One of the most important features of the Hubble Space Telescope is its ability to be maintained and upgraded on orbit. Every few years, a team of astronauts carries a full manifest of new equipment on the Space Shuttle for the ultimate "tune-up" in space.

The Telescope was being designed as the Space Shuttle was being readied for its first flights. NASA realized that if a shuttle crew could service HST, it could be upgraded and maintained indefinitely. So from the beginning, Hubble was designed to be modular and astronaut-friendly.

Its modular design allows NASA to equip HST with new, state-of-the-art scientific instruments every few years – giving the Telescope exciting new capabilities with each servicing mission (see Fig. 7-1). In addition to science upgrades, the servicing missions permit astronauts to replace limited-life components with systems incorporating the latest technology (see Fig. 7-2).

7.1 Cost-Effective Modular Design

In February 1997 astronauts installed two next-generation scientific instruments, giving the Telescope infrared and ultraviolet vision. At the same time, they installed a state-of-the-art Solid State Recorder (SSR) to increase Hubble's observing capability. The 1993 and 1997 servicing missions increased scientific exposure time efficiencies 11-fold.

On Servicing Mission 3B (SM3B), scheduled for 2001, astronauts will add a camera 10 times more powerful than the already extraordinary cameras on board. They also will fit the Telescope with new, super-efficient solar array panels that will allow simultaneous operation of scientific instruments. These technologies were not available when Hubble was designed and launched.

The following sections identify some of the planned upgrades to HST and their anticipated benefits to performance. These improvements demonstrate that servicing HST results in significant new science data at greatly reduced cost.

7.1.1 Processor Improvements

During Servicing Mission 3A (SM3A), astronauts will replace Hubble's original main computer, a DF-224/coprocessor combination, with a completely new computer based on the Intel 80486 microchip. The new computer will be 20 times faster and have six times as much memory as the one it replaces (see Fig. 7-3).

In a good example of NASA's goal of "faster, cheaper, better," commercially developed, commonly available equipment was used to build the new computer at a fraction of the price it would have cost to build a computer designed specifically for the spaceflight environment.

The greater capabilities of the new computer will increase productivity for the Hubble observatory by performing more work in space and less work on the ground. The computer software uses a modern programming language, which decreases software maintenance cost.

7.1.2 Data Archiving Rate

With the addition of a second SSR on SM3A, Hubble's data storage capability will dramatically increase. The science data archiving rate will be more than 10 times greater than First Servicing Mission (1993) rates (see Fig. 7-4).

