APEX PI Forum

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Lessons-Learned Case Studies from two selected Step 2 CSRs

New Frontiers Program: OSIRIS-REx (Bennu Asteroid Sample Return)

Discovery Program: DAVINCI (Venus Atmospheric Probe mission)

OSIRIS-REx

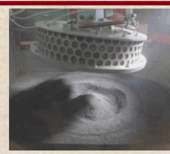
Current Mission Phase: E/F

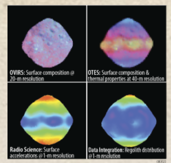
OSIRIS-REx

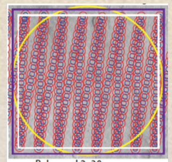
Asteroid Sample Return Mission
Origins, Spectral Interpretation, Resource Identification, and Security - Regolith Explorer

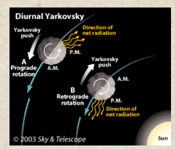
Science Objectives

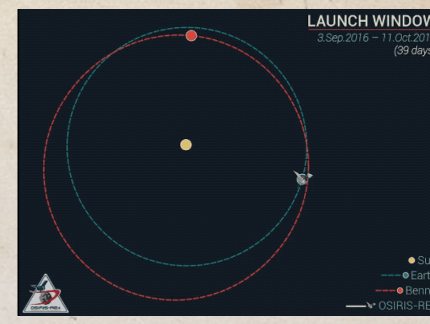
- **Return and Analyze a Sample**
- Create Maps of the Asteroid
- Document the Sample Site
- Measure the Orbit Deviations
- Compare to Telescope-based Observations







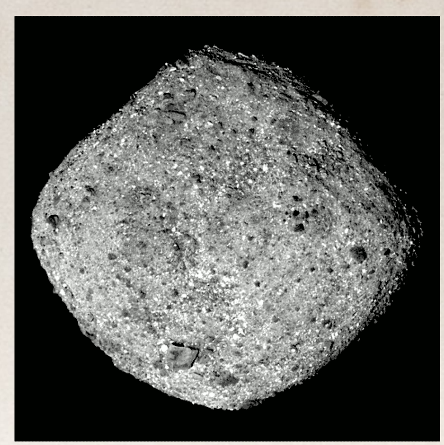




Mission Overview

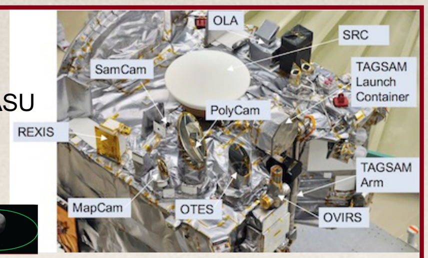
- **Principal Investigator Dr. Dante Lauretta, UA/LPL**
- Life Cycle Cost $1,020.8M (KDP-E Mgmt. Agreement)
- Launched on September 8, 2016
- Arrived at Bennu on December 3, 2018
- Studied Bennu for 505 days
- Obtain at least 60 g of pristine regolith/surface material
- Returned sample to Earth in September 2023
- Delivered samples to JSC curation facility

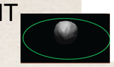
OSIRIS-REx
ASTEROID SAMPLE RETURN MISSION



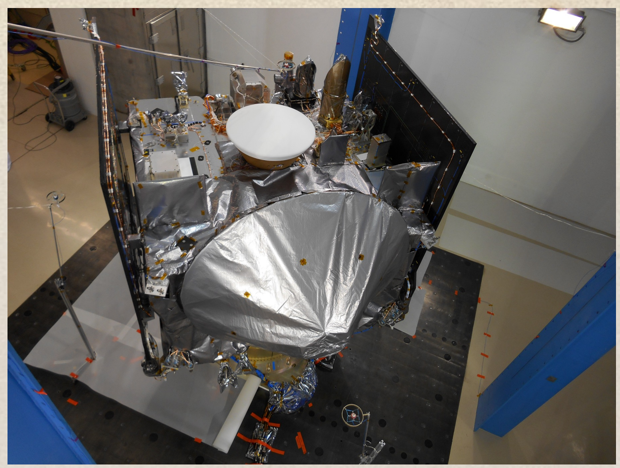
Science Instrumentation and Key Capabilities

