Galaxy Evolution Explorer Phase E Lessons Learned

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September, 2003
Greenbelt, MD

Phase E Lessons Learned

- I'll discuss Phase E lessons learned in the following aspects:
  - *Original proposal assumptions*
  - *Changing standard of NASA risk acceptance*
  - *Development phase turmoil*
  - *Handoff from Phase C/D to Phase E*
  - *Science operations*

Original Proposal Assumptions

- Institutional issues
  - *GALEX was proposed from Caltech campus*
    - Contract negotiated between Caltech and GSFC, bypassing JPL prime contract
  - *Caltech campus has no spacecraft development infrastructure*
    - JPL (an operating division of Caltech) was designated as lead for management, mission assurance & safety, systems engineering, and instrument development (sans detectors)
    - JPL is a NASA center with vast infrastructure for spaceflight, concentrating on large complex systems in deep space, but with its own distinct culture
  - *Explorers are typically implemented through Universities, not other NASA centers*
    - Explorer program office has unusually strong "hands on" approach, effective when dealing with less experienced/structured institutions, but is often in conflict with JPL's culture and implementation methodology

Lesson E1: Overlaying GSFC & JPL through Campus contract created conflicting direction to Project & resulted in "superset" of requirements and activities, driving up cost [now addressed in JPL/GSFC MOA]

Original Proposal Assumptions

- The original budget for Phase E from CSR was $11.222M (RY$)
  - *$6.088M Caltech Mgmt, Science Ops, Pipeline, Science Analysis, AIP*
    0.973M JPL EPO
    0.460M Orbital Mission Ops
    0.329M UPR Downlink
    0.305M UCB Science Support
    2.419M JHU Archive
    0.648M Reserve
  - *Assumptions were very optimistic:*
    - Launch Sep 2001, 28 months operations + 8 months science analysis
    - No JPL involvement other than EPO
    - Orbital performs mission ops with 1 FTE, using cost shared multi-mission ops center
    - “Virtually free” downlink from University of Puerto Rico at ~2 passes per day based on “soft” agreement with UPR
    - No IT-Security requirement

Original Proposal Assumptions

- AO-97-OSS-03 imposed several constraints
  - *GDS development (NASA cost) capped at $3M (FY97$)*
  - *Phase E (NASA cost) capped at $9M (FY97$)*
  - *A/B/C/D funding (including foreign contributions) capped at $38M (FY97$)*
- Including foreign contributions in development cost cap prevented us from later developing Korean ground station option to relieve network cost pressure

Lesson E2: Multiple AO constraints limited ability to propose optimum life-cycle cost solution

Changing Standard of NASA Risk Acceptance

- GALEX was proposed in June 1997, prior to:
  - *Loss of Lewis spacecraft* — *August 1997*
  - *Near loss of SOHO spacecraft* — *June 1998*
  - *Unexpected HST gyro failures* — *January 1999*
  - *Loss of WIRE spacecraft* — *March 1999*
  - *Loss of Terriers spacecraft* — *May 1999*
  - *Loss of Mars Climate Orbiter* — *September 1999*
  - *Loss of Mars Polar Lander & DS2* — *December 1999*

- NASA response via NIAT fundamentally altered threshold of acceptable risk
  - *Ramifications, especially at JPL, were sweeping, with many new requirements gradually imposed over time*

Lesson E3: NASA’s posture on risk acceptance is an ever changing standard; don’t get caught in the wrong swing of the pendulum

Development Phase Turmoil

- NIAT lessons learned invalidated assumption of no JPL involvement in mission ops
  - *Mission manager and Mission operations assurance function added*
  - *JPL Design Principles imposed*
- Incremental tightening of standards & processes continually pressured budget
  - *JPL process re-engineering changes to satisfy ISO 9000 impacted cost of doing business at nearly every level*
  - *Shifting of burden-funded activities to direct project charge increased costs at JPL*
  - *JPL conversion to new financial accounting system caused immense financial confusion for nearly a year*
  - *Interpretations of ITAR, IT security, Orbital Debris, IV&V, were all tightened over time, resulting in new requirements (exacerbated by 9/11)*

Lesson E4: Make allowance for unstable implementation environment, and be prepared for cost pressures beyond Project control

Development Phase Turmoil

- Ground network solution proved elusive
  - *UPR costs grew unaffordable based on educational grant expectations*
  - *Engineering realities resulted in need for ~4Gbytes/day of downlink, requiring more than one ground station (at X-band)*
  - *Mass, UV airglow, and radiation environment dictated low inclination orbit at 690 km altitude (not many X-band stations at low latitude)*
  - *Contracted with Universal Space Network (venture capital start-up company) at favorable rates, but subsequent renegotiation of contract resulted in substantially higher costs*
    - Limited operations experience, especially at X-band
    - Limited number of users
    - Significant expense incurred in bringing USN into compliance with IT security
    - Considered a residual risk at MRR

Lesson E5: Have a solid mission system concept with adequate margin by CSR

Development Phase Turmoil

- Industry consolidation, together with global economic downturn forced several compromises
  - *X-band transmitter*
    - Foreign manufacturer went bankrupt prior to delivery, forcing last minute cannibalization of another spacecraft with different transmitter
    - New transmitter operated at “earth science” frequency, requiring new NTIA license with proviso of “noninterference” with earth science missions
    - Required new ground station demodulators built/tested quickly ($$)
  - *Orbital shared operations center proved ellusive*
    - OV-4 lost in launch vehicle failure Sep 2001
    - VCL cancelled by NASA
    - GALEX forced to bear full cost of 24x7 operations until “lights out” capability added
    - 1 FTE assumption for flight ops team was unrealistic

Lesson E6: Be prepared for economic downturns, supplier bankruptcies, and mission failures, and budget adequate reserves to cope with them

Handoff From Phase C/D to Phase E

- Development is Explorer Office responsibility (Code 410), but operations is responsibility of GSFC Code 444
  - *GSFC controls development funding, but HQ appears to control operations funding (split between separate UPNs for MO and DA)*
- We experienced significant disconnects in this transition (not yet resolved)
  - *Code 444 not involved early enough (should be players in ORR; MRR; Phase E SOW, budget and contract negotiation; and mission operations assurance planning)*
  - *Inadequacy of Phase E budget known well in advance, but not effectively addressed*
    - ◆ Code 410 reluctant to broach cost issue with HQ until successfully in-orbit
    - ◆ By then it was too late to incorporate into the budget cycle
    - ◆ Proposal submitted in December 2002 not negotiated by June 2003!
    - ◆ Project incrementally funded based on submittal of actuals – no budget!
    - ◆ New HQ program executive unaware of budget issues at time of launch

Lesson E7: Transition to operations needs better coordination at NASA

Science Operations

- Launch, IOC and science operations have been remarkably smooth
  - *No safeing of spacecraft or instrument*
  - *No issues on satellite except for detector "current spikes"*
  - *Detectors safed on five occasions*
    - Phenomenon not anticipated, resulted in loss of about 500 orbits
    - Has not recurred in last two months of operation
    - Probably associated with energetic particles at unusually low altitude
    - Attempts to recreate on flight spares inconclusive
- Main problem currently is USN network reliability
  - *Stations using Avtec PTPs prone to crashing*
    - Problem with Avtec PTPs experienced by DSN, UC Berkeley, and others
  - *Very limited spare hardware maintained by USN*
    - Station location in Australia involves ITAR & EAR restrictions that slow movement of hardware in/out of country
  - *Significant number of "operator errors"*

Lesson E8: Scrub the network as hard as possible for reliability issues prior to launch; assure contingency plans for equipment failure