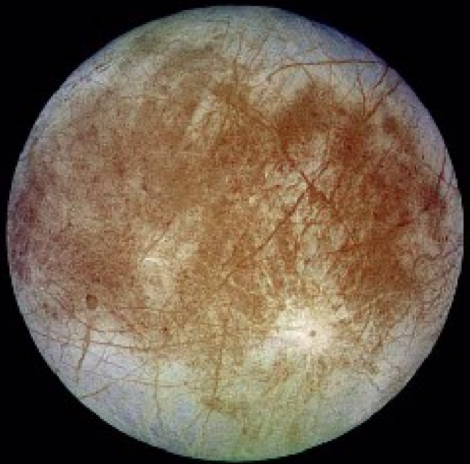
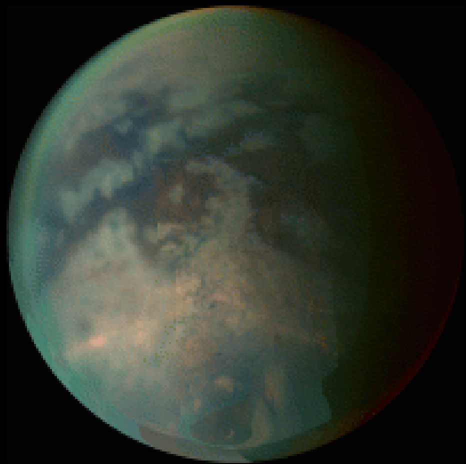
Outer Planets Flagship Mission

