Future Exploration of the Outer Planet Satellites: A Decadal Perspective

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David Stevenson •  Caltech
Elizabeth Turtle •  Applied Physics Laboratory
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Fall AGU Meeting, San Francisco
December 18 2009
The Playing Field

Numerous very diverse targets
Satellite Meetings

• Open session audio transcripts and presentations are available via [http://www.spacepolicyonline.com](http://www.spacepolicyonline.com) and [http://sites.nationalacademies.org/SSB/CurrentProjects/sb_052412](http://sites.nationalacademies.org/SSB/CurrentProjects/sb_052412)

• Washington DC, August 24-26, 2009
• Irvine, CA, September 21-23, 2009
• Boulder, CO, April 14-16, 2010

• Weekly panel telecons throughout

• Multiple mission studies initiated...
Europa Orbiter

- Highest priority outer satellite mission in the 2002 Decadal Survey
- Extensive study since then has converged on a specific mission design, JEO, part of EJSM
- JEO cost ~$2.7B (FY07)
- We have requested an Independent Cost Estimate of this mission concept
Io Observer

- A recommended Mid-Sized mission in the 2002 Decadal Survey
- Multiple Io flybys from eccentric Jupiter orbit
  - Radiation can be minimized by high-inclination orbit
- Detailed study beginning at JPL, based on 2008 Discovery/SMEX Mission Capability Extension (DSMCE) study
Ganymede Orbiter

• A recommended Mid-Sized mission in the 2002 Decadal Survey
• Likely to be realized by the ESA Jupiter Ganymede Orbiter (JGO) component of EJSM
• However JGO is one of three missions competing for a single “L” class mission slot
• We recommend a study so the mission can potentially be competed under New Frontiers if JGO does not proceed to a new start
Titan Saturn System Mission (TSSM)

- 2008 Flagship study:
  - NASA-supplied Saturn/Titan orbiter
  - ESA-supplied balloon and lake lander, costed separately
  - Several Enceladus flybys
- Independent Cost Estimate required for recommendation by the Decadal Survey for the next decade
Titan In Situ Elements

• ESA-supplied TSSM in situ elements
  • Montgolfière balloon
  • Lake lander

• Can these elements be flown as stand-alone missions before the next Flagship?
  • Mongolfière requires high data rate for remote sensing of surface: difficult to support with direct-to-Earth communication
  • Considerable technology development
  • Lake Lander’s prime goal is chemistry: requires lower data rates, so direct-to-Earth communication is feasible
  • Also, likely to require less technology development

• Lake Lander thus chosen for detailed study by the Decadal Survey
  • Stand-alone mission, or
  • Element of Flagship
Enceladus

- Biggest game-changer in satellite science since the 2002 Decadal Survey
  - Active tectonics and tidal heating
  - Potential habitable zone with increasing evidence for liquid water
  - Ability to sample the PHZ directly
- Many potential mission architectures
  - Saturn Orbiter
  - Enceladus Orbiter
  - Lander
  - Sample Return
- These are being studied as part of a Rapid Mission Architecture study at JPL
  - Incorporate improved trajectory options relative to previous studies (Thursday talk by Nathan Strange)
  - Emphasize lower cost missions
- Follow-on full studies of promising architectures may follow
Uranian Satellites

- Not clones of the mid-sized Saturnian satellites!
- Only intact ice-giant satellite system
- Satellite science is being considered as part of a Uranus orbiter study
Neptune and Triton

- Neptune orbiter and flyby were discussed by the 2002 Decadal survey
  - Neptune orbiter: High priority but deferred
  - Neptune flyby: not highly rated
- Improved instrumentation and the addition of the KBO flyby (and possible continued deferrment of a Neptune Flagship) make the flyby worth reconsidering
- JPL Rapid Mission Architecture study nearing completion
  - Flybys optimized for Neptune, Triton, or KBO
  - Simple orbiter
  - Complex orbiters
- Follow-on full mission studies TBD
Existing Flagship Study
Decadal Focused Study
Decadal RMA Study
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OPAG White Papers


• Recommendations:
  • The Decadal Survey should explore the possibilities for a program structure/categorization that could allow ‘small flagship’ class missions to be considered
  • Endorses the prioritization by NASA of the Jupiter Europa Orbiter (JEO) as the next Outer Planets Flagship and as part of the Europa Jupiter System Mission (EJSM) with ESA.
  • Strongly endorses approval by NASA of the Cassini Solstice Mission
  • Advocates the need for a focused technology program for the next Outer Planet Flagship Mission, which should be to Titan and Enceladus, in order to be ready for a launch in the mid-2020s
  • New Frontiers class missions that should be considered in the interim include (not in priority order) a shallow Saturn probe, an Io observer, a Titan in-situ explorer or probe, a Neptune/Triton/KBO flyby, Uranus Orbiter
# OPAG White Papers

Beauchamp et al: *Technologies for Outer Planet Missions*. 

**Recommendations:**

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Selected White Paper Findings

Missions and Science

- Outer planets program with small flagships?
- Include outer small satellite flybys in missions when possible
- Europa lander needed for astrobiology
- New Frontiers mission to Enceladus might be solar powered
- Enceladus sample return - Organics captured by Stardust technology
- Importance of astrodynamics for enabling missions e.g. to Enceladus
- Titan geophysical network
- Titan aircraft- some of the advantages of balloon, but steerable
- Life in hydrocarbons- plausible?
- Titan greenhouse as an analog for Earth greenhouse
- Uranus orbiter- possibly doable under New Frontiers on solar power?
- Good Triton science from a flyby
Some White Paper Findings

Near-Earth observations

• Importance of Thirty Meter Telescope and other giant telescopes for outer satellite science
• UV space telescope for Io and Europa observations
• Small telescopes for monitoring Io
• More NASA time on 8-meter telescopes
• IRTF capability needs to be maintained, in the absence of a larger dedicated planetary telescope
• SOFIA- Valuable for Titan, but also Io, stellar occultations
• Balloons- working group, balloon-borne observatory. Satellite spectroscopy in the UV (if we can get down to 200 nm) and some near-IR wavelengths obscured from the ground
• Space telescope for temporal monitoring- useful for Io and Titan
• JWST- can track moving target

Lab work

• Importance of lab work, need for increased support
• Planetary surface simulators
• Instrument development funded element NASA of strategic plan?
• Need to invest in infrastructure, train new people
• Lab work is slow and therefore expensive and can thus have trouble competing in current funding programs
• Encourage archiving of lab results in the PDS
Some White Paper Findings

**Technology**
- Need for a focused long-term technology program
- Radioisotope electric propulsion
- Entry technology, including thermal protection. Research into new materials and maintenance of facilities
- Ka-band improvements
- Spacecraft autonomy: data mining and autonomous acquisition
- Planetary protection- research into less invasive techniques for sterilizing spacecraft

**Research Data Analysis and Archiving**
- PDS needs to be able to keep up with increasing volume and complexity of data sets
- Need for making archived data user-friendly, e.g. archiving in physical units and high-level cartographic products

**Other**
- Importance of high-value, high-risk missions- something like New Millennium
- Importance of team member interactions and management structure in the effectiveness of a mission, and how these might be improved
- Concerns about ITAR
Specific Infrastructure Concerns

• $^{238}$Pu supply
  • Essential for ambitious outer planet satellite program

• Deep Space Network
  • Current DSN plan:
    • Possible retirement of 70-m antennas, construction of new 34-m antennas, by early 2020s
    • Transition from X-band to Ka-band as primary wavelength for communications
    • Need to maintain X-band for time-critical radio science, contingency communications