



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

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SpaceOps2012

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: IDI





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 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
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- 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

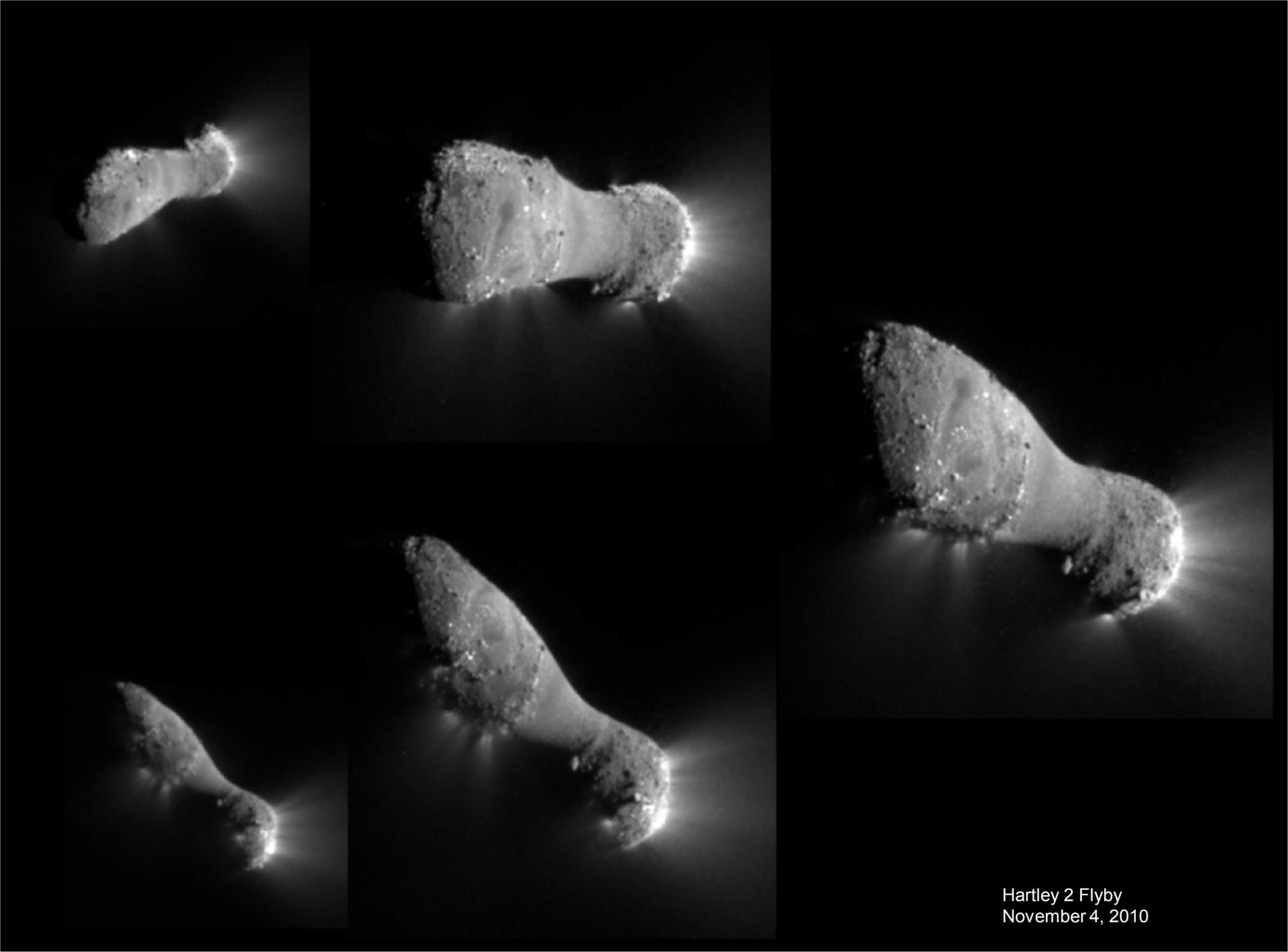
- Key decision points identified well in advance
 - Decision makers, data inputs, and decision criteria well defined
 - Exercised these decisions in advance of the event to ensure timely and consistent decision-making process
- Operational Readiness Tests and Table Top Sequence Of Events walk-throughs
 - 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



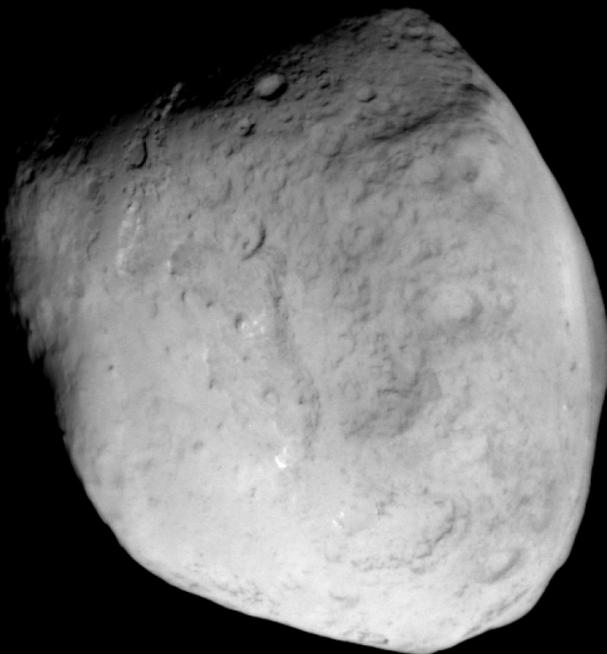
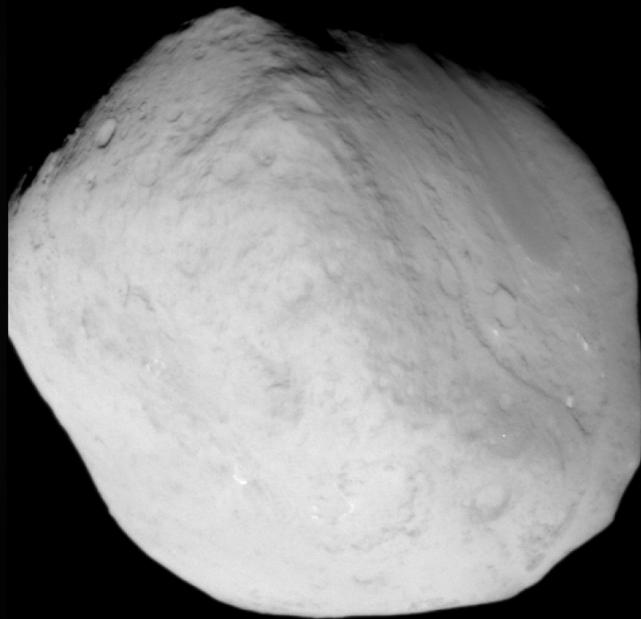
- EPOXI
 - Tempel 1 flyby used ‘shield mode’ – flew past comet in a fixed orientation to minimize risk of particle impact damage
 - This limited the observational coverage of the nucleus
 - Hartley 2 flyby – desired to track and image comet nucleus all the way through approach, closest approach, and 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



- 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
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