Status of Outer Planet Flagship Mission Studies

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Expectations and Groundrules

• Need studies to be as complementary as possible
  – Each study has unique heritage and readiness, but studies must address common items
    • Define and prioritize science
    • Characterize mission concept and implementation
    • Technology definition and readiness assessment
    • Estimate cost
    • Identify and assess risk

• Mission cost target of $3B

• Conservative Philosophy
  – Cost estimates will not decrease as we move toward development
  – Funds for technology development are limited, so adopt a conservative approach to the use of new technologies
  – Provide descopes with cost deltas to provide flexibility in sizing mission

• Studies guided by common groundrules to provide a standard for content, final product, and common assumptions
Study Structure

• Phase 1: define science, explore architectures, conduct trades, narrow concepts

• Phase 2: Refine concepts, define implementation, estimate cost, assess mission risk and value

Phase I

Phase II

Concept(s) A (and B) Implementation

Cost Method
Cost Estimate
Cost Drivers
Science Value, Msn Risk
Mission Summary: Tech, Cost, Sci value, Risk
Status and Schedule

• All studies have completed Phase 1 gate review
  – All teams have defined and prioritized science objectives
  – Europa, Titan, and JSO teams working on detailed design of downselected concepts
  – Enceladus team will continue exploring its trade space

• Phase 2 Review: July 19-20
• Final Report: August 29
• TMC and Science Review: Oct. 2, 4, 16, and 18
• Briefings to community
  – OPAG: May 2
  – COMPLEX: July 23
  – Ices, Oceans, and Fire Workshop: August 13
Europa Study: Status and Progress

• Study led by JPL
  – Study Lead: Karla Clark (JPL)
  – SDT Chairs: Ron Greeley (ASU) & Bob Pappalardo (JPL)
• Study builds on long history of previous work to quickly proceed through trades to detailed design
• Progress
  – Significant progress on two critical issues of mission
    • Radiation: refined radiation model indicates significant reduction of dosage; many rad hard components now available at high TRL
    • Mass: currently carrying 54% mass contingency plus additional ~200 kg of LV capability unused
  – Draft final report complete
  – Mission design requires minimal technology development
  – 17 step descope list halves payload mass and power
  – Coauthoring white paper with JSO SDT on science synergy with JSO concept
• Issues:
  – Mission requires near 24/7 DSN coverage at Europa
  – Significant jovian system science possible but not yet defined
  – Rad hard parts availability and performance must be validated (ongoing)
  – Lifetime analysis needs to be completed
  – Rad hard memory
Europa Mission Concept

- Concept: Europa Orbiter with Galilean tour
- Science: Explore Europa and investigate its habitability
- Launch Vehicle: Delta IV-H
- Trajectory: VEEGA
- Power Supply: MMRTG or ASRG
- Mission Timeline
  - Launch: ~6/2015
  - Jupiter Arrival: ~7/2021
  - Galilean Satellite Tour Science: ~1.5-2.5 yrs
  - Europa prime mapping: ~90 days
  - Spacecraft operates until loss of control and impact into Europa surface
- Instruments: 11 (163 kg, 172 W)
- Mass and Power Margins: 54%
- Unallocated Mass: ~200 kg
Titan: Status and Progress

- Study led by APL
  - Study Lead: James Leary (APL)
  - SDT Chairs: Hunter Waite (SWRI) & Ralph Lorenz (APL)
- Study builds on history of previous work second only to Europa to quickly proceed through trades to detailed design
- Team considered variety of combinations of orbiter, lander(s), aerial vehicle(s) in Phase 1
  - Downselect guided by science and technical considerations led to architecture with orbiter and lander plus aerobot for detailed study in Phase 2
- Progress
  - Robust descope options available to reduce cost, risk, mass, and power (descope list is TBD)
  - Architecture provides comprehensive and exciting science
  - Early analysis indicates mission will fit on an Atlas 551, reducing costs while allowing for possibility of mass growth to a Delta IVH
- Issues:
  - Mission complexity arising from three spacecraft
  - Technology development: 3.5 years required for technology readiness demonstrations
    - Aerocapture (enabling for this mission)
    - Balloon technology, deployment, operation
    - Cryogenic environment and sampling
  - Significant detailed design work (especially for lander and aerobot) remains to be done and will impact mission details
  - Aerobot treated as Mars Pathfinder-class mission: technology demo with significant science
  - Planetary protection approach needs to be developed
Titan Mission Concept

- Concept: Titan orbiter with lander plus aerobot
- Science: Exploring an organic-rich Earth-like world
- Launch Vehicle: Atlas 551
- Trajectory: gravity assists (TBD)
- Power Supply: ASRG for orbiter, MMRTG for lander and balloon (trades TBD)
- Mission Timeline
  - Launch: ~6/2018
  - Titan Arrival: ~2028
  - Lander and Aerobot released
    - Lander targeted to dunes
    - Balloon targeted to 30deg latitude, completes 2 circumnavigations
  - Orbiter aerocaptures into 1700 km circular near polar Titan orbit
- Three mission elements
  - Titan Orbiter: 4 year lifetime, 163 kg payload, 319 W
  - Titan Lander: 1 year lifetime, 46 kg payload, 65 W
  - Titan Balloon: 1 year lifetime, 36 kg payload, 97 W
- Mass and Power Margins: TBD
- Unallocated Mass: TBD
JSO: Status and Progress

