ASK DR. GYRO

Q: What will IUE do if another gyro fails?

A: We have developed a backup attitude control mode using one gyro and the Fine Sun Sensor (FSS). The system should be completed this fall. At that time we will be ready to test the system on the spacecraft.

Q: What if a gyro fails tomorrow?

A: The current version of the system is capable of controlling the satellite to insure its safety. We believe that some basic science observations could be done while the full system is completed under an accelerated time scale. We have contingency plans in place to notify our IUE Guest Observers and keep them informed, to conduct the testing and implementation of the new mode, to familiarize the NASA and VILSPA IUE staff members with system modifications, and so forth.

Q: How many gyros does IUE have, and what happened to them?

A: IUE has 6 gyros, originally intended to provide 3 prime and 3 backup gyros. The first gyro to fail, Gyro #6, is stuck off. It was turned off, along with the other two backup gyros, during the spring 1979 shadow season to conserve power. When the 3 gyros were commanded to turn on again on April 18, 1979, only 2 spun up. Subsequent attempts to restart the gyro have been unsuccessful. The second gyro to fail, Gyro #1, experienced a failure in its control electronics on March 2, 1982. It continued to spin, but in an uncontrolled fashion. The next gyro failure was Gyro #2, on July 27, 1982. Finally Gyro #3 failed on August 17, 1985, bringing about the implementation of the two-gyro/FSS backup control mode.

Q: When do you think that the next gyro failure might occur?

A: Who knows? These 12-year old gyros have 5-year expected lifetimes. The engineers who designed them are learning from our experiences and can't make any predictions.

Q: Do either of the remaining gyros show signs of failing or degrading?

A: Gyro #4 is behaving fine. Gyro #5 has always had a somewhat higher drift rate than the other gyros, but still within the design specifications. Recently the drift rate of the gyro accelerated noticeably for a few weeks, then levelled out again. This caused some nervousness among the staff, but had no apparent ill effects or repercussions, aside from some poor trims.

Q: What are gyro trims anyway? The TO seems to spend a lot of time on them.

A: When the TOs trim the gyros, they are updating the calibration between the changes in spin rate of the gyros (in revolutions per second) and the actual angular motion of the spacecraft (in arcsec per sec).

Q: Why must this be updated?

A: The gyro calibrations are sensitive to temperature. The original gyro package was temperature controlled, but over the years the control thermistors that cycled the heaters to maintain constant temperature have failed. Currently all but one of the gyro heaters are left on "low" (one is on "high"). When the satellite is slewed to different beta angles, the solar illumination of the spacecraft changes and thus the thermal balance also changes. The gyro trim permits us to compensate for the thermal calibration changes. Otherwise when the pointing control is on gyros, during an acquisition or during short exposures, the target would drift slowly within the field of view (perhaps 3 to 5 arcsec in 10 minutes). An additional effect of changing beta angles is thermal flexure of the telescope tube. This causes some slow apparent motion of the target in the field of view, due to the change in the optical path. We use the gyro trims to compensate for this effect as well.

Q: How are the gyros used to control pointing?

A: Actually the on-board computer (OBC) controls the pointing. The gyros and the FSS function as motion sensors. The OBC uses this information to command reaction wheels to compensate for underdesireable spacecraft motion.

Q: Reaction wheels? What are they?

A: They are basically flywheels, used to store angular momentum. The angular momentum can then be transferred to the spacecraft.

Q: Why do the engineers "unload the wheels"?

A: The wheels are best used in a specific range of speeds, typically 200 to 800 RPM. If they are spinning too slowly, they are not effective in communicating angular momentum to the spacecraft. If they are spinning too fast, they may saturate (i.e. spin at an undefined maximum rate) and thus provide no control. We also try to keep the total angular momentum of the wheels under a reasonable limit to prevent the wheels from saturating during slews and to facilitate regaining control if the spacecraft loses attitude (i.e. loses pointing control). Finally, we keep the roll wheel under 400 RPM so that it does not causes microphonic noise on SWP camera image.

Q: What is the Fine Sun Sensor?