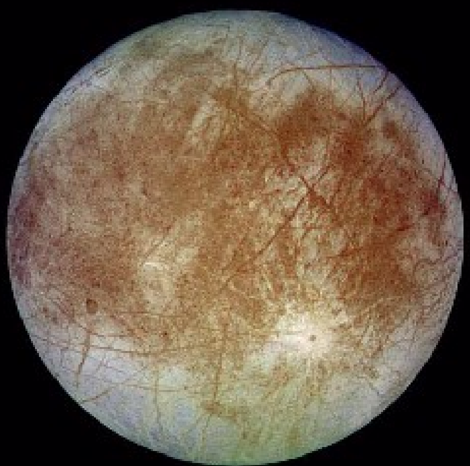


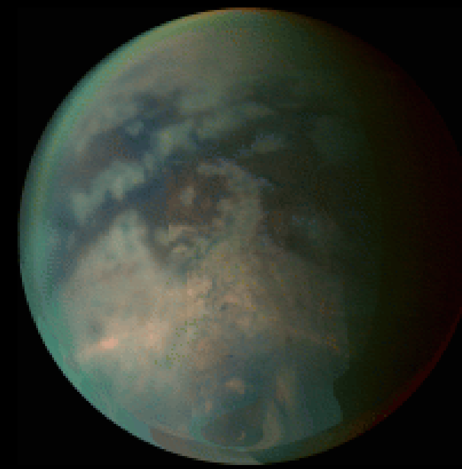


Briefing to OPAG
Steering Committee

OPF Study Team

August 28, 2008





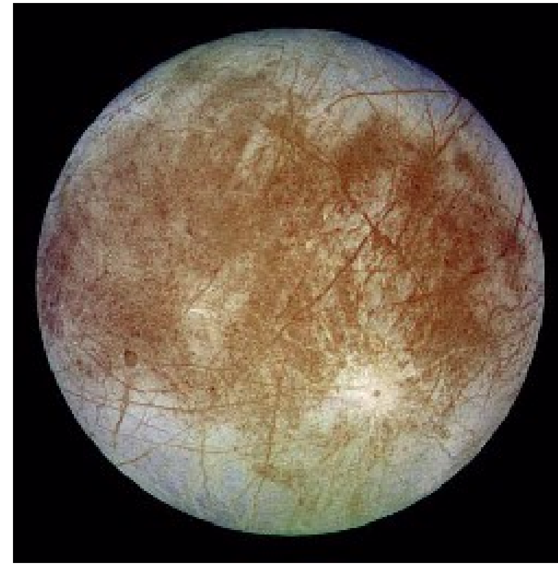
Overview

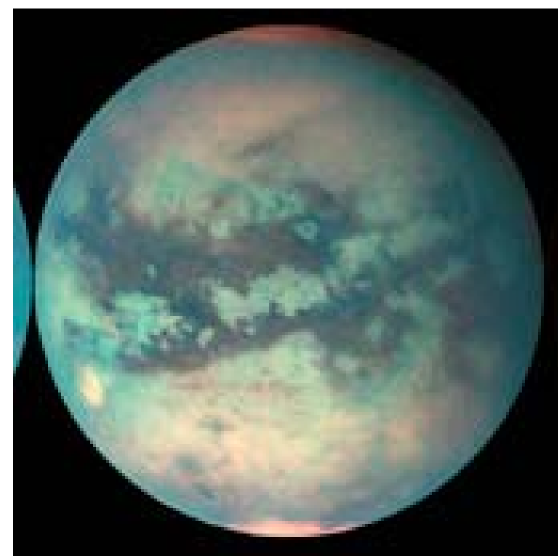
Outer Planet Flagship Mission - Context

- **NASA is currently mid way through a nine month long outer planet study which is being conducted jointly with the European Space Agency. Two missions are being studied**
  - Europa Jupiter System Mission (EJSM)
  - Titan Saturn System Mission (TSSM)

- **NASA plans to down select to a single *Outer Planet Flagship mission* in Feb 2009 which will be pursued jointly with ESA and other international partners.**

- **This presentation highlights current status and developments over the last year**





NASA-ESA 2008 Outer Planet Flagship Studies Decision Process

Submitted 8/07

Down-selected 12/07

Titan Saturn System Mission

Europa Jupiter System Mission

Key Milestones

Initial Instrument Workshop……………June 3-5, 2008
Final Report due to HQ………..…………..Nov 3, 2008
Site Visit…………… ……………….…..Dec 9,11, 2008
Review complete………………………..Jan 15, 2009
Down-select ……………………………..Mid February, 2009

http://opfm.jpl.nasa.gov

Down-select 02/09

Titan Saturn System Mission
or
Europa Jupiter System Mission

Key Aspects

- International cooperation integral to both concepts
  - ESA is primary international partner
  - JAXA & ESA member-states may participate
- **JPL leads partnership with APL**, other NASA centers
- President's FY09 budget: funding begins in FY09

Initial Ground Rules – Feb 2008

- **NASA Life Cycle Costs <$2.1B in $FY07**
  - Includes reserves of 33% (minus Launch Vehicle)
- **Assume international contribution of $1B to a joint mission**
  - However, NASA must be able to fly complete mission for $2.1B
- **Launch dates in 2016-2017 with a preference for earlier dates**
  - Provide backup launch dates thru 2020

“Sweet Spot” Mission – June 2008

- **In June 2008, NASA changed its strategy**
  - the strict cost cap strategy with science as the only free variable was dropped since the $2.1B cost cap mission was not compelling
  - a new strategy to seek a “sweet spot” - optimum balance between science and cost was adopted to better respond to the 2003 NRC Decadal Survey Report on Solar System Exploration

- **The study teams were directed to identify a “sweet spot” mission consistent with this new strategy**

- **An assessment of science value vs cost was developed based on science goals set down in the NRC Decadal Survey**

