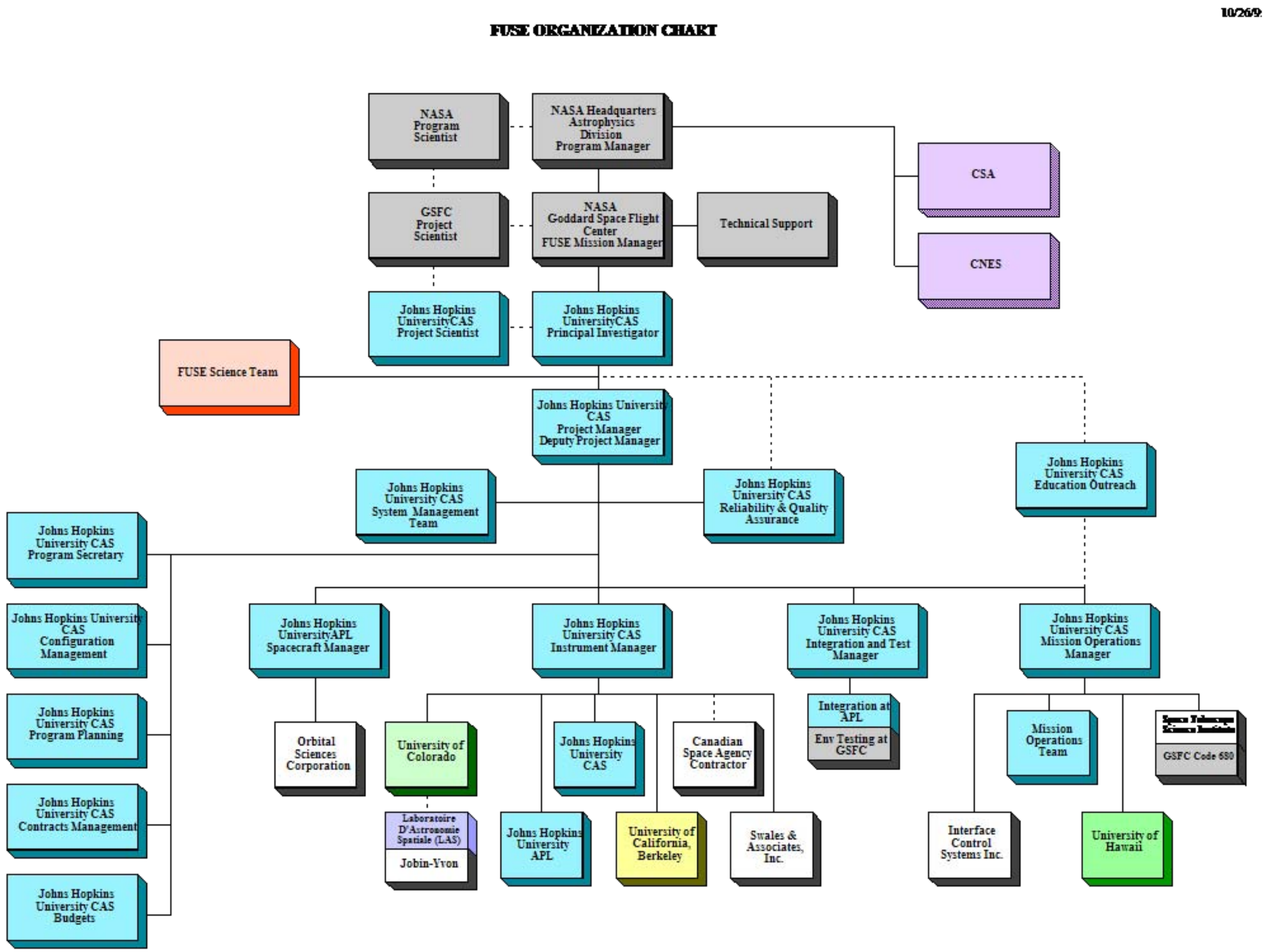
FUSE
The Far Ultraviolet Spectroscopic Explorer