Advanced Scientific Instruments
Pave the way to New Discoveries

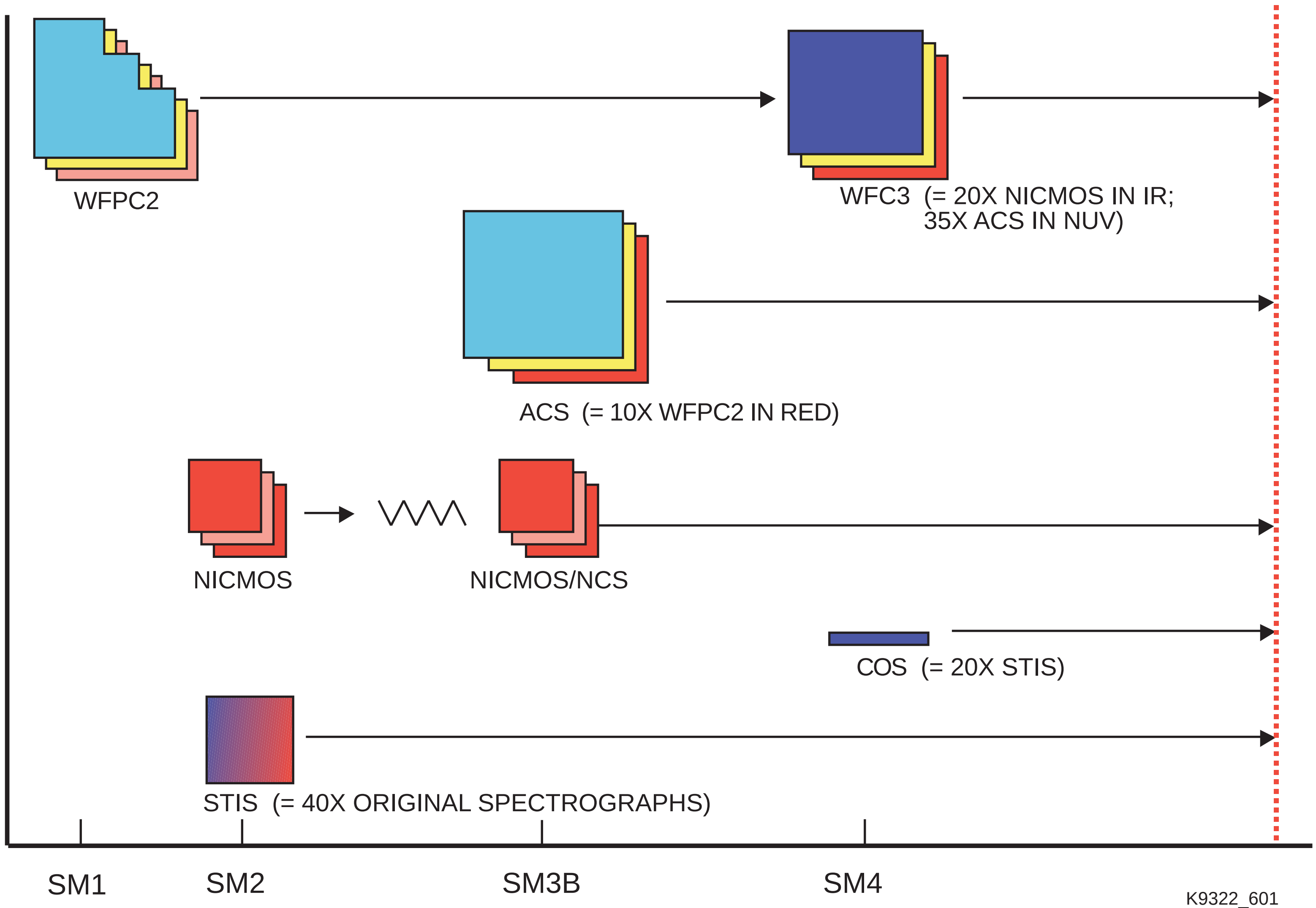

Fig. 7-1 Advanced scientific instruments installed (or to be installed) on HST

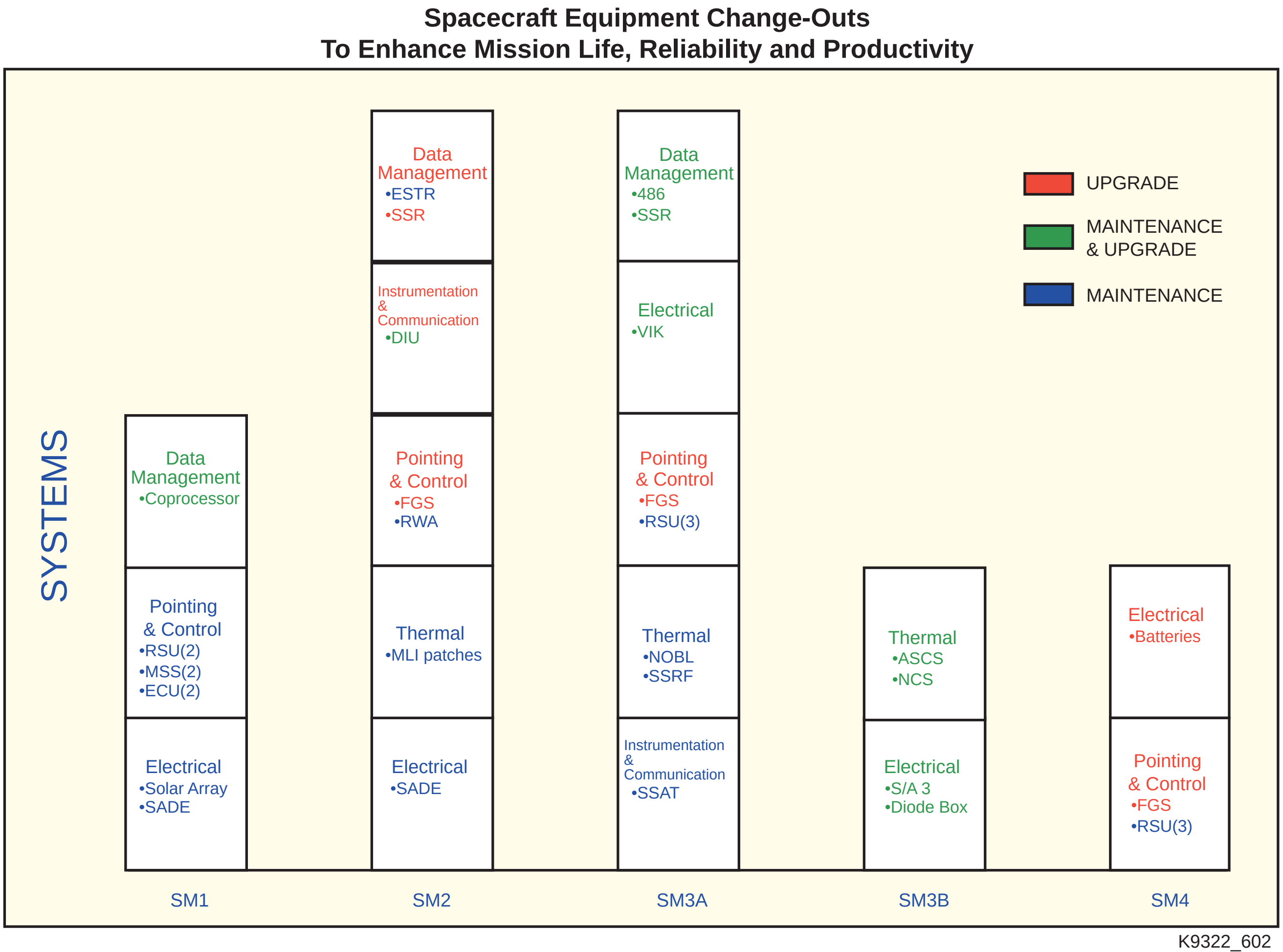

Fig. 7-2 Systems maintained and upgraded during each servicing mission

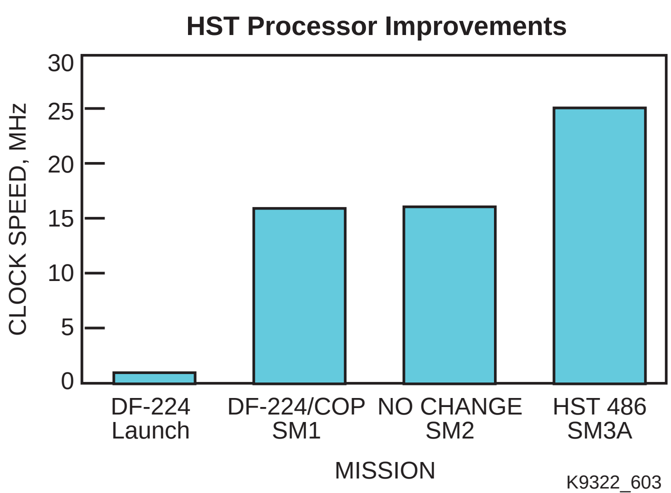

Fig. 7-3 Processor improvements on HST

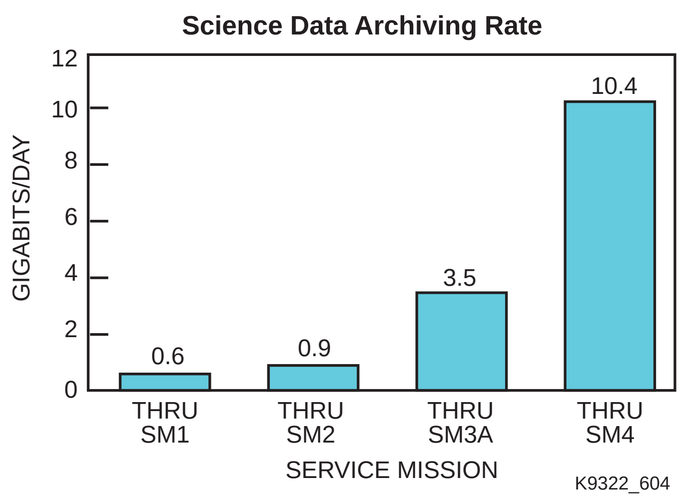

Fig. 7-4 Data archiving rate improvements

Prior to the Second Servicing Mission (SM2), Hubble used three reel-to-reel tape recorders designed in the 1970s. In February 1997 astronauts replaced one of the mechanical recorders with a digital SSR. During SM3A astronauts will remove a second mechanical recorder and install a second SSR.

Unlike the reel-to-reel recorders they replace, the SSRs have no reels, no tape, and no moving parts that can wear out and limit lifetime. Data is stored digitally in computer-like memory chips until Hubble's operators command its playback.