- OSIRIS-REx Camera Suite (OCAMS) – UA
- OSIRIS-REx Thermal Emission Spectrometer (OTES) – ASU
- OSIRIS-REx Visible & IR Spectrometer (OVIRS) – GSFC
- OSIRIS-REx Laser Altimeter (OLA) – CSA
- Regolith X-ray Imaging Spectrometer (REXIS) – MIT
- Spacecraft Telecom/Radio Science
- Touch-And-Go Sample Acquisition Mechanism (TAGSAM) – Lockheed Martin
- Sample Return Capsule (SRC, Stardust Heritage) – Lockheed Martin
- Sample Curation and Laboratory Analysis – NASA/JSC and world-wide





64 months of development – ready for launch

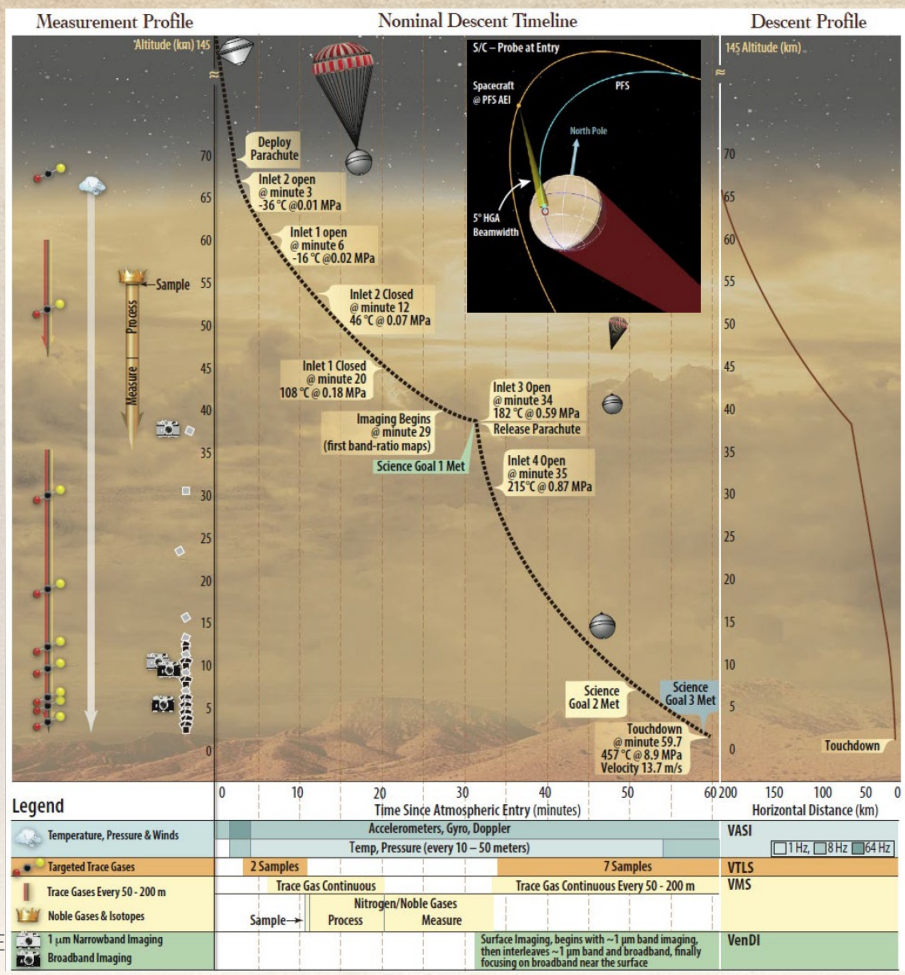


Key Information	
Mission Phase	E/F
Mission Life	7 years
Category	2
Class:	B
LV	Atlas 411
Dry Mass	860 kg
Launch Mass (fueled)	1955 kg
Power	1025 W
Downlink rate	820 kbps (typical)
Km traveled	3.86 Billion

DAVINCI

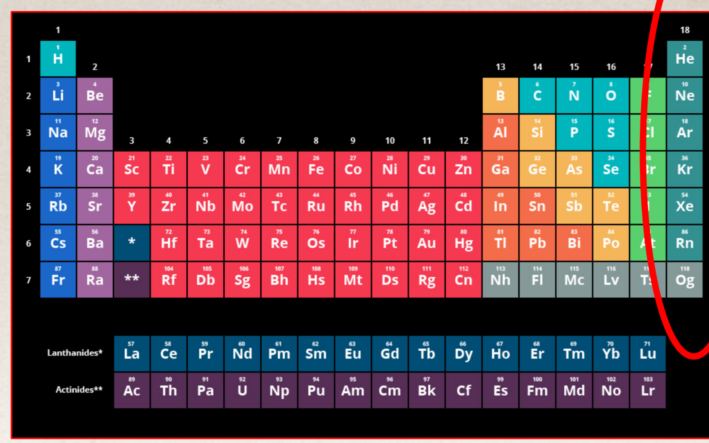
Current Mission Phase: Early Phase B

DAVINCI will learn about Venus's past by descending to the surface through its current atmosphere