A: There are actually 2 Fine Sun Sensors, a prime and a redundant system. Each one consists of two sensor heads which can view +/- 32 degrees of sky along the pitch and roll directions. Two heads are aligned so that together they can view 128 degrees of sky, from a beta of 13 to 137 degrees, with a few degrees of overlap at beta 75. Each sensor has two reticles, a fine reticle and a coarse reticle, for each axis. The illumination pattern produced by sunlight illuminating the various reticles is encoded and converted to beta and roll readings.

Q: Why wasn't the FSS used on IUE from the beginning?

A: The resolution of the FSS is 15 arcsec, while the gyros give 0.25 arcsec resolution. Thus the gyros give much better information and yield better pointing control.

Q: Isn't the cruder 15 arcsec accuracy of the FSS a problem?

A: For the two-gyro/FSS mode, it has been only a small problem. The FSS is generally used to monitor roll motion, which is not as important for science observations than pitch and yaw. You can picture an FES image of the field of view, then rotating it by 15 arcsec around its center. For a star at the edge of the field 7 arcmin away, this corresponds to an apparent motion of only 0.03 arcsec. There are some minor stability problems however. After a slew, the roll motion may be rocking back and forth by a few arcmin. We have to wait a little for this motion to damp out, as the OBC brings the motion under control. In the early days of the two-gyro/FSS mode, this was a problem at low betas. However new control algorithms have greatly improved stability.

Q: How much time is typically spent waiting for this roll motion to damp out?

A: A couple of minutes per target, a little longer at low betas.

Q: Does this mean that slews take longer on the two-gyro mode?

A: Actually the slews are often shorter. One of the slew legs is along constant beta. This requires simultaneous yaw and roll motion, effectively doing two slews at once. The 3-gyro mode couldn't do this.

Q: What about FSS accuracy problems with the one-gyro mode?

A: During slews between targets, the pitch axis will be controlled using FSS data. We don't expect the 15 arcsec resolution of the FSS to be a problem for this. However when the slew is done, the spacecraft will probably bobble in the pitch direction for awhile. Even when the motion damps out, the pitch motion will still be roughly 15 arcsec. To stop that, we will switch to a different control mode which uses the FES. So we think we can work around the FSS resolution.

Q: Are there any problems with using the FSS?

A: In general it is quite reliable but we have seen some instances in which it has yielded corrupted data. This happens most frequently at the extreme beta angles which the FSS reads. The lower head can yield corrupted data below a beta of 28 degrees, so we do not normally observe there (there are power problems at such low betas as well). On rare occasions we have also seen corrupted data near 75 degrees, which is the crossover point between the lower head and the upper head.

Q: You've mentioned pitch, yaw, and roll motion - what are they?

A: Spacecraft are generally controlled in three axes, which are oriented with respect to the spacecraft itself: pitch, yaw, and roll. A way to describe this (without drawing a picture) is to think of yourself riding the satellite, with the solar arrays to your left and right and the telescope tube in front like a horse's neck and head. When the satellite pitches, the tube dips down or rises (this motion causes a change in beta angle). When the satellite yaws, it is twisting to turn left or right. When it rolls, it rotates around the optical axis of the telescope. To control in 3 axes, we need 3 pieces of motion information. Thus the 2 gyros and FSS give the required 3 pieces of information.

Q: How will you get 3 pieces of information from only 1 gyro and the FSS for the one-gyro mode?

A: The FSS actually yields 2 pieces of information, motion in both pitch and roll. So for slews from target to target, information from the FSS will be used to control the pitch and roll motions and the gyro to control in yaw.

Q: Does it matter which of the 2 remaining gyros is used for the one-gyro mode?

A: Each gyro is oriented in a different direction, described by a vector which includes components in pitch, yaw, and roll. Each gyro is thus more or less sensitive to any given axis depending on its individual vector. Of the 2 remaining gyros, Gyro #5 has more sensitivity to yaw motion than Gyro #4. So the one-gyro mode might work a little better with Gyro #5. For our simulator testing, we always try out the worst case scenario. So we've been testing the system using Gyro #4.

Q: So Murphy's Law says that Gyro #5 will fail first?

A: You've got it! Our worst case scenario for the two-gyro mode was the failure of Gyro #3, and sure enough it was #3 that failed.

Q: Is it possible to get Gyro #6 turned on again?