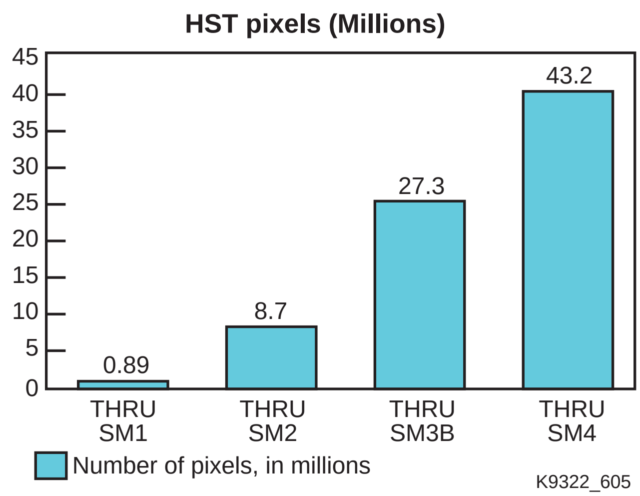

Fig. 7-5 Increase in onboard pixels

Although an SSR is about the same size and shape as the reel-to-reel recorder, it can store 10 times as much data: 12 gigabits of data instead of only 1.2 gigabits. This greater storage capacity allows Hubble's second-generation scientific instruments to be fully productive.

7.1.3 Detector Technology

Hubble's state-of-the-art detector technology allows the Telescope to capture and process faint amounts of light from the far reaches of space. Increased power and the resolution refinements achieved through advances in detector technology will greatly improve Hubble's performance and deliver even sharper, clearer, and more distinct images.

With the addition of the Advanced Camera for Surveys during SM3B, the total number of onboard pixels will have increased 4800 percent from SM2 in 1997 (see Fig. 7-5).

7.1.4 Cryogenic Cooler

Installation of the Near Infrared Camera and Multi Object Spectrograph (NICMOS) Cryogenic Cooler (NCC) during SM3B will greatly extend the life of Hubble's infrared cameras. The cryogenic cooler will increase NICMOS's life span from 1.8 years to 10 years (see Fig. 7-6).

NICMOS, which was installed on Hubble in 1997, has been a spectacular success. However, in January 1999 it ran out of the coolant necessary for conducting scientific operations. The NCC will preserve and extend the instrument's unique science contribution. The cost to develop and install the NCC is approximately $16 million, while the cost of NICMOS was $100 million. Installing a new cryocooler will increase by sevenfold the lifetime of the instrument and ensure a greater scientific return on the original investment.