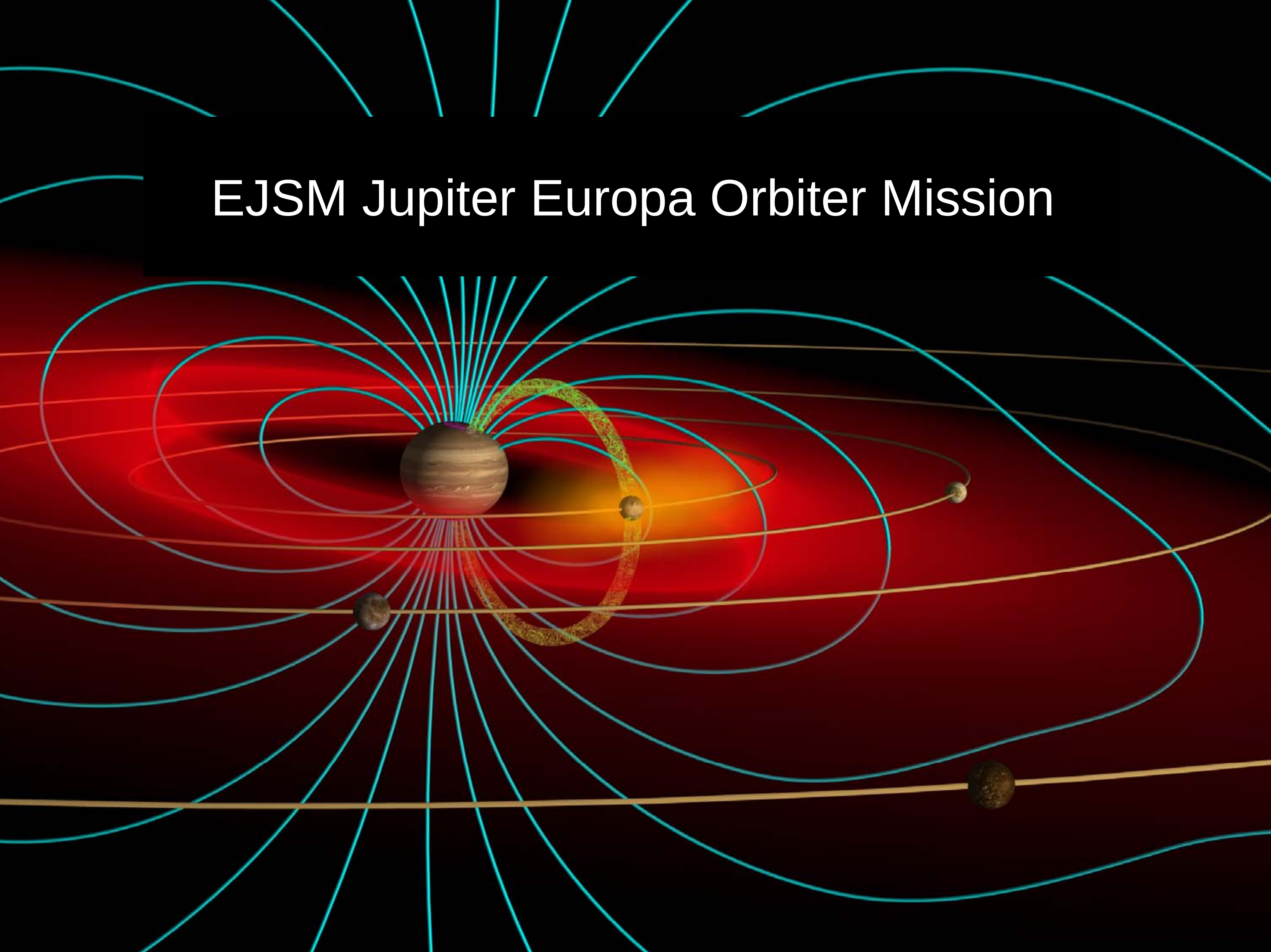
- **Following the Second Interim Briefing to NASA on June 20, the study teams were directed to**
  - Focus the remaining study efforts on the “Sweet Spot” Mission
  - Defer nominal launch date to **2020.** Evaluate launch date options in the range of **2018 to 2022** in order to align with ESA’s probable launch schedule

Cost summaries for Europa and Titan options

	Europa Jupiter System Mission		Titan Saturn System Mission	
	FY07 $B	RY $B	FY07 $B	RY $B
NASA Only	2.1	2.6	2.1	2.7
Core			2.2	2.8
Sweet Spot	2.5	3.0	2.3	3.0
Full Decadal	3.1	3.8	2.4	3.2

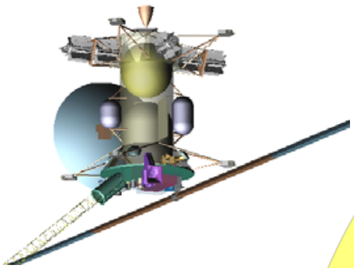
These costs are still under review and will be refined in the study report to be submitted on August 4