- The noble gases in Venus's atmosphere are "chemical fossils" to understanding the planet's early evolution and origin
- The abundance and isotopic ratios of these gases will be compared to Earth and Mars to give insight into Venus early history
- About ¾ of the Venusian atmosphere is thought to be in the lowest 20 km above the surface and has never been measured

Noble Gases

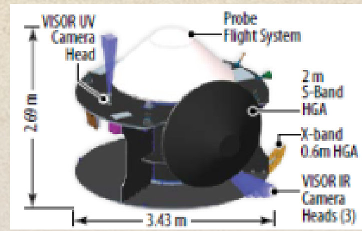


DAVINCI Mission Overview

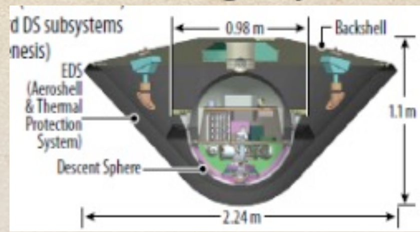
Science Description

DAVINCI will measure the composition of Venus' atmosphere to understand how it formed and evolved, as well as determine whether the planet ever had an ocean. The mission consists of a **Descent Sphere** that will plunge through the planet's thick atmosphere, making precise measurements of noble gases and other compounds to understand why Venus' atmosphere is a runaway hothouse compared the Earth's. It also includes Venus flybys for remote sensing of the composition and dynamics of the upper clouds, as well as of the nightside emissivity of highlands including the target area for descent sphere entry, descent, and imaging (Alpha Regio).

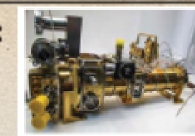
Spacecraft (CRIS):



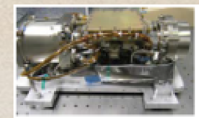
Probe Flight System:



VMS:



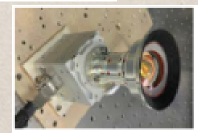
VTLS:



VASI:

VenDI:

VISOR:



DS:

VfOx CUVIS

Project Description

DAVINCI will launch in CY2029, perform two Venus flybys and image the planet's upper clouds & surface with VISOR and CUVIS, then release its Descent Sphere to conduct an in situ science of the atmospheric chemistry over 59 minutes, descending over the Alpha Regio highlands.

Key Information

Mission Phase: B
Launch Date: 2030
Mission Life: 2 yrs
Category: 2
Class: C
Launch Vehicle: TBD

Instruments

VenDI (Venus Descent Imager): MSSS
VMS (Venus Mass Spectrometer): NASA GSFC
VASI (Venus Atmospheric Struct. Invest): NASA GSFC
VTLS (Venus Tunable Laser Spectrometer): NASA JPL
VISOR (Venus Imaging Sys for Observ Recon): MSSS
CUVIS (Compact Ultraviolet to Visible Imaging Spectrometer): NASA GSFC
VfOX Student Collaboration: JHU/APL

Partners & Contractors

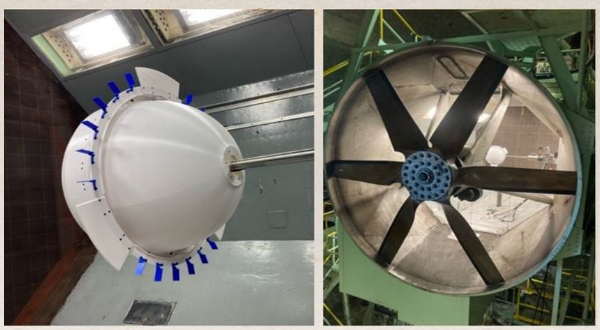
NASA GSFC – PI Institution, Project Management, Systems, Mission Assurance, VMS, VASI, Descent Sphere (DS), SOC, Flight Dynamics [with APL for Frontier Radio]
Lockheed Martin Space – Spacecraft (CRIS), Ground System, Mission Operations Center
NASA JPL - VTLS
MSSS (Malin Space Science Systems) – VenDI, VISOR
NASA KSC – Launch Services
KinetX – Navigation

