gyro #4 is especially sensitive to pitch motion.

c) Fixed-Rate Slews

The test results verify that IUE is able to execute short (e.g., 5') accurate single-axis fixed-rate slews in both pitch and yaw under FES control, and longer (up to 27') yaw slews using the default control mode. The OBC can use either FES individually to control the slew, or may use both devices simultaneously; this latter option is not currently viewed as part of normal one-gyro operations, but this slew mode is clearly feasible. The 5' slews have characteristic errors of approximately 10"-20" in each axis, depending on which control mode is used for the maneuver. Part of this error may originate in the FES geometric distortion, which can be largely eliminated using off-line software. The test also demonstartes that the spacecraft can carry out the two-axes fixed-rate slews that are executed to bring a target to the reference point (or e.g., from the reference point to an aperture) after a maneuver. Determining the ability of the system to very accurately position a target in a science aperture using such slews would be an important part of any future one-gyro science test.

d) Minimum-Time Slews

An important aspect of the system is its ability to maneuver between widely separated targets. Two of these minimum-time maneuvers were carried out during the test. One maneuver has pitch and yaw legs of approximately 3 degrees length, and moves the spacecraft from beta 67 to 64 degrees. This maneuver shows modest slew errors of approximately 1.5' in each axis. In the second case, a 10 degree yaw is performed at beta 64 degrees, followed by a 15 degree pitch to higher beta; this slew is a critical test, because the pitch portion crosses the beta 75 degree line at which the FSS switches the detector head it uses for beta determinations. While this switch appears to cause no major problems (the pitch error is 2.5′), the yaw slew has an error of approximately 6′. Large yaw errors are also seen in the simulator test results, and are probably related to a firm limit on the roll rate during the sun-line yaw (actually a yaw + roll maneuver) slew. The simulator tests indicate that the magnitude of the error depends on the beta of the target and that at which the yaw is executed, with yaws at high betas to targets at those betas having small errors; in fact, the current operational software is written to partially accomodate this effect. Unfortunately, there was insufficient time during the test to exercise more of the maneuver options.

III. Problems

a) Spacecraft Heating

This experience confirms that having both FESs on simultaneously noticably increases the operating temperatures of a number of spacecraft components. In the present case, the heating is undoubtedly enhanced by the fact that the four days in question occur during late winter, when the usual solar heating is still appreciable. The spectrograph camera heads display temperatures (THDAs) that are characteristic of the upper range of those now seen during noraml science operations. These temperatures pose no danger to the cameras, but their presence indicates that additional camera calibration observations will be necessary when the one-gyro system is implemented. The temperature of the OBC is also relatively high during this time; this fact is unlikely to pose extreme difficulties for science operations given the recently relaxed OBC operating temperature guidelines.

Of greater importance is the observation that the temperature of an electronics box containing the science camera electronics can reach its maximum allowed value in the two-FES configuration. Excessive heating of this box could cause the science cameras to spontaneously shut down. On one occasion during the four day interval, the spacecraft had to be maneuvered to a low beta attitude to cool this electronics box. While the problem is still being studied, it appears very possible that some restrictions on target betas, similar in concept to limits that now exist to prevent overheating the OBC, will be required for one-gyro operations.

b) Software

The test results identify necessary, or simply desirable, changes to the current one-gyro software procedures. Two cases of a failure of the FESTRK procedure to activate commanded tracking modes signify the presence of coding errors in that procedure. In addition, the success of the fixed-rate slews indicate that such slews could be allowed under more attitude control modes than currently planned, requiring corresponding changes to the relevant software. Also, the use of updated scale factors for converting FES units to arcsecs for each of the FESs should improve the accuracy of fixed-rate slews performed under FES control. None of these changes should pose a major obstacle to the continued development of the one-gyro system.

IV. Summary

A spacecraft enginneering test of the one-gyro operating system was held on March 18, 1991. The telemetry, tracking, fixed-rate slew, and minimum-time slew capabilities of the system were examined. The performance of the spacecraft during these operations was very encouraging; all of the tests were basically successful. Errors in the ground software were uncovered. The heating of certain spacecraft components when both FESs are activated represents a more important problem, and may require the imposition of target beta restrictions similar to those that now exist to prevent overheating of the OBC. The success of this enginneering test suggests that a test (perhaps this summer) of the system's ablity to carry out actual science operations would be worthwhile.