EJSM Jupiter Europa Orbiter Mission

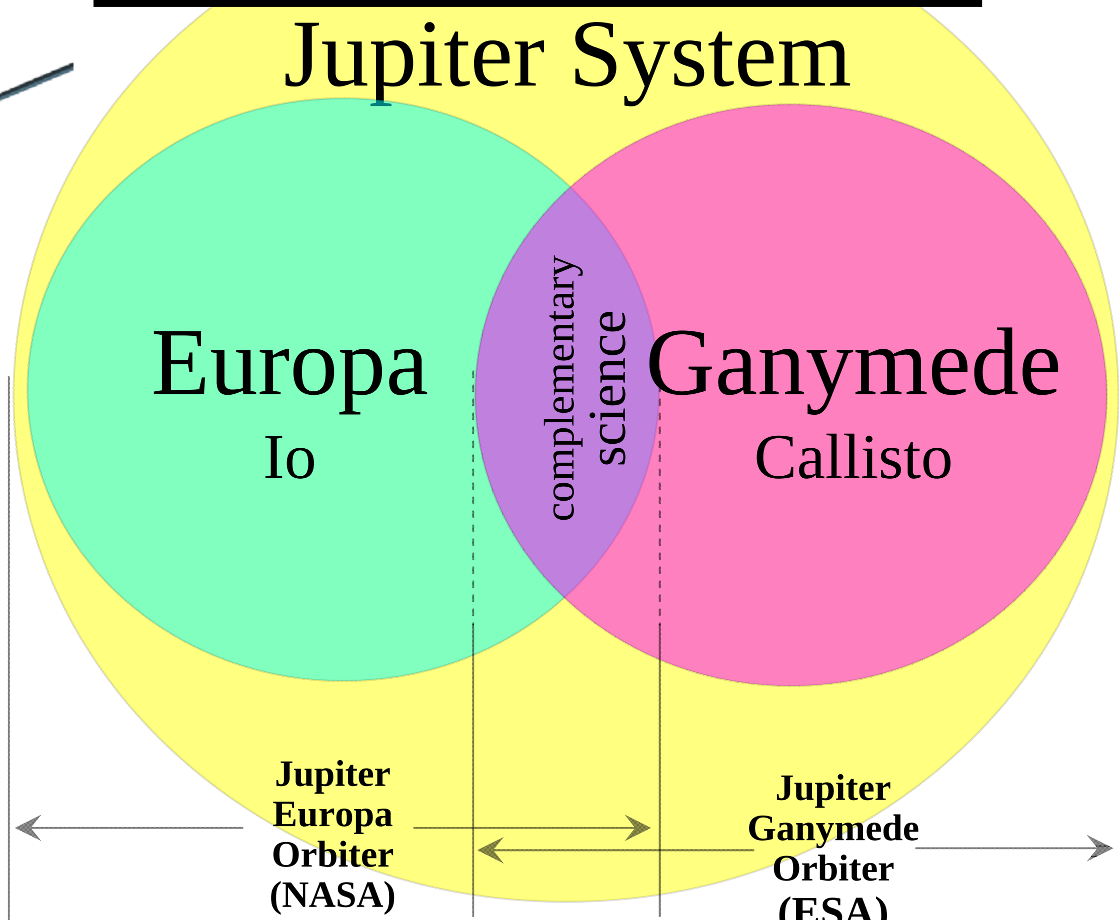


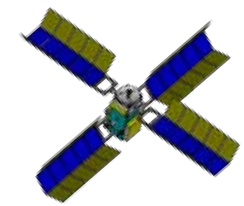
Europa Jupiter System Mission
Jupiter Europa Orbiter (JEO)

The Emergence of Habitable Worlds Around Gas Giants

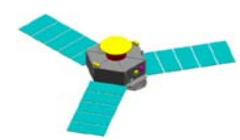


NASA Jupiter Europa Orbiter (JEO)