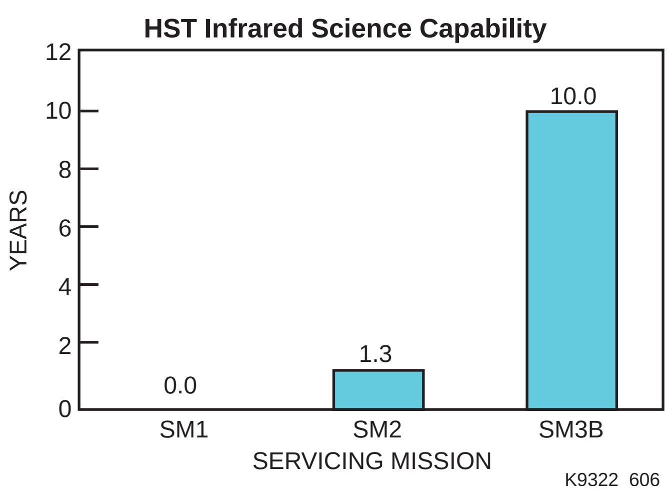

Fig. 7-6 Increase in HST infrared capability

7.1.5 Solar Arrays

The SM3B addition of new, rigid solar arrays will provide substantially more energy to Hubble. The increased power will enhance productivity by allowing simultaneous operation of up to four Hubble instruments (see Fig. 7-7).

7.1.6 Simultaneous Science

One of the most exciting advances afforded by servicing has been the ability to increase simultaneous operations of scientific instruments from two to four. Originally, the instruments were designed to work in pairs. Following SM3B, advances in solar array technology and thermal transport systems will allow four science instruments to operate at the same time, dramatically increasing Hubble's ability to study the universe (see Fig. 7-8).

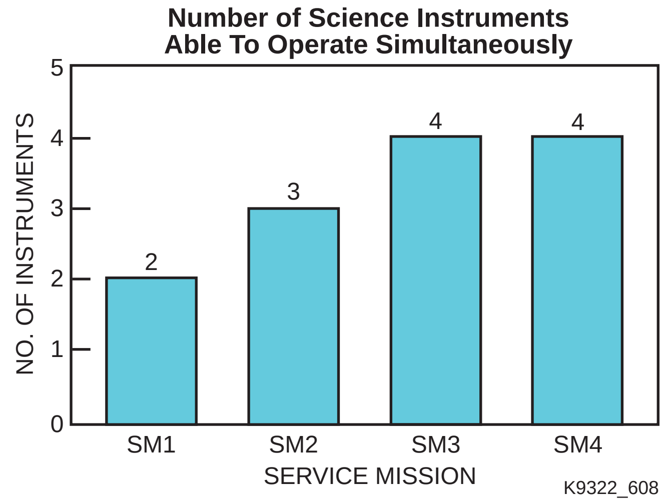

Fig. 7-8 Simultaneous use of HST science instruments

7.2 Accelerated Innovations

The same cutting-edge technology that allows Hubble to peer deep into the universe also touches life closer to home. Hubble's innovative technology benefits mankind in numerous facets of everyday life, including medicine and manufacturing. Ultimately, these spin-off dividends enhance the U.S. economy and raise the American standard of living, making Hubble an even better value for the investment.

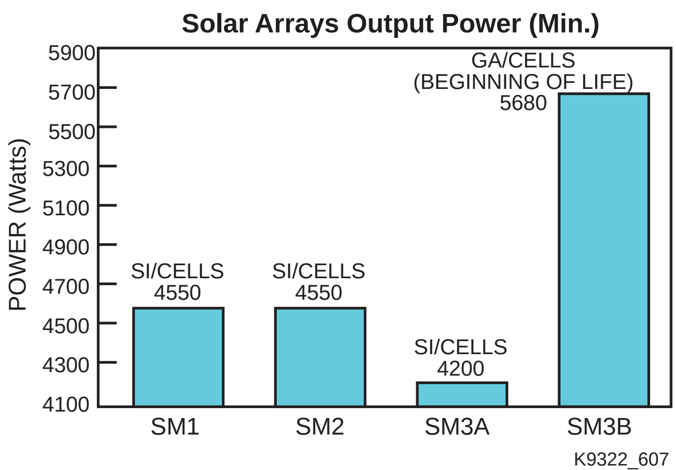

Fig. 7-7 Productivity gains on HST with new solar arrays

By teaming with companies and universities, Hubble's scientists and engineers push technology to new levels of sophistication. An example is the medical application of technology from the Space Telescope Imaging Spectrograph (STIS). A cancer detection application grew out of Hubble's need for highly sophisticated imaging capability, saving patients a significant amount of money and trauma.

Figure 7-9 shows the projected cost savings to patients as a result of the application of STIS technology.