• Study led by JPL
  – Study Lead: Johnny Kwok (JPL)
  – SDT Chairs: Louise Prockter (APL) & Dave Senske (JPL)
• Team benefiting from Europa work to increase pace of progress
• Mission Philosophy: Long-term (~5 year) Jupiter system science encompassing objectives for entire Jupiter system
• Team considered 4 mission concepts during phase 1
  – Ganymede elliptical orbiter with Jupiter atmospheric probe
  – Ganymede elliptical orbiter with large (1m or greater) optical system
  – Ganymede circular orbiter (selected for Phase 2)
  – Ganymede elliptical orbiter on smaller launch vehicle with reduced payload
• Progress
  – Evaluated science and technical aspects of all four concepts to support downselect
  – Significant effort finding tour and Ganymede orbits that meet science needs
  – Integrating diverse science objectives and targets proved a challenge
  – Coauthoring white paper with Europa SDT on science synergy with Europa concept
  – Final Team X design session next week
• Issues:
  – Detailed design work (mass, downlink, power, etc.), is currently underway and will change some mission details
  – Similar radiation dosage as Europa; further analysis may slightly decrease dosage
  – Planetary protection approach needs to be developed
JSO Mission Concept

• Concept: Long-lived (~5 year) Jupiter System Observer encompassing science objectives for entire Jupiter system
• Science: Study the Galilean satellites (surfaces, interiors, atmospheres) and Jupiter (atmosphere and magnetosphere) as a means of understanding the jovian system as a whole
• Launch Vehicle: Delta IV-H
• Trajectory: VEEGA
• Power Supply: MMRTG (trade TBD)
• Mission Timeline
  – Launch: 8/2022 (worst case opportunity)
  – Jupiter Arrival: ~6 yr cruise
  – Galilean Satellite Tour: ~2.5 yrs
    • 2 Io flybys, 6 Europa, ~15 Ganymede, ~10 Callisto
  – Ganymede Orbit: ~2 years
    • 1 yr elliptical orbit for magnetospheric science (200 x 25000 km, ~60deg incl.)
    • 1 yr circular polar orbit for mapping and geophysics (100 km, ~90deg inclination)
  – Spacecraft operates until loss of control and impact into Ganymede surface
• Instruments: 14 (234 kg, ~200W)
• Mass and Power Margins: set at ~43%
• Unallocated Mass: TBD
Enceladus: Status and Progress

• Study led by GSFC
  – Study Lead: Andrea Razzaghi (GSFC)
  – SDT Chairs: John Spencer (SWRI) & Amy Simon-Miller (GSFC)
• Enceladus is a new destination with extremely little study heritage
  – Unlike other studies, this team is starting from scratch
• Team identified 11 broad mission concepts of interest
• Progress
  – Performed rapid evaluation of science value and technical feasibility of all 11 concepts
  – Completed design runs on two of three downselected mission concepts (Saturn orbiter with Enceladus lander and Enceladus orbiter)
  – Final IMDC design run next week
• Issues:
  – Results of two design runs suggest more work needs to be done identifying and investigating tradespace to meet major technical hurdles for mission
    • Delta V requirements and trajectories
    • Landing systems
    • Sampling systems
  – Technology Development:
    • More efficient nav support
    • Cryogenic environment and sampling
    • Lander EDL for small, airless, rough bodies with poorly known surface properties
  – Planetary protection approach needs to be developed
  – Consensus from larger science community on scientific goals and measurements for mission
Enceladus Mission Concept

- **Concept**: Saturn Orbiter drops off small Enceladus (soft) Lander
- **Science**: Understand the formation, maintenance and implications of the unique geyser features on Enceladus
- **Launch Vehicle**: Delta IV-H
- **Trajectory**: 25 kW SEP stage with EGA
- **Power Supply**: ASRG
- **Mission Timeline**
  - Launch: 4/2018
  - Saturn Arrival: 7.5 yr cruise
  - Orbital Adjustment: <1 yr
  - Enceladus Tour: ~1.5 yr
    - ~50 Enceladus flybys
    - Short lived soft lander (1 week)
  - Spacecraft disposal into Saturn
- **Orbiter Instruments**: 8 (~63 kg, ~90 W)
- **Lander Instruments**: 8 (~12 kg, ~50 W)
- **Mass and Power Margins**: set at ~30%
- **Unallocated Mass**: Maybe