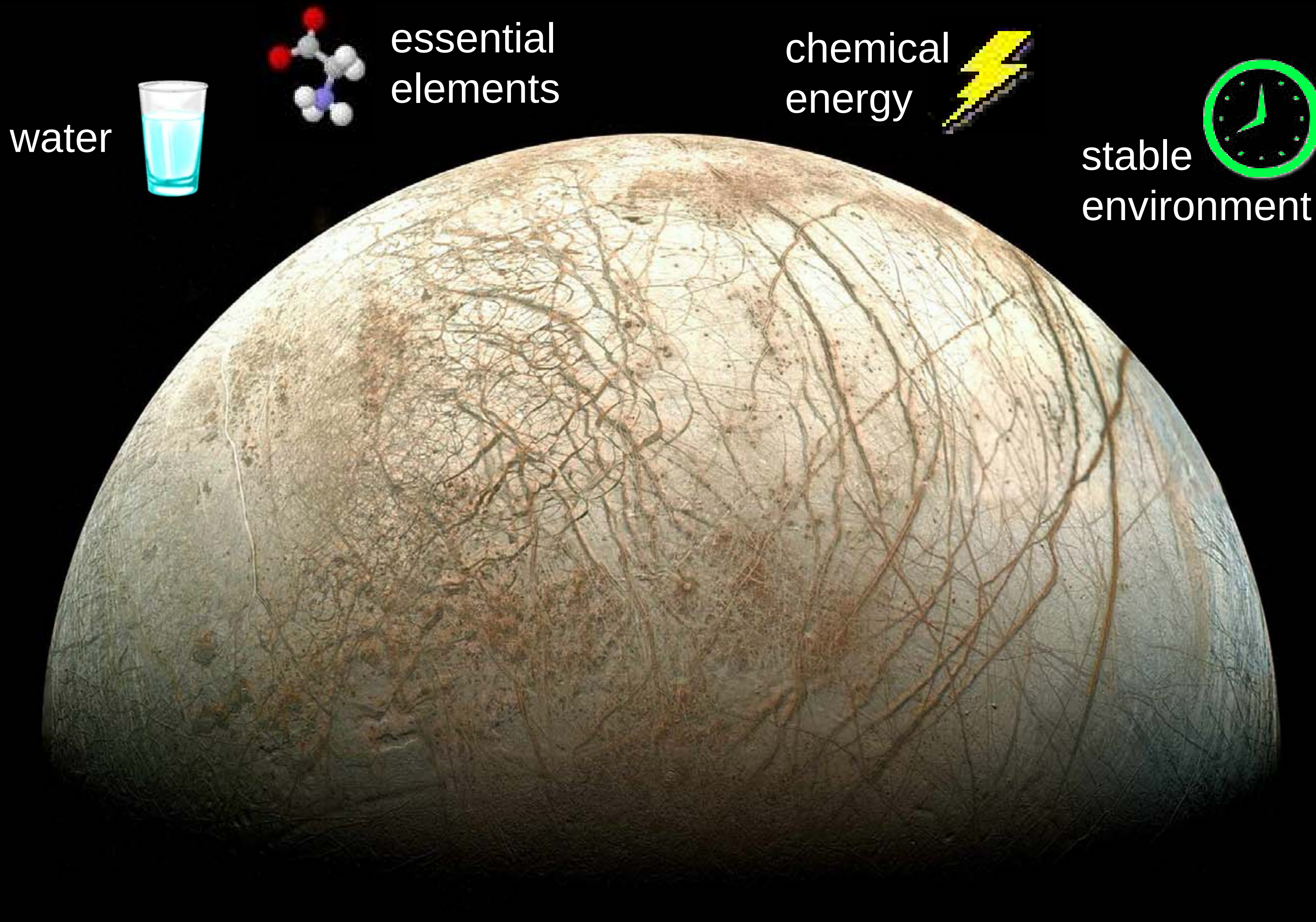
ESA Jupiter Ganymede Orbiter (JGO)



