Doing Development Right

Lessons Learned from the Development of the Cassini Saturn Mission Operations System

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Agenda

- The Cassini Challenge
- What did we learn?
  - System Engineering
  - Developing While in Operations
  - Development Practices that Paid Off
- Summary

Cassini Ops Development Challenge

- One of NASA's most complex planetary missions ever
  - 4 year science collection at Saturn
    - 74 orbits, 44 targeted Titan flybys
  - Early spacecraft design decisions to reduce pre-launch costs resulted in increased complexity and conflicts
    - Body-fixed instruments
    - Power limitations
  - Large complement of sophisticated science instruments (16) & investigations (27) and ESA Huygens Probe Mission
    - Large, geographically distributed science team
    - Significant instrument observation conflicts
    - Varying degree of operations knowledge and experience at science sites

Cassini Ops Development Challenge (cont.)

- Significant deferred post-launch development
- Mix of multimission and mission provided capabilities
- Changing technology over development period
- Post-launch development occurring while in-flight

Cassini System Engineering Paradigm

- Traditional hierarchical System Engineering team prelaunch led development of Cassini operations system requirements and design, provide implementation oversight, and lead system test activities.
  - Led by the Mission Operations System Engineer (MOSE) and a deputy MOSE who were responsible for the overall leadership of engineering activities across the project
  - Six additional system engineers on the team led system development in specific areas of: Uplink, Downlink, Ground Data System (GDS), Operations, Training, and Verification & Validation (V&V).
  - Other SE team members supported configuration management and GDS test.
- Effective but costly

Cassini System Engineering Paradigm

- Historical System Engineering Diagram Here

Cassini System Engineering Paradigm

- SE function remained significant in scope due to large number development tasks deferred until the cruise phase of the mission
- To reduce costs and increase both efficiency and productivity across the Program, a new system engineering paradigm was instituted.
- Key characteristic of new SE paradigm involved migration of system-wide engineering responsibilities to the implementing Offices at next lower level
- "Ownership" for pieces of the system were allocated to directly to the Offices.
- Cross-office issues were no longer worked only by a centralized team, but instead directly between offices.

Cassini System Engineering Paradigm

- New system engineering paradigm graphic here

Cassini System Engineering Paradigm (cont.)

- Single SE working team known as the System Engineering Round Table (SERT)
- Membership consisted of a small (4 person) program SE team and a single SE for each of the three Offices.
- As implied by its' name, the group members shared equally the responsibility for the development of the system.
- Level 3 SEs were intended to function as facilitators, system experts, and conflict resolvers

Benefits of New SE Paradigm

- During paradigm transition, development tasks were re-examined for value-added and efficiency.
- Redundancy eliminated as were a significant number of lower priority tasks.
- Training and the majority of V&V activities were delegated to the offices, resulting in incorporation of system V&V activities in office testing
- Downlink portion of the system (though delivery of raw data to the science and engineering teams) oversight allocated to the Mission Support and Services Office (MSSO).
- ~$2 M program wide cost reduction in FY'00.
- Another benefit of the new paradigm was a more integrated team.

Drawbacks of New SE Paradigm

- To make the paradigm work successfully, a high caliber of level 4 engineers was needed with strong technical, leadership, communication, and decision-making skills
  - Office SEs to be the central point of contact for their office.
  - Difficult to find SEs able to represent the large number of diverse tasks being undertaken in some offices.
  - In many cases, the Office SEs were not empowered to make decisions or recommendations for their offices.
- Office SEs were selected and funded by the Office managers themselves. Although Office SEs had a responsibility to look at the "big picture" rather than focusing on their own office's needs, this was difficult where office and system needs or priorities were not the same.

Drawbacks of New SE Paradigm (cont.)

- Frequent questions and disagreements about ownership and responsibility for tasks
- Sometimes issues would fall through the cracks because of mis-matched assumptions.
- Need to be vigilant about redundancy

Developing While Operating

- Benefits:
  - Immediate feedback on implementations

    Able to "port" people easily between development and operations

    Allows highly realistic testing

    Developing JIT allows easier infusion of new technology
- Drawbacks:
  - Health and safety issues
  - Competition between developers and operators for project resources (money, people, flight system)

Practices that Paid Off

- Teams pay directly for for services / hardware needed to develop and operate their systems
  - Forces teams, who are most familiar with their own needs to make intelligent trades.
  - Team budget serves to limit appetite to only what's needed
- Formal project-wide automated system for tracking receivables and deliverables among project entities
  - Several thousand items tracked over life of mission
  - Forces detailed planning and negotiation
  - Requires vigilance and management

Practices That Paid Off

- Making smart multimission versus project-supplied trades
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Summary

- Long development life of Cassini spanning 10 years provided a laboratory to try new technology and new system engineering practices
  - Those that paid off include:
    - Virtual System Engineering Paradigm
    - Giving developers full control of development budget
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