- **Concept**: Enceladus Orbiter
- **Science**: Understand the formation, maintenance and implications of the unique geyser features on Enceladus
- **Launch Vehicle**: Delta IV-H
- **Trajectory**: VEEGA (chemical)
- **Power Supply**: ASRG
- **Mission Timeline**
  - Launch: 9/2018
  - Saturn Arrival: 11.5 yr cruise
  - Orbital Adjustment: ~3 yrs
    - Including ~25 Rhea flybys to pumpdown orbit
  - Enceladus Orbit: ~2.4 yr
    - Mapping orbit at 45deg inclination and 200 km
    - Short duration polar orbit at 100 km
  - Spacecraft impacts Enceladus at EOM
- **Orbiter Instruments**: 8 (~65 kg, ~80 W)
- **Mass and Power Margins**: set at ~30%
- **Unallocated Mass**: Yes
Supplementary Material
Background and Implementation

• In response to PSS/OPAG recommendations and discussions, PSD is conducting detailed studies for several flagship missions
  – Europa (JPL)
  – Titan (APL)
  – Enceladus (GSFC)
  – Ganymede/Jovian System Observer (JPL)
• At OPAG’s suggestion, studies distributed across several institutions
• Science community participation via SDTs and reports to OPAG
  – Public call for SDT members in December 2006 resulted in >300 responses
• Studies started in Jan 2007 and will be completed fall 2007
• Study results will be used as input to near term NASA strategic planning for flagship missions
SDT Charter

• The SDTs are charged with defining the science content of the missions and working closely with the engineering team to define a mission concept(s) that optimizes science, cost, and risk. The SDTs are also responsible for defining and defending the science value of the mission concept(s).

• To accomplish this, SDTs must work closely with engineering teams

• SDTs should not work in a vacuum
  – Build upon previous work by other groups (Decadal Survey, OPAG, etc.)
Independent Review

• All studies will undergo independent review
• TMC panel run by NASA Langley
  – Will assess technical factors, risk, readiness, cost, schedule, etc.
• Science panel formed by HQ
  – Will assess clarity and prioritization of science objectives, relevance, methodology, value of science floor, etc.
• Reviews scheduled for early October
• Study and review results will be factors considered by HQ when deciding how to proceed
Overview of Groundrules

• RPS
  – Restricted to MMRTG, ARTG, SRG, RHU
• Planetary Protection
  – Categorizations obtained from PPO at HQ
• Launch Vehicles and Cost
  – Restricted to Atlas 5 and Delta IVH
• Technology Philosophy
  – Adopt a conservative approach to the use of new technologies and development plans for development of needed technology
• Launch Dates (2015-2022)
• DSN Capability
• International Contributions
  – Although international participation is expected to be an important component of any flagship mission, for the purposes of this study it should be assumed that no international collaborations or contributions are available
Study Final Report

• Final Report due to NASA on Aug. 29
• A public version of the report will be released in October

1.0 Executive Summary
2.0 Target Body Science Goal and Objectives
3.0 Mission Architecture Assessment
4.0 Mission Concept A Implementation
  4.1 Architecture Overview
  4.2 Science Investigation
  4.3 Mission Design
  4.4 Flight System Design and Development
  4.5 Operational Scenario
  4.6 Planetary Protection
  4.7 Major Open Issues or Trades
  4.8 Technology Needs
  4.9 Technical Risk Assessment
  4.10 Schedule
  4.11 Cost
5.0 Mission Concept B Implementation (if applicable)
  Repeat as above
6.0 Changes if launched in second launch window
7.0 Summary
Europa Science Objectives

*Goal:* Explore Europa and investigate its habitability.
Titan Science

Exploring an organic-rich Earth-like world

- Titan is a thematically broad science target ideally suited for a capable flagship mission
- Science Objectives:
  - Titan’s Origin and Evolution: What was Titan formed of, what is the extent of differentiation and geochemical processing that has occurred since formation, and how does it contrast with other solar system bodies?
  - Titan as a System: How do we explain the similarities and differences between Titan and other solar system bodies in the context of the processes operating there?
  - Organics and Life’s Origins: What are the processes responsible for the complexity of Titan’s organic chemistry?
Jupiter System Science

- Four science themes for the mission
  - **Galilean Satellites**: Understand the mechanisms responsible for surface features; determine surface compositions; and determine the composition, origin, and evolution of satellite atmospheres
  - **Interiors**: Determine the interior structures and processes operating in the Galilean satellites in relation to the formation and history of the Jupiter system and potential habitability of the moons
  - **Magnetosphere**: Understand the magnetospheric environments of Jupiter, its moons and their interactions
  - **Jovian Atmosphere**: Understand the processes that maintain the composition, structure and dynamics of the jovian atmosphere as a type example of a gas giant planet
Enceladus Science

- Overarching goal is to understand the formation, maintenance and implications of the unique geyser features on Enceladus
  - What role, if any, does tidal heating play in geyser formation?
  - What is the nature of the interior structure, and is liquid water ubiquitous?
  - What is the composition, including organics, ammonia, clathrates and silicates?
  - What drives the extensive tectonics and are they influencing surface features?
  - Is cryovolcanism active elsewhere on the planet and what are the resurfacing and escape rates at the pole?
  - What other processes alter the visible surface and do they influence the interior?
  - What is the biological potential and is there evidence of life, past or present?
  - How does Enceladus interact with the rest of Saturnian system?