A: It is possible in principle. It would require an extended period of time, during which repeated turn-on and turn-off commands would be sent to it. This would have the effect of heating the gyro, hopefully reducing the vicosity of the fluid in the gyro mechanism so that it could spin again.

Q: Why haven't we tried this?

A: It is expected that this would not work unless we can raise the temperature of the gyro to about 100 C. This effort would require hours, even days, of sending commands. During one previous, much shorter attempt to turn on the gyro, a "glitch" was experienced by one of the other gyros. This raised the concern that such a heavy use of the control electronics could imperil the remaining functioning gyros. So no such extensive attempt to turn on Gyro #6 has yet been made. The option exists for the future, however.

Q: When might you try to turn on Gyro #6?

A: When we get desperate. If we are using the one-gyro mode and it works pretty well, we wouldn't try until the last gyro failed. If the one-gyro mode doesn't function well, we might try it then so that we could go back to the two-gyro mode.

Q: Will my ability to observe with IUE be pretty much the same with the one-gyro mode as with the two-gyro mode?

A: We hope so, but we know it will take more work. For instance, ALL targets will have to have guide stars with accurate relative coordinates because this will be a neccesary part of the acquisition. If the target is a solar system object, we will need an accurate ephemeris for the guide star. We will also need to use both FESs for the acquisition.

Q: Why is that?

A: As I mentioned before, control using the FSS is pretty crude, with the satellite bouncing around by 15 arcsec or so. We suspect that an FES image taken when this is going on would blur out the image sufficiently to obscure the fainter stars. This would make it hard to identify many fields or acquire fainter targets and guide stars. So what we might do is command the FES to search for a star, any star that it can track on. Then we would command the OBC to use the FES information to control pitch and yaw, with roll on the FSS.

Q: But if you are tracking on a star with the FES, how can you take an FES image at the same time?

A: We can't. That's why the second FES would be needed.

Q: Are there any problems with using 2 FESs at the same time?

A: The 2 FESs view the same field via a beam splitter. FES #2, currently in use, receives about 70 percent of the light. Thus FES #1 is less sensitive. A possible problem is that having two FESs on generates more heat in the science instrument. A test of the FESs performed during the summer of 1987 showed that the cameras warmed up by about 4 degrees. This may be expected to have some small effects, such as the known sensitivity effects with temperature (about 0.3 percent per degree C for the SWP and LWP). Any such effects should be measurable and taken into account in the calibrations and data reductions. A potentially more serious problem might occur if the temperature of the on-board computer is affected.

Q: Are there any estimates of how much the OBC might be affected?

A: The IUE spacecraft analysts looked at the data obtained during last summer's test. They estimate that the OBC might be warmed by 1 degree.

Q: Wouldn't that make observing difficult by increasing the thermal constraints?

A: Yes, if it occurs. There are several ways out. First, the analysis might be off and the OBC might not run warmer. Second, we might relax the OBC temperature constraints. Third, we may be able to come up with a clever way of using only 1 FES to obtain obsevations.

Q: Couldn't you just turn off the second FES when you don't need it?

A: In principle, yes. However we always hesitate to turn any equipment on and off any more than we must, in case the switch fails. That is why we never turn off the SWP camera.

Q: If the satellite is bouncing around by 15 arcsec, how could you get the star into the center of the aperture? Would this smear out the spectrum?

A: We would not use that control mode (pitch on FSS) to acquire the target. First, we would command the FES to track on the target and then command the OBC to use the FES information to control pointing in pitch and yaw. The FES resolution is 0.25 arcsec so that should give very stable pointing. The next problem is to move the target to the reference point without losing this fine stability. To do this we have invented a new control mode.

Q: And what is that?

A: At present, we command the OBC to keep a star at a specific, fixed x and y location in the FES. This is what we do when we "put track on" a guide star. In the new mode, we will input variable x and y values. The OBC then moves the spacecraft to follow the changing x and y values, in effect slewing the star across the field of view. This should allow us to move accurately around the FES field of view so that we can set up on the target and put it accurately at the center of the aperture for the observation.

Q: What happens, though, when the star disappears into the aperture?