WBS	Element	2023	2024	2025	2026	2027	2028	2029	2030	2031
		A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J
	NASA PHASES					Phase C		Phase D		
	NASA HQ Milestones	KDP-B (Selection) was 06/21				KDP-C (Confirmation) 04/27		KDP-D 09/29	KDP-E 10/30	
1.0	DAVINCI Mission Milestones	Mission Requirements Review (MRR) - 05/23				PDR 02/27	CDR 04/28	SIR 08/29	LRD 12/30	PLAR (L+30d)

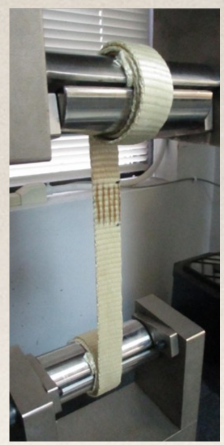
DAVINCI Hardware in early development

Aeroacoustic entry loads test at NASA-Ames in the Bay Area

Atmosphere-sniffer test in Univ of Maryland wind tunnel



Half-Size Probe Wind-tunnel testing at NASA-LaRC in Virginia



Strength testing of parachute materials after sulfuric acid exposure

Thermal Testing in industrial forging kiln – before and after

Lessons Learned – Phase A

The CSR is your project's first contractual deliverable

- Typically a Step 1 proposal is evaluated on Science merit while the Step 2 / CSR is evaluated on implementation feasibility as well
- Step 2 should transition team's thinking to being a real project in Phase A and focus on execution of a successful CSR delivery and formulation planning of your mission.
- Your team should always be thinking with the end (CSR delivery) in mind and should manage the CSR development as you will do the mission:
  - Understand AO expectations, constraints and guidelines (requirements)
  - Clear definition of end product (scope)
  - Establish Budget allocations and schedule margin for CSR products themselves (in addition to the actual mission you will be describing in the CSR)
  - Staff your Step 2 team ASAP and front-load the CSR prep as much as possible with gatechecks for outside eyes to make sure that your CSR is on track
  - <u>Do not let your team fall behind in CSR preparation</u>

Mold Your Team's Roles/Responsibilities Wisely

- A CSR is evaluated and selected on the strength of the entire team, including roles / responsibilities
- Even with strong partner institutions, roles and responsibilities need to be well thought out between team members
  - Examples: System integration (I&T/ATLO) responsibilities, ground systems and mission operations, science operations/planning center
- The PI will be working with the teams they assemble for the life of the mission – PI must be comfortable with the key personnel
  - PI must be comfortable with key/critical programmatic and technical leadership in particular
- Collocate teams as much as possible during CSR development
  - Frequent travel of key personnel is still important in age of collaboration tools
  - DAVINCI CSR was done during COVID and was difficult to coordinate
- Maximize use of Partnership Opportunity Documents (PODs) in the proposal/CSR process
  - Selection of the proposal by proxy selects all team partners that have PODs
  - No need to subsequently compete or sole-source the partners
- If international contributions (science team or hardware) are part of your mission, get the firmest commits possible in writing as early as possible

Evaluate Subcontractor/Major Vendors Wisely

- CSRs give limited time to evaluate potential vendors with whom team may have minimal experience
- Step 2 funding limitations inhibit putting firm agreements in place but the team should have primary/backup plans for critical technologies
- OSIRIS-REx lesson-learned:
  - Presumed GNC LIDAR vendor in CSR chose to “no-bid” in Phase B after mission was selected
  - Schedule pressures compressed the time available to select backup vendor in Phase B
  - Chosen vendor turned out to have less experience than implied in their proposal
  - Project had to supply considerable technical support to ensure successful delivery
  - Lessons-learned:
    - Identify backup vendors or (backup approaches) for critical deliveries via RFI process during CSR
    - Do not rush selection of critical vendors – do the homework

PI relationship to PM and PSE is critical

- Although the PI is in the end responsible for all aspects of the mission, the most successful PIs delegate day-to-day management to the PM and PSE
  - PI must always pay close attention to the details that affect science data quality
  - In the end, the overall success of the mission is still the PI's responsibility
- PM and PSE need to remember at all times that their job is to make the PI successful
- PI, PM and PSE need to forge close working relationships in Phase B because there will always be challenges later in development
  - Successful PIs need to be able to trust their leadership teams to get through the difficult times
- A PI needs to be willing to make changes in the PM and PSE if necessary, but also show patience and loyalty within their team
  - Institutions will also make changes in PM/PSE but need to have the PI's concurrence