Dr. Warren Moos, PI

Dennis McCarthy, PM

The Johns Hopkins University

FUSE Organization



Management Methods

To achieve low development and flight operations costs:

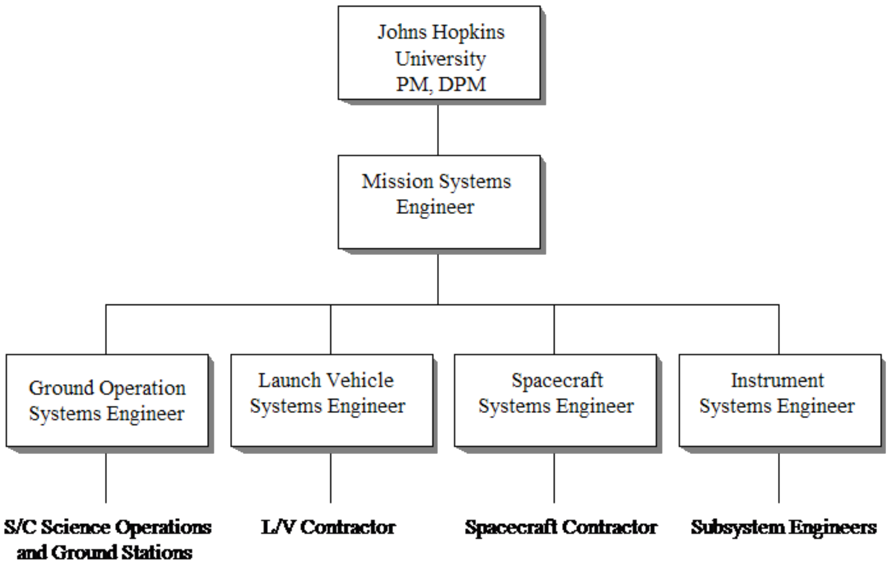
- Maintained a cost-conscious management and engineering philosophy, and continual systems engineering involvement in all aspects of design and test.
- Maximized use of team member facilities, equipment, and personnel.
- Reused of existing ground support equipment (GSE) designs and equipment from previous programs.
- Extensive use of component, subsystem, and systems tests to verify and understand actual performance and design margins instead of complex analyses and simulations.
- Established a “quick react” process to respond to critical component failures during I&T.
- Formal accept/reject responsibility resided with the cognizant design engineer with JHU product assurance manager concurrence.
- A malfunction and/or software problem reporting process with accept/reject responsibility resting with the engineers at the integration level with JHU product assurance concurrence.

Management Plan (Cont'd.)

Specifically, we:

- Designed to cost
- Maintained a fixed schedule
- Tailored documentation to meet unique mission requirements
- Centralized the systems engineering
- Integrated the team to insure maximum communication at minimum cost
- Streamlined the management team, with the JHU PI responsible for the mission, and the GSFC providing contract administration and oversight

Systems Engineering



Risk Management

- **Web-based tools for:**
  - **problem reporting**
  - **Action item tracking**

- **Weekly meetings for:**
  - **CCB Meetings**
  - **Systems Engineering, re: problem reports and risk identification**

Risk Management (Cont'd.)