A: If that happened, the control would jump back to the "sloppy" mode on the Fine Sun Sensor. Normally we will want to avoid that. So we are carefully mapping out all the holes, slots, apertures, and so forth in the aperture plate that the FES views - so that we can avoid them.

Q: But you still must get the star into the aperture. How will you do that?

A: We will have to rely on accurate positioning of the guide star. We will need to have accurate RA and declination for both the target and the guide star. Then we need to position the guide star at precisely the correct position in the FES so that the target falls accurately at the center of the aperture. In other words, every observation will be made like a "blind offset". The FES, however, has some distortion, ranging up to several arcsec near the edge of the field. We have been carefully mapping out the geometric distortion of each FES so that it can be taken into account for the guide star position.

Q: Does this mean that I will have to measure RA and declination for all my guide stars before I come to observe?

A: Quite possibly. We may be able to use guide star locations from previous scripts. But this would have to be planned in advance to insure that a good guide star is available. Having good coordinates for more than one potential guide star would probably be a good idea, in case a particular star proves to be too faint, too near the edge of the field, or happens to fall in a slot.

Q: Will I still be able to get FES counts on my target?

A: We could still take FES counts on the target when needed. This might take a few minutes, so we may or may not do this routinely for all acquisitions.

Q: Are there any other problems that you anticipate?

A: We may have some maneuver accuracy problems, based on the results of our simulator testing. So far our tests slews have not been very accurate. If this problem can't be overcome, we might have to break up long slews into a few short ones or choose a different set of slew legs which would be more accurate but require longer to slew. However we are looking into the problem and there may be a solution.

Q: So what's the bottom line? Will the one-gyro mode work?

A: I think so. The main questions which will determine how well it will work are (1) how many FESs are neccesary or desireable to use, and (2) how stable are the various modes? These two factors will affect how much extra overhead will be required to acquire a target and obtain observations. That extra overhead could range from a few minutes to many extra minutes per observation. Our first spacecraft test will help answer this. Also, with time, we may come up with clever ideas to improve the performance of the control mode and observing efficiency. This happens with any new system.

Q: You wouldn't have to turn off a gyro to test the one-gyro mode, would you?

A: No. We would command the on-board computer to ignore the information coming from one gyro and use only information from the other gyro and the FSS.

Q: What else must be done before you test the one-gyro mode on the satellite?

A: First we must test changes to the ground computer software that allow us to command and receive telemetry from both FESs. The spacecraft analysts and Resident Astronomers will test the one-gyro/two-FES system on the IUE simulator (testing of the one-gyro/one-FES system is essentially completed). We hope to finish the testing by early fall. We are also putting together detailed plans on how we conduct such a test. Finally, we may need to get permission to try out the new system on the spacecraft. This may involve a formal NASA review. If all goes well, we hope to conduct a test on the satellite sometime in the late fall.

Q: Is there some danger in conducting this test?

A: Not really. The main problem might be if we lose attitude, that is lose pointing control. To help in regaining control of the satellite if that were to happen, we have a "short version" of the current two-gyro/FSS mode which will be loaded into the backup 4 k memory of the on-board computer. If we have any problems, we could switch almost immediately to this backup system.

Q: Did you do a spacecraft test of the two-gyro mode?

A: No. A formal NASA review advised us not to. There was some concern that the two-gyro mode would cause more wear and tear on the reaction wheels (this did not turn out to be a problem). The two-gyro mode was a major change from the three-gyro mode. So they advised us to put the completed system "on the shelf" until we needed it.

Q: So why test the one-gyro mode?

A: First, there is much less risk because it is very similar to the two-gyro mode. Second, some experience with the mode would give us a chance to "fine tune" how we will run science opearations.

Q: Doesn't the simulator help you to do that?

A: To some extent. The simulator is just a program that runs on the Sigma 9 computer. It models how the IUE spacecraft would respond to various commands either directly or from the on-board computer. We have a duplicate of the OBC connected to it which sends commands and reads the "telemetry" the simulator sends to it. Like all models it has its limitations. We learned from the two-gyro mode that you can get a broad feeling about the system with the simulator but the details you can learn only by using the spacecraft itself. The two-gyro mode had some surprises for us when we first tried it on the spacecraft, and we can expect some more surprises with the one-gyro mode.

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