Make sure your Step 2 proposal is actually feasible

- Build enough ”honest” reserves into your proposal – technical and financial – that you can actually execute the mission that you propose
  - Do low-TRL (TRL < 6) technology developments have a realistic development plan?
  - Does schedule to Mission PDR/confirmation fully address work necessary get to PDR?
- Perform enough systems engineering from L1 requirements through L2 (and ideally to L3) to demonstrate to yourself that the mission is executable
  - Work will result in the Science Traceability Matrix for CSR, and then baselined L1/L2 requirements documents once you move to Phase B
- Descope plans should be practical and implementable
  - Evaluation factor from TMCOs
  - May become necessary for actual delivery of mission
- For a long-duration development and mission, have a succession plan for all critical personnel, including the PI
  - Include development plans for mid-career personnel

Fully respond to the Announcement Of Opportunity

- Identify someone to crosscheck every AO requirement to ensure that it is addressed
- Establish internal ”gate checks” during proposal preparations to make sure that proposal messages and win themes are clear
  - Occasional “outside eyes” will help identify concerns that the proposal team themselves are too close to the material to see
- If funding profile or constraints are provided as part of the AO, be sure that the proposal funding profile conforms to the budget

Funding profile (proposed and actual) is critical

- Ensure that the optimal funding phasing profile by fiscal year is clearly communicated in the CSR
- Strong recommendation – Adequate funding to get to Mission PDR and Confirmation is critical, including initial purchase of long-lead items
- OSIRIS-REx and Lucy (positive) examples:
  - Funding profile "S-curves" identified in CSR following successful heritage developments on planetary missions
  - SMD / PSD provided funding profiles consistent with CSR request and both missions delivered on-schedule and under budget
    - SMD/PSD also authorized purchase of long-lead procurements in Phase B as a schedule risk mitigation
- DAVINCI (pending) example:
  - CSR identified optimal funding profile based on earlier successful projects
  - However, SMD / PSD available funding has been significant problem since selection
  - Early-year funding has been highly constricted, far below heritage projects
  - Early-year formulation planning to get to Confirmation has been disrupted multiple times by in-year budget cuts
  - DAVINCI programmatic results: TBD

Foreign Contributions require special attention

- Foreign contributions can be an invaluable asset but need to be approached with diligence
- In some cases foreign partners have unique capabilities and experience
  - Special Instrumentation (e.g, Scanning Laser Altimeters, collimated Neutron Detectors)
  - Special science team analytical experience
- NASA encourages “smart” foreign collaborations
  - Can increase mission science return and are not included in the mission funding cap
- Note that foreign contributions can have unstable funding and fragile agreements which can imperil development
  - Securing funding is a recurring challenge with foreign partners because the foreign Agency needs to know that the mission has been awarded before they get serious on finding the funding
  - OSIRIS-REx OLA funding startup was delayed almost 18 months due to Canadian Administration change
- If contributing hardware interfacing to a spacecraft, ITAR/EAR concerns must be handled
  - For ITAR information, Project will need to work with Spacecraft vendor and foreign partner to establish a Technical Assistance Agreement (TAA) which describes explicitly how controlled technical data will be shared with the foreign partner – usually restricted to interface/ICD information
  - TAA will likely need to be updated for Phase E operations support
- For a Step 2 CSR ensure that the proposed contribution has a draft agreement from the foreign space agency that you include in your CSR in the International Participation Plan section
  - Deliverables and personnel participation should be defined clearly and concisely

Risk Management starts in Step 2

- "All Project Management is Risk Management"
  - Risk Management is a key communications tool in the CSR that will demonstrate how the technical leadership team approaches complex technical questions
- Active Risk Management should start from the beginning of the Step 2 proposal
  - Identification of most critical risks <u>and risk mitigations</u> is key
  - Consider whether any weaknesses identified in the Step 1 feedback should be treated as risks to be discussed in the CSR
  - Retire any risks possible within schedule/budget constraints during the Step 2 proposal itself; identify Mission Phase when other Risks are predicted to be retired
- In your Risk Management section, anticipate the risks that the evaluation committee will likely be looking for and your mitigation approach to minimize the risks

Example of Step 2 Risk Mitigation from DAVINCI

- Key Technical challenge – keeping interior temperatures benign (~50C) even after exposure to mission Venus temperature profile (900 F after one hour of descent)
- Prior proposal weakness – thermal design had not been demonstrated to achieve mission requirements
- Project treated this concern as a risk with the mitigation being a test demonstration of the design prior to the Site Visit
- Results: testing confirmed thermal design performance, and turned finding from a weakness into a strength at the Site Visit

