The Hubble Space Telescope

Thundering through space at 5 miles per second, what started as one of science's biggest mistakes has evolved into one of mankind's biggest triumphs.

Nestled into orbit on April 25, 1990, the Hubble Space Telescope took decades to plan and design. However, after only a few months, scientists quickly realized that the Hubble Space Telescope's vision was blurred. Unlike the private "first light" of a traditional telescope (when a telescope is tested by its maker for the first time,) the "first light" of the Hubble Space Telescope was a highly publicized event. When the Hubble Space Telescope relayed its first pictures, the media celebrated in ignorant bliss. The scientists at NASA, though, shifted uncomfortably in their seats. Stars showed as hazy orbs of scattered light rather than tightly focused points of light .

After scientists publicized this discovery, the media quickly ridiculed the 2-billion dollar "technoflop." NASA, however, brainstormed a solution. On December 2, 1993, the astronauts of the space shuttle Endeavor performed the most difficult and challenging satellite repair mission ever attempted. The mission was so successful that it fixed the Hubble "beyond their wildest dreams." On December 18, 1993, the astronomers at NASA were treated to a long awaited sight: a single, clearly resolved star.

Although the astronomical and scientific aspects of the Hubble Space Telescope program are obvious, very few people realize how deeply intertwined the program is with modern *computer science*.

Modern Collaboration

The computer science aspect of the Hubble Space Telescope program lets scientists and astronomers enjoy an unprecedented ease of collaboration. The Hubble Space Telescope Archive is the prime example. It holds an enormous 1.2 terabytes of information and contains all of the observational data, calibration files, and related catalog information produced by the Hubble Space Telescope since its deployment. To put this in perspective, the 20 million-books in the United States Library of Congress contain about 10 terabytes of information. In contrast to electronic archives of many other programs, this archive can be accessed completely through the Internet. Along with size of database comes the associated complexity of indexing it. Because the HST archive contains approximately 5000 distinct astronomical targets, engineers must index it with the most powerful database language of our time: the Structured Query Language (SQL).

Scientists at NASA have gone one step further than a "simple" SQL database, however. They prefer to access the HST archive with a groundbreaking program called StarView. Starview lets scientists perform a streamlined search on one of several common fields – or lets them load one of the more advanced StarView screens. These separate screens include: exposure parameters, target properties, proposal information, planned exposures, instrument parameters, calibration files, and engineering files.

Realizing that much of this data is beyond the interest of the common public, NASA's public education team separately put together an astounding collection of processed images. Again on the internet, the NASA team posts and distributes press releases whenever they make a visually attractive discovery. Interestingly enough, most images they post are not simply as the Hubble Space Telescope sees them. When scientists form the images, they normally combine several images – each taken through a different colour filter. In fact, the HST only takes pictures in shades of gray! The process is similar to the traditional paper printing process where printers add colour layer by layer.

Guidance and Control

Since the Hubble Space Telescope is not always in direct communication with the ground stations, scientists plan every second of Hubble's activities in detail. To accomplish this, the experts at the Space Telescope Science Institute write computer programs that instruct the telescope what to do. These programs, sent to the HST times per day, are the only way that scientists control the telescope.

To make a requested observation, the HST first locates the object and locks onto it. Because direction is essentially arbitrary in space, the Hubble Space Telescope contains a database of over 15 million "guide stars" to help it. The HST points to and locks on any target using this framework of guide stars. This system gives the Hubble Space Telescope accuracy equivalent to pointing and holding a laser on a dime 400 miles away. Of course, this guidance system itself required very complex programming when the telescope was first designed. According to NASA, the 3 computers aboard the Hubble Space Telescope contain over 50,000 lines of code in the C and Assembly programming languages.

A sample HST program

```
051:20:46:56  051:21:26:36      FGS_AVD    (ENT,L=  15.8)       06095:11:01 01
051:21:03:55  051:21:19:13   M  Slew (AN=112,RA=279,DE=-33,PA= 79,OR=  0,SN=55)
051:21:19:13  051:21:24:43   M  FHST Updte (FULL ,MAN,E= 185,1,2,3)

051:21:24:43 ********        Main SU 0609511    ******************************

051:21:24:43  051:21:33:43   M  PCS AQ(FGS ,E= 54,BASE1   ) 06095-2VO:11:01
051:21:26:36  051:22:23:27      FGS_AVD    (EXT,L=   7.8)       06095:11:01 01
051:21:33:42  051:21:33:43   SI UP   WFII      OPER         06095-2VO:11:01 01
051:21:33:43  051:22:23:43   M  Sci  WFII UPC1FIX       1  06095-2VO:11:01 01
051:22:23:27  051:23:03:04      FGS_AVD    (ENT,L=  15.8)       06095:11:01 01
051:22:23:43  051:22:24:43   SI DOWN WFII      READY        06095-2VO:11:01 01

051:22:23:43 ********    End Main SU 0609511 *********************************

051:22:24:43  051:22:25:43   SI DOWN WFII      STANDBY      06095-2VO:11:01 01
051:22:48:58  051:23:00:15      SAA 02     (ENTRY)
051:23:00:15  052:00:27:07      SAA 02     (EXIT)

051:23:03:14  051:23:19:48   M  Slew (AN=128,RA=167,DE= 73,PA= 12,OR= 2,SN=118)
051:23:19:48  051:23:25:18   M  FHST Updte (FULL ,MAN,E= 213,1,3, )
```

This is a section of a typical program used to control the Hubble Space Telescope. Although the listing might look choppy and difficult to understand, English is too ambiguous to control the Hubble Space Telescope. Each line gives the HST a simple instruction in the form: *start time, end time, instruction,* and *optional parameters*. What commands does the HST understand? There are many, but the example program illustrates some of the most useful ones.

On the first line of the program and throughout, we see the command FGS_AVD. Scientists use this command to tell the sensitive Hubble to avoid the harmful glare of the earth. On this occasion, the first avoidance is of the “bright limb” of the earth. Because the bright limb is relatively intense, the parameter to FGS_AVD is 15.8 degrees. The second instance of FGS_AVD tells the HST to avoid the “dark limb” of the earth by a much smaller 7.8 degrees. Because of its glare, scientists must avoid the sun by 50 degrees!

On the second and second-last lines, the programmers of the Hubble use the SLEW command to point the telescope. At $8 per second, this 15 minute SLEW is an expensive operation! The two important parameters to this command are “right ascension” (RA) and “declination” (DE), the astronomical coordinates of the target. In this example, scientists point the Hubble to the middle of the Milky Way in the constellation Sagittarius. Scientists follow each SLEW with a FHST UPDTE, a “Fixed Head Star Update Tracker Update”, that rechecks the guide stars to make sure the SLEW command positioned the Hubble correctly. If necessary, the FHST UPDTE routine adjusts the aim of the HST.

The eighth line of the program uses the UP command to tell the Hubble to prepare an instrument for operation. The parameter, in this case, is WFII: the “Wide Field Planetary Camera II.” The next command, SCI, collects scientific data. When we look at this line’s time stamp, we can see that the Hubble exposes this image for fifty minuets. The parameter, again, is WFII. The next two DOWN commands relax the WFII instrument to READY, then STANDBY modes.

Although the HST has long been touted one of the great accomplishments of science and technology, the project simply would not have been possible without the input and advances in computer science.