

billion by 1998. That's just about how much domestic spending subject to annual appropriations—not counting interest on the debt or social entitlements outlays—will be allowed to rise under the budget reconciliation act. The average increase would be about \$8 billion or somewhat more than the expected inflation rate of 3% per year. Appropriations have already been under the same pressure for two years now. That's because of the caps that were put on by the 1990 budget agreement, which limited any real rise in discretionary spending. The truth is in the consequences: Outlays for research

have been hard hit and will endure more sacrifice in coming years.

To pass his budget plan in August, the President had to promise further spending cuts from the fiscal 1994 budget. The form that such cuts will take is now unclear, but some lawmakers want to tighten the appropriations caps even more this fall. It is no wonder, then, that John D. Rockefeller IV, who took Al Gore's chair at the top of the Senate's science, technology and space subcommittee, has cautioned the research funding agencies that "the old era is over."

—IRWIN GOODWIN

HUBBLE SPACE TELESCOPE MAKERS PAY FOR COSTLY MIRROR MISTAKE

Concluding a churlish three-year dispute on 4 October, the US Justice Department dropped all its claims against the makers of the defective main mirror in NASA's \$1.6 billion Hubble Space Telescope. The settlement calls for NASA to receive \$25 million from Perkin-Elmer Corporation's optics division in Danbury, Connecticut, which produced and polished the mirror between 1978 and 1981, and Hughes Aircraft, a subsidiary of General Motors Corporation, which bought the optics firm in December 1989, just four months before the telescope was launched and the mirror's spherical aberration was discovered. As part of the agreement in purchasing Perkin-Elmer, Hughes had assumed the company's liabilities.

In a statement about the settlement, the Justice Department said Perkin-Elmer "knew or should have known of the defect" in Hubble's primary mirror. Even so, Justice's statement added, the government has released both companies from all further liability under the False Claims Act. Ever since the distortion was detected in the Hubble mirror, a concave hyperboloid 2.4 meters in diameter, Perkin-Elmer had resolutely denied any wrongdoing. The company insisted that NASA was fully informed of all data for judging whether the telescope's mirror had imperfections.

Hubble's specifications had called for 70% of the "first light" from a star to fall within a circle of 0.1-arcsecond radius. Analysis of the images sent back from the telescope during its checkout in orbit had indicated that only 15% of the starlight was doing so. Optics experts called in by NASA calculated that the edges of the main mirror had been ground 0.002 mm

lower than was called for. As a result, light striking the edge of the mirror focuses 4 cm beyond the focal point of light from the center of the mirror.

NASA's investigation of what went wrong was led by Lew Allen Jr, then director of Caltech's Jet Propulsion Laboratory. The Allen report, issued in November 1990, identified the cause of the flaw that hobbled the Hubble (PHYSICS TODAY, November 1990, page 19). The fault was in an instrument known as the null corrector, which served as an optical template that guided—or rather misguided—the final polishing of the mirror. The report further said that the mirror's makers had ignored at least three telltale signs of danger, all involving tests of the mirror's surface contours that are based on interferograms taken with another null detector of somewhat different design. Another study of the mirror problem was done by NASA's inspector general, who found evidence that Perkin-Elmer withheld significant information and thereby misled space agency officials into believing that the mirror was technically perfect.

Some astronomers and space scientists have questioned the adequacy of the settlement, considering that Perkin-Elmer received \$440 million for building the optical and fine guidance systems for the Hubble. But Edward A. Frankle, NASA's general counsel, argues that the settlement was "fair and reasonable." Indeed, a statement by C. Michael Armstrong, chairman and CEO of Hughes, suggested that Perkin-Elmer and NASA might share the blame. "It is our understanding that NASA knew everything that Perkin-Elmer knew

about the polishing of the mirror. But no one at NASA or Perkin-Elmer ever told Hughes Danbury about a potential problem with the mirror when Hughes Danbury became involved with the Hubble. If they had, Hughes would not have gone through with the purchase or taken over the Hubble contract without proper indemnification."

Despite troubles with the mirror, the telescope has unique capabilities to make observations. For certain studies, such as how galaxies form and evolve over time, Hubble's findings have "absolutely changed our way of thinking," says John Bahcall of the Institute for Advanced Study in Princeton, New Jersey, one of the earliest advocates of building the Hubble.

In early December, NASA plans to send the Endeavour shuttle to the telescope so that astronauts can replace the Wide Field/Planetary Camera with a second-generation camera that was scheduled from the start and install the Corrective Optics Space Telescope Axial Replacement. The camera was redesigned by JPL to correct the effects of the spherical aberration in the main mirror, while COSTAR, which contains optics that can be adjusted from NASA's ground control, is intended to align the light reaching three other Hubble instruments.

—IRWIN GOODWIN

NSF Crosses Potomac and Gets New Digs

Since mid-October the National Science Foundation has been moving to more spacious quarters in a posh new skyscraper—by Washington standards—on the Virginia side of the Potomac, in the Ballston section of Arlington. On the weekend of 3-5 December, the NSF's Mathematics and Physical Sciences directorate will take over most of the 10th floor, with the physics division occupying suite 1015 and astronomy suite 1045. The directorate for the geosciences is scheduled to move house starting 12 November and for computer and information science and engineering on the weekend of 12-14 November.

NSF's official new address is 4201 Wilson Boulevard, Arlington, VA 22230. While telephone calls to agency officials and program directors at the old numbers are now being forwarded, the foundation's new general information number is 703-306-1234. Electronic mail addresses will not be affected.