Thermal Testing in industrial forging kiln to Venus temperatures demonstrated validity of thermal design

Prepare for the unexpected at Site Visit

- Technical, Management, Cost and Other Factors (TMCOs) will evaluate not just the answers to questions, but also how the teams respond
- Significant weaknesses, Questions and Requests for information Lists (SQRLs) are sent before, during and even after the site visit
  - Spend time between proposal submission and site visit to anticipate the most likely SQRLs and prepare mock responses
- Establish a "Backroom" with a manager and systems engineering lead to field SQRLs in parallel while the PI and PM/PSE keep the site visit going
- Establish single Points-of-Contact to respond to SQRLs so that well-meaning team members aren't stepping on each other

Lessons Learned – Phase B - specific

Anticipate surprises at Mission selection

- Per NASA 7120.5F, for a two-step competed AO mission, selection constitutes transition from Phase A to Phase B
- Selection may come with surprises, questions and additional work
- DAVINCI example -
  - Launch Readiness Date (LRD) slipped three years at selection (compared to dates proposed) due to SMD funding availability
  - Proposed Venus orbital phase deleted in Selection Letter
    - o SMD even directed mission name change as part of Selection
  - Project given 60 days to prepare response to justify retention of remote sensing instruments for flybys due to deletion of orbital phase

Establish positive relationships with stakeholders

- Early Phase B is a critical time to establish positive relationships with HQ and Program Stakeholders and implementing institutions:
  - Program Office / Mission Manager
  - SMD Program Executive (PE)
  - SMD Project/Program Scientist(s)
  - Standing Review Board Chair (may be later in Phase B)
  - Institutional leadership with NASA Centers, industrial partners as appropriate
- Relationship begins with demonstrating to stakeholders that any findings at Selection are worked off promptly and fully
- Strong recommendation: have in-person kickoff meeting(s) with SMD and Program Office
- Meet with Standing Review Board (SRB) Chair early and often
  - Work with SMD PE and Program Office to select SRB Chair
  - Invite SRB members to early subsystem reviews so that Mission PDR is not the first exposure of the SRB to the project
- Consider creating a "Leadership Council" comprised of directors of each lead institution that get convened only in times of great need
  - OSIRIS-REx convened "Leadership Council" twice to discuss project leadership personnel concerns

Keeping team focus despite budget reductions and Launch Readiness Date (LRD) slips

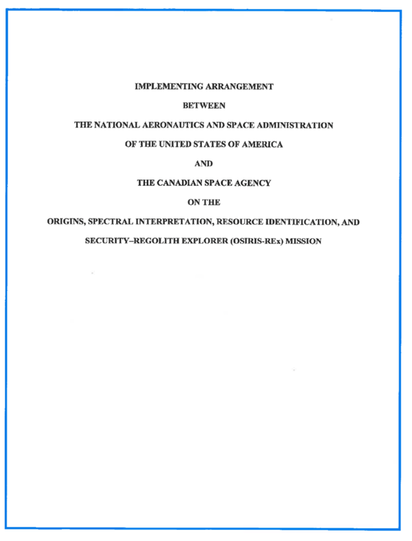
- Decide on who you need for a “core team” during the slow start up phase
- Suggestion: ensure full PI team and Systems Engineering leadership is in place – defer subsystem engineering
  - Keep flat management approach befitting a small team
  - Confine status reporting and meetings to value-added activities
- Define modest, discrete goals and manage/track the project just like you will when the funding faucet turns on
- DAVINCI defined a “SORR” phase during the extended Phase B
  - Identify highest-impact Risk Reduction activities we could afford within budget
    - Focus on critical path(s) and highest risk elements
    - Focus on Instrument and lowest-TRL aspects of mission
  - Last chance to perform Science Optimization activities
  - Perform systematic top-down requirements definition starting with L1 requirements
  - DAVINCI identified just under 100 “shovel-ready” SO/RR tasks that we could start on

Take full advantage of Bridge Phase

- Bridge Phase – typically first 3-5 months or so of Phase B startup before ”Phase B proper” starts
- Bridge Phase allows teams to start working quickly to letter contracts/tasks while the Phase B contracts/tasks are being negotiated
- Avoids “startup quicksand” for large partners like spacecraft bus vendor
- Bridge Phase time moves quickly – need to jumpstart contract activities for Phase B ASAP
  - Recommendation: have draft Phase B SOWs for all contracts in place by Site Visit so that you can quickly move to Phase B RFPs while the Bridge Phase letter contracts are still in place