- **The inherent redundancy of the FUSE design limits effects of random component failures and the instrument is extremely robust to single failures. This redundancy is intrinsic to the four-barrel optical design.**
- **To correct for structural distortions or channel misalignments during an observation, data could be taken in a time-tag mode or if using the time-integrated histogram mode, the observation duration could be shortened. Both techniques were needed during operations.**
- **All electronics are redundant and cross-strapped.**
- **All key functions degrade gracefully.. Examples of graceful degradation:**
  - **If any one channel is lost, FUSE will still have complete wavelength coverage, but it will take proportionally longer to achieve the same science.**
  - **If the pointing control is less than optimal, then JHU will use a larger aperture, the FES data will indicate the true pointing position, and the full-resolution spectrum can be reconstructed on the ground. Note: this saved the day when pointing problems arose late in the mission.**
  - **At present, all archived FUSE observations carry pointing information and the data pipeline routinely corrects for pointing.** (I might add that this required getting data from the engineering stream onto the science side of the house. OK after the system is set up, but painful when you have to go back thru all the old engineering files!)
  - **If a mirror actuator fails, focus control is lost on that channel, possibly increasing the spot size.**
- **Since the satellite attitude is controlled to put the light through a particular slit, even if two actuators fail on the same mirror assembly so that tip-tilt control is lost, that channel can become the reference channel for the other Focal Plane Assemblies (FPAs), and the only potential loss is due to additional coma.**
- **The baffle doors are redundant and fail-safe, and even if a door fails shut, it is only a loss of effective area.**

Risk Management (Cont'd.)

De-scope Process

- The detailed de-scope plan was a primary tool for managing risk and dealing with circumstances which could bring unacceptable cost or schedule impacts.
- De-scope options and contingencies were identified during the remainder of Phase B.
- The Principal Investigator and Science Team prioritized the requirements on the mission and its systems, and defined the Minimum Performance Floor, MPF.

Governance

- JHU formed a standing review team which was a small, highly experienced group to review and evaluate the FUSE Program semi-annually. These semi-annual reviews were tied to the semi-annual GSFC review and the following JHU/FUSE reviews:
  - Mission NAR/PDR
  - Mission CDR
  - Pre-ship spectrograph
  - Pre-ship spacecraft
  - Pre-test satellite
  - Pre-ship satellite
- JHU conducted informal incremental “peer reviews” at the subsystem level between expert teams, and as part of the process leading up to major project reviews. Technical experts from JHU, Goddard and other institutions engaged in informal roundtable reviews of plans, designs, and implementations at key development stages.
- The results of each individual peer review were presented at each major Program Review.
- Peer reviews were demonstrated to be very effective in developing the proper subsystem designs, interfaces, design margins, analyses, implementation plans, and proper testing.
- The JHU review Team presented their findings to Goddard independently prior to launch.

FUSE Development

- First PI mission managed by an academic division of a University, i.e. Johns Hopkins University
- Modus Operandi: Procure an ‘off the shelf” spacecraft at a fixed price
  - Procure the ground system at a fixed price
  - Develop the instrument
  - When you <u>buy 2</u> systems (spacecraft and ground system) and only <u>develop 1</u> system (instrument), the cost and schedule can be maintained.
- The spacecraft was redundant, except reaction wheels (selective redundancy): cost ~$35M
- Ground system was ~ $4M
- Management of International Partnerships were not adequate
- The Science Team "got religion" on holding to a fixed cost and were realistic in deciding what capabilities we had to keep and what we could sacrifice.
- As a result of the integrated nature of the team there was sufficient interaction between the scientists in operations and instrumentation with the engineering staff that requirements were (generally) communicated, clarified and kept realistic. The communication was two way - hence the clarification and keeping it realistic.
- Total Program cost was $120M with other contributions from CSA (Fine Guidance Sensor), and France (Glass gratings)

FUSE

on-Orbit

Summary

- The launch date was accelerated by two years,
- The total program cost was reduced by 60%,
- The FUSE instrument retained a majority of the original FUSE science capabilities, including the premiere science,
- There were credible, viable designs for the spacecraft bus as well as the ground system at fixed price contracts.
- The following assumptions were met:
  - **adequate Phase B funding;**
  - **Phase C/D funding profile which matched the requirements;**
  - **clear understandings and agreements established between NASA and the International partners;**
  - **recognition that NASA will allow the JHU PI to manage and direct the development effort, with proper government oversight.**

This restructured project produced a comprehensive program that achieved the high-priority science, two years earlier at a substantially reduced cost and operated for 8 years on-orbit..