The Space Telescope proves its survivability

The cause of the Hubble's focusing problem is not known, but the necessary remedies are evident, and prospects for its planned observations are excellent. David Cherry reports.

Attempts to complete the fine focusing of the Hubble Space Telescope, commencing June 14, led to the discovery that the telescope cannot be focused to anything like the intended sharpness. Instead, as an imaging instrument, the telescope only achieves the sharpness of a very good ground-based telescope on an excellent night. NASA officials announced the shocking news at a press conference June 27.

The images the telescope is sending to Earth indicate that its mirror system suffers from spherical aberration. A mirror with spherical aberration cannot focus all of the light at a single focal plane, making a sharp image impossible (**Figure 1**).

The magnitude of the Space Telescope's spherical aberration is scarcely believable, according to David Leckrone, deputy associate director of sciences for the Space Telescope, at NASA's Goddard Space Flight Center in Greenbelt, Maryland. In the interview with Leckrone that follows, he explains that the mirrors are designed and tested "all the way out to the seventh decimal place. The kind of error we are talking about here would be an effect in the second or third decimal place. It is enormous. It is immense. It is so big that we can't believe it. Therefore, there are a lot of us who think that there is a real mystery here."

Such an aberration could result from the mirror being figured (shaped) incorrectly by half of a wavelength of visible light, and there is also the possibility that its figure has changed since it was completed. Other possibilities are more remote and mysterious.

Lennard Fisk, NASA associate administrator of the Office of Space Science, appointed a Space Telescope Optical Systems Board of Investigation on July 2 to "review, analyze, and evaluate the facts and circumstances regarding the manufacture, development, and testing" of the mirrors. The board is chaired by Air Force Gen. Lew Allen (ret.), head of the Jet Propulsion Laboratory, and includes administrators and technical specialists with knowledge of large optics. The contractor for the mirrors, Hughes Danbury Optical Systems, Inc. (formerly Perkin-Elmer), has turned over all of its documentation to NASA for study.

Some politicians and the press, compelled by their own questionable agendas, have already rushed to judgment, and are sure that one of the mirrors was ground wrong, thanks to "NASA's laxity and ineptitude," as a *Los Angeles Times* editorial of June 30 expressed it.

Leckrone commented, "I am really concerned about our assuming that we know what actually is the matter and what the cause of it was, until people have had a chance to meticulously go through all of the information. And that is going to take a little while to accomplish. Anything beyond that really is speculation."

Impact on observations

The mission of the Space Telescope will be almost entirely accomplished and all of its highest priorities will be accomplished—partly in spite of the focusing problem, and partly by correcting the problem. The telescope should put 70% of the light from a point source within a circle only 0.2 seconds of arc in diameter. At present it puts only an estimated 10-25% of the light there; a precise percentage is now being sought by finding the best focal point. With longer exposures, that well-focused 10-25% of the light can be exploited by some of the instruments, provided neighboring sources of light are not too close to the object under study.

Edward Weiler, the Space Telescope program scientist, estimated the projected impact for each instrument at the June 27 press conference. Weiler's estimates, which follow, are rough and subject to refinement.

The Wide Field/Planetary Camera (WF/PC), he said, cannot be used at all. It was designed, for example, to photograph hundreds of distant galaxies at a time and to study changing meteorological patterns on other planets in the Solar System. The second-generation WF/PC, however, can be fitted with optics to correct the aberration. It is being built now and is already scheduled to be installed by Shuttle astronauts in 1993. WF/PC is considered by many as the single most important instrument on the telescope. Other instruments, planned for replacement in 1996 and 1997, can also be fitted with corrective optics.

The Faint Object Camera (FOC), designed for extremely high resolution at visible and ultraviolet wavelengths, will now only be about as good as ground-based telescopes in the visible range, but computer processing can improve the visible-light images significantly beyond that level. In the ultraviolet range, FOC will still constitute a unique capability. Ultraviolet light does not penetrate Earth's atmosphere. The only other near-term ultraviolet mission is Astro-1, which goes up in August for the duration of a Shuttle flight and has even poorer resolution than the Faint Object Camera, even with the focusing problem, by a factor of 4 or 5.