Foreign Contribution Phase B Tips/Tricks

- After selection, start in Phase B as early as possible on the "Implementing Arrangement" (IA) which codifies the agreements between the two countries
  - "Diplomacy in the form of hardware as gift to the US Government and American people from the (foreign nation)" (wording from Russian instrument on LRO)
  - Work through your Program Executive (PE) when the actual proposal from the partner is concisely defined and they consider it "final"
  - PE will work with:
    - SMD Directorate Associate Administration (DAA)
    - HQ Office of External Relations
  - Actual agreement in an IA is made between NASA Office of International & Interagency Relations (OIIR) and corresponding Space Agency Director
  - Can easily take up to two years to get to signed-off IAs
- When possible, freeze one side of interfaces as early as possible
  - Utilize build-to-print heritage where possible
- In Integrated Master Schedules (IMS), baseline more than the typical amount of schedule slack to absorb late deliveries
  - Foreign Contributions have a history of late deliveries to NASA missions
- Ensure your Level 1 requirements can still be met if for some reason the foreign contribution falls through:
  - Do not use foreign contributions for baseline (L1) science products if possible
    - Mars InSight is the cautionary tale
  - Even if needed for threshold science requirements, have a backup hardware plan if possible
    - OSIRIS-REx GNC LIDAR was partial backup to the CSA-supplied "OLA" Laser Altimeter



IMPLEMENTING ARRANGEMENT
BETWEEN
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OF THE UNITED STATES OF AMERICA
AND
THE CANADIAN SPACE AGENCY
ON THE
ORIGINS, SPECTRAL INTERPRETATION, RESOURCE IDENTIFICATION, AND
SECURITY–REGOLITH EXPLORER (OSIRIS-REx) MISSION

Start Phase B with Confirmation in mind

- Always remember that the target goal is Mission Confirmation (KDP-C)
  - Tied to Mission PDR
- Move quickly to establish the core, senior team that will lead the formulation team through from Selection to Confirmation
- Even though the schedule pressure begins at Mission Selection, to the maximum extent possible maintain a systematic, methodical flowdown of mission requirements and freeze first L1 requirements and then L2 requirements
  - ”Less Haste, More Speed”
- As soon as feasible, identify major system/architecture trades outstanding from the proposal and conduct the trades as soon as engineering team is in place
- As soon as feasible, take a deeper look at mission risks and lay in concrete mitigation plans (within budget constraints)

Initiate Phase B procurements as soon as practical

- Long-lead non-flight procurements tend to be schedule critical path for getting to the Element (Instrument, Spacecraft Bus) PDRs which precede Mission PDR
  - Especially true for post-COVID supply chain vendors (e.g., EEE parts)
- Placing long-lead flight procurements in Phase B has been shown to be one of the best ways to maintain flight hardware delivery schedules
  - Note: placing flight hardware procurements prior to Confirmation typically requires HQ/SMD approval but that approval is typically not an issue
  - Positive Lesson Learned from GSFC planetary missions such as MAVEN, OSIRIS-REx and Lucy to maximize early long-lead procurements
- Work with HQ/SMD sponsor to maximize early-year funding in development

Lessons Learned – Transition to Phase C

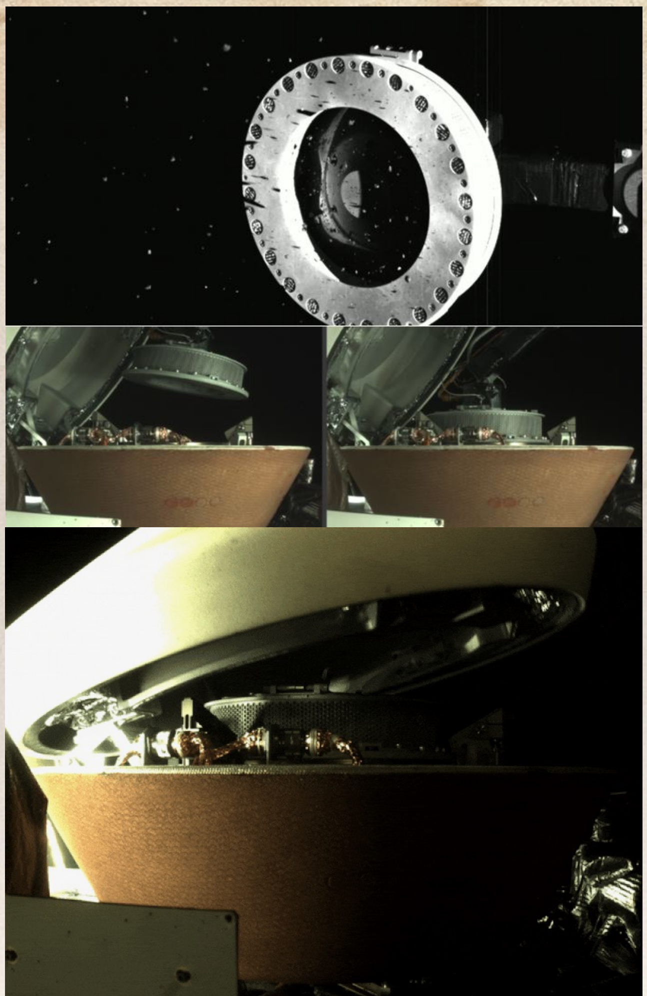
Change mindset from planning to execution

