Hubble Telescope has misshapen mirror

■Non-imaging work to be emphasized

■Corrective lens by 1993?

Washington

THE Hubble Space Telescope (HST), its builders have proudly claimed, contains the most precise optical system ever made, with reflecting surfaces polished to an accuracy of less than one-fiftieth the wavelength of light. That claim is still true.

But unfortunately, as officials of the National Aeronautics and Space Administration (NASA) admitted last week, the optical system was precisely made to the wrong shape, making HST's resolving power the same as that of the best ground-based telescopes, not ten times better.

But HST astronomers are confident that much of the science programme can be salvaged, and the defect is simple enough that replacement cameras equipped with corrective lenses, which could be installed by a space shuttle crew three years from now, will restore HST's full acuity.

The flaw was discovered as NASA engineers began to adjust the position of HST's secondary mirror, a small convex mirror that reflects light from the 2.4-m concave primary into the scientific instrument package. By shifting the secondary up and down the axis, astronomers expected a stellar image to come into perfect focus.

But the image could not be focused, and analysis of the way it changed as the secondary was moved indicated that HST suffers from spherical aberration caused by a departure of the radial profile of one of the mirrors from the required shape. The defect was such a "textbook example", according to deputy project manager Jean Oliver, that it must have been ground into the mirror during manufacture.

The departure of the optical surfaces from the required shape is small — about half a wavelength of light — but enough substantially to reduce the image quality (see below).

Most planned HST observations requiring high-resolution imaging will be put aside, but NASA officials were anxious, when announcing their predicament last week, to emphasize the "unique and important" science that HST can still do. Project scientist Ed Weiler pointed out that three of the HST instruments, the high-speed photometer, the high-resolution spectrograph and the faint object spectrograph, are non-imaging devices and had been expected to do much of their most significant work in ultraviolet regions of the spectrum, which are inaccessible from the ground.

The loss of resolution means that observations of faint, finely detailed objects

will generally not be feasible, and HST managers will replace such observations with proposals that had been turned down for lack of available time.

Weiler, along with deputy project manager Jean Oliver, was hopeful that HST's spherical aberration can be so exactly diagnosed that it will be possible to design a simple corrective lens to restore HST's full ability. An improved Wide Field/Planetary Camera is in fact already partly built, and with corrective lens added could be installed during a scheduled shuttle flight as early as June 1993.

The same can in principle be done for the Faint Object Camera, but Peter Jakobsen, HST project scientist for the European Space Agency (ESA), which provided the camera, said that no specific plans could yet be made.

While astronomers were mostly interested in finding remedies, NASA is setting up a review panel chaired by Lew Allen, director of the Jet Propulsion Laboratory, to determine the cause of the defect. Oliver was adamant that HST's optical design was correct, and Bob O'Dell of Rice University, who chaired a space telescope planning group in the 1970s, agreed that the design had been checked by so many people that any possibility of a flaw had been eliminated. The error, Oliver concluded, must therefore have been in the mirror testing procedure.

The primary and secondary mirrors were never tested in combination. According to Oliver, a test of the optical system of HST would have required the construction of an optically flat surface as big as the primary; the cost would have run into hundreds of millions of dollars. Instead, the two mirrors were separately tested for conformity to the desired profile. Somehow, during the manufacture and testing, one of the mirrors was made to the wrong shape, and it will be the job of the review panel to discover how an error that should easily have been caught remained hidden until three weeks ago.

That job may not be easy. HST's mirrors were completed in 1981, and few of the people now involved in the project have any connection with those early days.

When NASA put construction of the HST optical system out for bids, the Perkin-Elmer company, an experienced builder of high quality optics, sent in a proposal that included a detailed account of how the optical surfaces would be separately finished to NASA's specifications. Although, as O'Dell recalls, some astro-

...and the good news

THE optical system of the Hubble Space Telescope was designed to put about 70 per cent of the light from a point source into an image spot 0.1 of an arc second in diameter. Atmospheric turbulence prevents the best ground-based telescopes from producing images smaller than about one arc second.

A photograph made on 20 May by HST's Faint Object Camera (FOC) resolved stars into a central bright spot less than 0.1 arc second across and containing about 20 per cent of the light, the remainder being spread across a one arc second disc. It now turns out that FOC's first shot is as good as it will get.

At first, NASA officials and astronomers emphasised HST's capacity to do non-imaging photometry and spectroscopy, especially in the ultraviolet, where HST's chief advantage is simply to be above the Earth's atmosphere. But in the days following the announcement of the flaw, some have become more optimistic.

Peter Jakobsen of the European Space Agency, which built the FOC, says that because HST's images have a prominent core surrounded by a fainter halo, images of high-contrast objects, such as densely packed stars at the centre of globular cluster, will still be informative. And the fact that HST's distortion is of a constant, wavelength-independent form means some computer image-reconstruction techniques may be useful.

On the other hand, HST will not be able to see extended objects of low surface brightness any better than ground-based telescopes. It had been hoped, for example, that the FOC would be able to photograph the faint galaxies in which distant quasars are thought to reside, but Jakobsen now thinks the quasar light that spills into the one-arc-second halo will overwhelm any galactic light that might be there.

Nevertheless, Jakobsen thinks NASA was too "downbeat" in saying that virtually all the imaging work of HST will be useless, and emphasized that it is "early days" for astronomers thinking of ways to compensate for HST's deficiency. **D.L.**

nomers at the time would have been happier with an integrated test of the optics, Perkin-Elmer's proposal was judged adequate to the task.

Perkin-Elmer (now Hughes-Danbury after a take-over) won the contract and built the mirrors, but project managers at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama, had responsibility for ensuring that the terms of the contract were fully carried out. The review panel will reconstruct what happened both at MSFC and at Perkin-Elmer to find out how the faulty mirrors passed muster at both places. **David Lindley**