EPOXI and Stardust NExT: The Management Challenges of Two Comet Flybys in Three Months

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Overview

Stardust

- Launched February 1999
- Built and operated by Lockheed Martin
- Asteroid Anne Frank Flyby 2002
- Comet Wild 2 Flyby 2004
- Earth Return – Sample Return Capsule – 2006
- New mission to comet Tempel 1 selected in 2007 (Stardust NExT)
  - PI: Joe Veverka, Cornell
  - Operations: Lockheed Martin Space Systems
  - Navigation and Project Management: JPL

Deep Impact

- Launched January 2005
- Built by Ball Aerospace
- Operated by JPL and BATC
- Comet Tempel 1 encounter 2005
  - Delivered Impactor
  - Flyby spacecraft observed results
- New mission to comet Hartley 2 selected in 2007 (EPOXI)
  - PI: Mike A'Hearn, University of Maryland
  - Operations: JPL & BATC
  - Navigation and Project Management: JPL

Extended Mission Features

- Consolidated both projects into one project office at JPL
- Small operations teams
  - DI/EPOXI – Ops and navigation at JPL with subsystem and spacecraft systems engineering support from BATC
  - Stardust NExT – Ops at LMSSC, mission management and navigation at JPL
- Experienced teams teams are essential to low cost missions of opportunity
  - Key portions of EPOXI operations team had experience dating back to the DI prime mission – particularly the Spacecraft Team Chief and the Science Operations Lead
  - Stardust spacecraft operations team had been operating the spacecraft since launch in 1999
- Communications among distributed teams
  - Regular telecons – started weekly, increased to 2-3 standing meetings per week, daily status meetings during approach
  - All team members had access to JPL flight ops network and support tools
  - Yearly encounter planning meetings brought science teams and operations teams together for detailed planning sessions
    - Face-to-face communications
    - Detailed discussions covering science requirements and implementation constraints and trade-offs

Mission Features – con't

- Key Position – Science Operations
  - Liaison between operations and science
  - Funded early to ensure proper interpretation and implementation of science requirements
  - Located with project office at JPL
  - Member of science team (Co-I on EPOXI and Deputy PI on Stardust NExT) active when most of science team had not yet been funded
  - Designed observations sequences, reviewed implementation in the operations sequences, and reviewed rest results prior to uplink
- Integrated project schedule
  - Standing meetings for each project
  - Reviews for each project – Encounter Peer Review, Risk Review, Critical Events Readiness Review, JPL and NASA readiness briefings
  - 6 months leading up to each flyby intensified with reviews and final sequence build and test
  - Significant overlap with the two critical events 3 months apart

MOO Challenges

- Using a spacecraft designed for one mission to accomplish a different mission
  - Configuration
    - In both cases the spacecraft configuration was designed for the original flyby
    - The geometry of the new flyby would preclude communicating with Earth while imagers were pointed at the comet
  - Propellant Margins
  - Aging equipment
  - Telecom links
    - Stardust NExT encounter was at >2 AU from Earth – no real time telemetry would be supported for large number of possible flyby attitudes
- Key decision points identified well in advance, decision makers, data inputs, and decision criteria well defined – exercised these
- ORTs and Table Top SOE walk-throughs

Risk Mitigation

- Key decision points identified well in advance
  - Decision makers, data inputs, and decision criteria well defined
  - Exercised these decisions in advance of the event to ensure timely and consistent decision-making process
- Operational Readiness Tests and Table Top Sequence Of Events walk-throughs
  - Exercised the teams in realistic operational scenarios using the test bed to generate telemetry data at the rates expected during the encounters
  - Simulated anomalies and responses
  - Table-top walk-throughs were performed with the entire team
    - Talked through mission scenarios
    - Identified what could go wrong in each phase
    - Identified observables would accompany each scenario
    - Discussed possible responses and their effects
    - This process not only help train the team for anomalies, it also helped inform the design of the fault protection strategies

Risk Management

- EPOXI
  - Tempel 1 flyby used ‘shield mode’ – flew past comet in a fixed orientation to minimize risk of particle impact damage
    - This limited the observational coverage of the nucleus
  - Hartley 2 flyby – desired to track and image comet nucleus all the way through approach, closest approach, and departure to maximize the observational coverage of the surface
    - Would expose unshielded s/c surfaces to particle impacts at a higher flyby velocity
    - Updated coma dust distribution model and used existing impact damage models to assess risk to s/c – estimated significantly lower risk of damage than prime mission
      - Primarily due to higher flyby altitude and more benign dust environment
  - Tracking comet through closest approach at 700 km would slew the s/c faster than ever used in flight
    - Analysis showed this was well within the capability of the reaction wheels
  - In-flight demo for ‘do-si-do’ maneuvers – observe the comet 16 hrs/day followed by an 8 hr DSN pass punctuated by hourly turns back and forth for imaging/downlink – fast turns combined with hourly reacquisition of the spacecraft signal

Risk Management

- Stardust NExT
  - Fuel – Launched with 87 kg, began extended mission with 17 kg
  - Time of Arrival adjustment consumed much of the remaining fuel
    - The primary goals of the mission were to study changes in the surface of Tempel 1 and to extend the mapping to new territory
    - What about the DI impact crater?
      - Required predicting the phase of the comet at arrival 5.5 years after the previous flyby
      - Challenging effort undertaken by two teams – Belton and Chesley
      - Maneuver had to be executed 1 year before arrival at the comet
  - Navigation
  - Fuel – Finished mission with an empty tank 5 weeks after the flyby
  - (more about this on Thursday)

Hartley 2 Flyby
November 4, 2010


Tempel 1 Flyby
February 14, 2011

Conclusions

- Experienced teams required for successful completion of low cost MOOs
- Science Operations personnel provide important interface that ensures successful accomplishment of science objectives
  - The more they understand both the spacecraft operations and constraints as well as the science objectives, the more likely they are to be successful
- Integrated schedules between projects help manage the overlap
- Frequent communication is essential between all the teams
  - Project manager needs to continually monitor interfaces to make sure communication is sufficient and effective
- Travel as much as necessary – need face-to-face time with the implementing teams
- Encounter Planning Meetings – bring science and ops together early and regularly
- Risk Management
  - PM needs to stay involved to understand the risk drivers
  - Not all decisions need to be elevated to PM level, but make sure decisions are being made so the team can move forward
  - Open communication during reviews is essential – follow up on the actions quickly
  - Not going to happen by just dialing in to MMRs