- Close out all trade studies and freeze design as quickly as feasible
- Set up tracking mechanisms to ensure you can assess and track progress in time to take corrective actions
  - Understand the limitations of Earned Value Management systems
- Finish Technical Risk Mitigation activities where practical, leaving only residual risks
- Baseline I&T plans where possible (“ATLO – Assembly, Test and Launch Operations”)
- Begin detailed Launch Operations planning with Launch Vehicle provider – typically starting at L-30 mos
  - Recommend asking stakeholders to move the LV selection as early as they are willing – OSIRIS-REx and Lucy both moved to L-36 months with stakeholder concurrence
  - HQ/Stakeholders provide LV funding and so moving LV selection ”to the left” increases the nominal cost but significantly reduces interface risks
- Begin detailed Mission Operations and Phase E planning
- Ensure that adequate testbeds are put in place for Flight Software and Fault Protection V&V, I&T execution and mission operations
  - Key Psyche IRB finding

Questions?

Backup

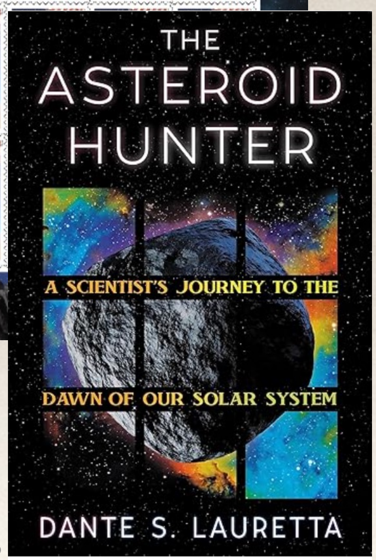
End results make the challenges worthwhile



Mission Complete! But not quite yet

Extended Mission – "OSIRIS-APEX" - "Apophis Explorer"

OSIRIS-APEX
APOPHIS EXPLORATION MISSION



NASA can't wait for its OSIRIS-APEX spacecraft to meet 'God of Chaos' asteroid Apophis in 2029

News By Robert Lea published December 29, 2023

Apophis will make an asteroid flyby like no other in recorded history in 5 years as it becomes visible with the naked eye, and OSIRIS-APEX will be on hand to supervise.

Comments (5)

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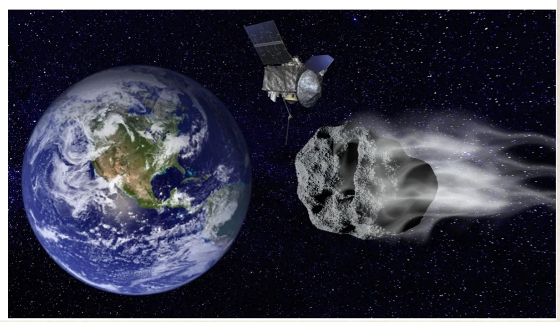

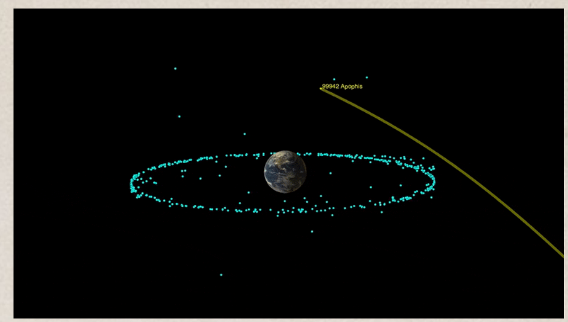

4/13/2029 – Apophis comes within 20,000 miles of Earth!