7.2.1 Detecting Breast Cancer Before Black Holes

With STIS, one of two next-generation instruments installed on Hubble in February 1997, scientists can see deeper into space than ever before. NASA's fastest black hole hunter, STIS finds and studies black holes, teaches us more

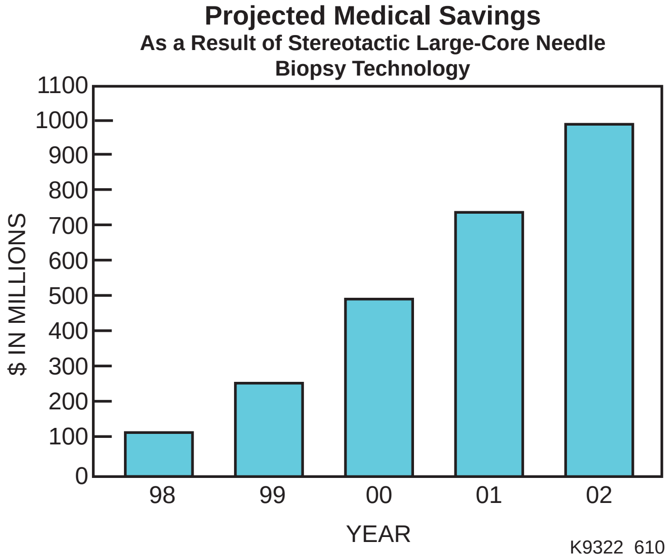

Fig. 7-9 Projected medical savings

about how stars and planets form, and looks at very distant, early galaxies.

However, the charge-coupled device (CCD) developed for STIS to study outer space was used first to study “inner space,” imaging breast tissue three years before STIS would ever see its first black hole.

To develop STIS, NASA needed a level of imaging technology not available commercially. NASA funded a company called SITe, Inc. to make a more sensitive CCD for Hubble. The new type of CCD found medical application as part of the Stereo Guide™ Breast Biopsy System manufactured by the LORAD division of ThermoTrex Corporation. The CCD enables the system to capture finely detailed digital x-ray images of breast tissue. The images help the doctor guide a needle into suspicious tissue and take a biopsy.

This procedure uses about half the x-ray dosage required for imaging for conventional surgical biopsies. It also saves patients time and pain and eliminates scarring and disfigurement. Patients can have the procedure under local rather than general anesthesia and can resume normal activities within minutes. Finally, because the new technique can be done in a doctor’s office, it is less costly to perform. With more than 500,000 women undergoing breast biopsies each year in the U.S., radiologists predict the procedure will save over $1 billion annually in national health care costs.

In 1997 this STIS detector technology was inducted into the United States Space Foundation’s Space Technology Hall of Fame and was a finalist for the prestigious Discover Magazine Award for Technological Innovation. In 1998 it earned the Federal Laboratory Commission’s Award for Technology Transfer.

7.2.2 Image Processing: Diagnosing Cancer Earlier

The CCDs used in digital mammography are not Hubble’s only exciting news in the fight against breast cancer. Techniques developed for processing images from the Telescope may soon help detect breast cancer in its very early stages. The image processing techniques, used to correct the blurry images sent back to Earth from Hubble before the 1993 servicing mission, have proven effective in finding microcalcifications, whose presence in mammograms indicates breast cancer.

The Space Telescope Science Institute (STScI) developed a large repertoire of image processing software to compensate for the effects of the spherical aberration detected in Hubble’s primary mirror soon after launch in April 1990. The software was designed to correct for the Telescope’s loss of dynamic range and spatial resolution.

A group of medical and astronomical researchers from the STScI in Baltimore, Johns Hopkins University, and the Lombardi Cancer Research Center at the Georgetown University Medical Center in Washington, DC, is testing this image processing technique to detect signs of breast cancer in digitized mammograms. The collaborative effort has received funding from the National Science Foundation.

Although about one-third of breast cancer cases have microcalcifications smaller than 50 to 100 microns, current mammography can show only those 250 microns or larger. Image processing allows detection of smaller calcifications, therefore earlier cancer detection and treatment. The sooner a cancerous lesion is treated, the greater are the odds of full recovery. Applying image processing to medical treatment can save lives and preserve quality of life.