Techniques used to Reduce Cost and Improve Quality for Hubble Space Telescope Science Operations

Glenn Miller and Tony Krueger

Space Telescope Science Institute

Baltimore, MD

Hubble Space Telescope Experience

Even though the Hubble Space Telescope is one of the archetypical "big science" projects, we have been able to increase quality of service while decreasing operations costs by applying new technologies and following general principles.

Overview

The science mission of NASA's Hubble Space Telescope (HST) is conducted by the Space Telescope Science Institute (STScI). NASA Goddard Spaceflight Center conducts mission operations and overall project management.

HST is the premier astronomical observatory. Multiple scientific instruments covering infrared, visible and ultraviolet. 15+ year mission. Thousands of observations per year for about 400 principal investigators.

STScI has encouraged a culture of continuous improvement and innovation to improve user service and reduce costs.

In 1995 NASA Goddard's HST Project and STScI initiated "Vision 2000" program to improve quality of service while dramatically reducing operations costs.

These slides highlight some of the technologies we've used.

Scripting Languages to "Glue" Legacy Systems

Used Tcl/Tk and client/server technology to build a user interface around several existing applications. This allowed us to provide HST users with a much more accurate view of how observations would be scheduled and executed. Result was increased user satisfaction and more efficient use of telescope time.

Have begun prototype project with CORBA technology for internal system integration projects.

Firewall Technology

Problem: Operations computers have to have a high level of security to protect spacecraft, but this severely isolated scheduling staff from others, e.g. they did not even have email communications with staff who developed observing programs.

Installation of firewall and router allowed us to merge 2 separate computer networks into one so that essentially all planning and scheduling staff are on same network.

Use authentication card technology for access across firewall.

Also use database replication technology to make copies of operational information available to users outside firewall.

On Board Data Storage

Second HST Servicing Mission (Feb 1997) installed a 10 Gb solid state recorder in place of a 1Gb tape recorder. (2 additional tape recorders remain).

Increased capacity needed for high data output of new generation instruments (larger format detectors); also facilitates "parallel" instrument operations (running 2 or more instruments at the same time).

In addition, essentially eliminated rework necessary by operations staff to overcome earlier data storage limitations.

World Wide Web

Allows our users to have up-to-the-second schedule information. Reduces work-load on staff answering status questions.

Straightforward to develop tools for use by observers, e.g. exposure time calculators.

All user documentation available via WWW.

Process Improvement Technology

Hardware/software technologies have led to important improvements.

However, we found that equally impressive improvements can be gained by focussing on processes and people.

We've applied this to many projects, from small to large. General principles are:

- **Automate routine steps**
- **Eliminate rework (e.g. downstream step checks validity of upstream step)**
- **Remove non-value-added work**

Some process/re-engineering methodologies can be useful. We used CPI (Continuous Process Improvement) for several projects

Organization Reengineering

Traditionally, groups are organized by function, e.g. software development, testers, operations staff, scientists are all in separate branches and divisions.

We found this to be a significant source of inefficiency. Different branches and divisions have, by definition, different goals so even small working level decisions have to be solved by 2 branch chiefs or 2 division heads or higher.

We reorganized by process - our processes is observing with the HST. One division now contains (most of) the staff who are responsible for this process.

Software Development

Long lead time (3-6 months or more) for software changes led to dissatisfaction by users, manually intensive "workarounds", errors and lack of feedback from operations to development.

Development is much shorter now, with key systems able to respond to critical and non-critical changes much faster, some as fast as 24 hours (yet with full testing).

Developers and testers have developed a team-oriented rather than adversarial approach. Testers begin testing much earlier in process which has shortened process time and finds bugs when their impact is less.

Key enabling technologies for this were:

1. Automated testing tools

2. Code management libraries which support multiple development versions (e.g. Unix CVS)

Measurement and Evaluation

Adopt a scientific approach

- **Measure important performance parameters**
  - **For HST science operations, observing efficiency (up by 70%)**
  - **Delay time for scheduling (from 56 to 21 days)**
  - **Observation failure rate (constant at about 3%)**
- **Perform experiments**
  - **due to time and cost constraints, experiments cannot usually be as controlled as a classical laboratory experiment**
- **After change is effected, verify that desired benefit has occurred**

Major Cost/Quality Drivers

Improvements in HST operations were made within overall constraints of mission. For new missions, important considerations are:

- **Orbit - A low earth orbit has inherently lower efficiency due to Earth occultation and South Atlantic Anomaly passages.**
- **Communications - Keep operations as independent of communications contacts as possible via large on-board data stores and dedicated communications**
- **Spacecraft design**
  - **Safemodes should be safe - only impact efficiency**
  - **Simplify flight software complexity by using more flexible on-board scheduling**
  - **Reduce cost of flight software development, upgrade and installation via use of more standard architecture and increased onboard resources**
- **Keep telescope and scientific instruments simple while meeting mission goals**