The High Resolution Spectrograph, which works only in the ultraviolet, will be able to do almost 100% of its planned work, according to Weiler. Only targets in very crowded star fields will be excluded, to avoid contamination of an object's spectrum with that of its neighbor.

Similarly, the Faint Object Spectrograph's ultraviolet work will not be affected except in crowded star fields.

The High Speed Photometer, which achieves high resolution in time by taking rapid-fire exposures of very short duration, loses none of that resolution, but will not be able to do observations where a high signal-to-noise ratio is required. As a result, about half of the planned work can still be done, most of it in the ultraviolet.

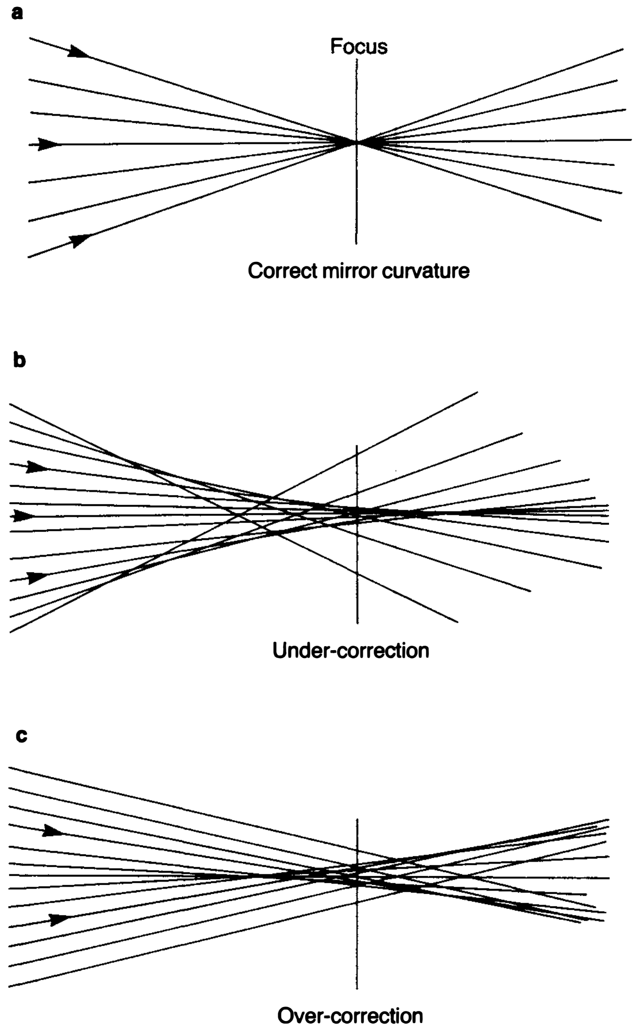
The Fine Guidance Sensors—in their role as precise measurers of positions and motions of objects—will not be affected, since high resolution is not required. They will still be able to search for evidence of planets orbiting other stars.

In addition to WF/PC II, two additional second-generation instruments are scheduled for installation in 1996 and 1997, and can also be fitted with corrective optics. They are the Near Infrared Camera and Multiple Object Spectrometer (NICMOS), and the Space Telescope Infrared Spectrograph, respectively. Which instruments they replace is to some extent a matter to be decided at the time they are sent up. The tasks for which they were designed are not identical to those of any instrument they would replace, although there is substantial overlapping. Some observations planned for the original instruments may thus have to be ruled out.

Even before corrective optics are put in place, the degree of improvement in imaging that can be accomplished with computer image enhancement may be dramatic. The possibilities are under intense study as we go to press.

As NASA's Lennard Fisk asserted July 2, "We're stubborn and clever. We're going to make it work."

FIGURE 1
Spherical aberration



A telescope's mirror or lens system must bring all points in the image into focus at a single focal plane (a). Mirrors or lenses with spherical aberration cause rays reflected from outer portions of the optic to come to focus (b) in front of, or (c) beyond, the focal point of the inner rays. Deviations toward the spherical produce the former result (so-called "under-correction"), but the term spherical aberration is applied to both cases.