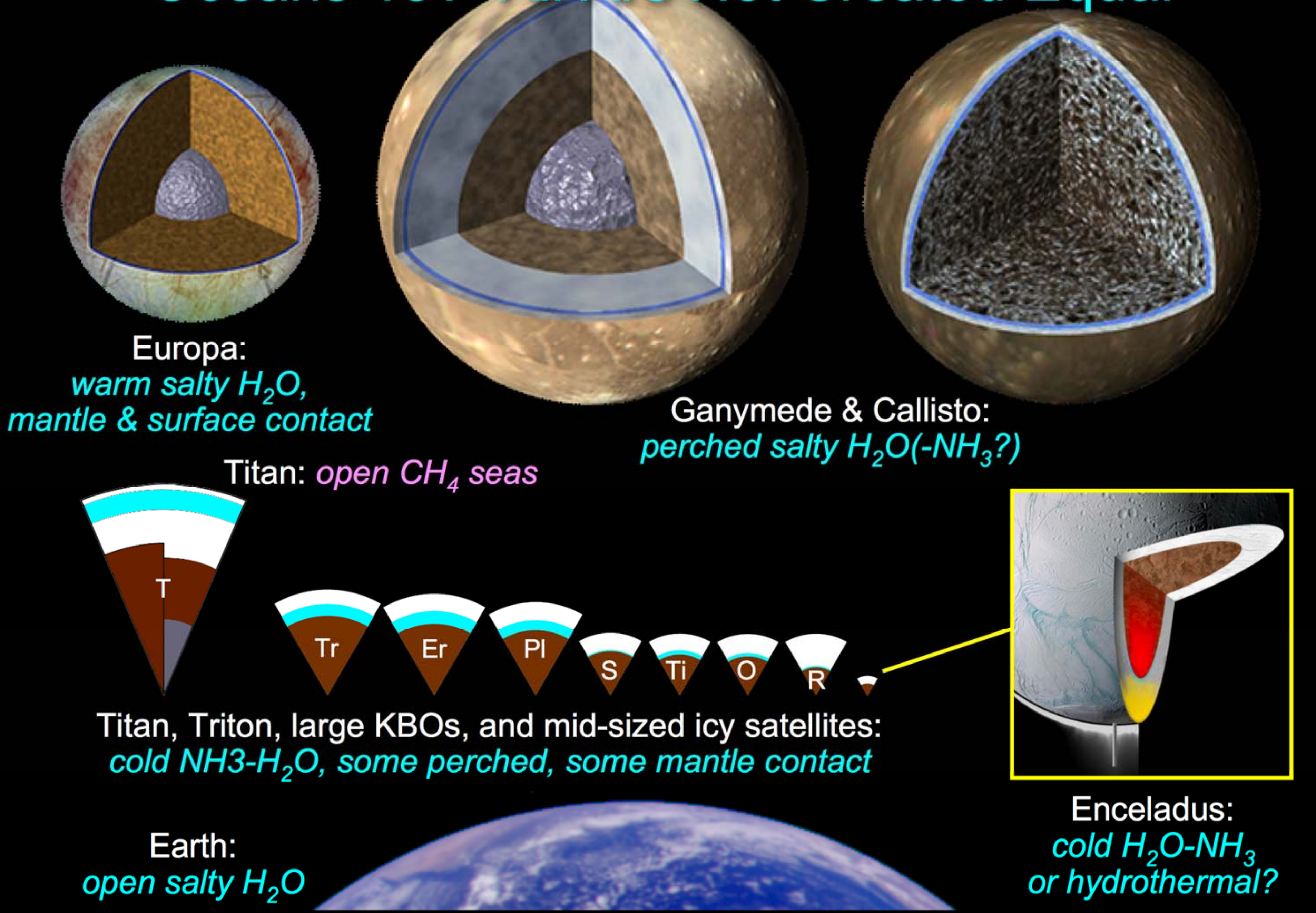
JAXA Jupiter Magnetospheric Orbiter (JMO)

JEO is designed to stand alone or operate synergistically with ESA JGO

Defining a “Habitable” Environment:
The Ingredients for Life

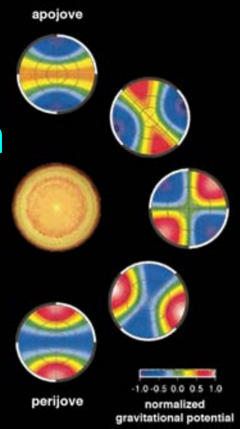


Oceans 13? All Are Not Created Equal



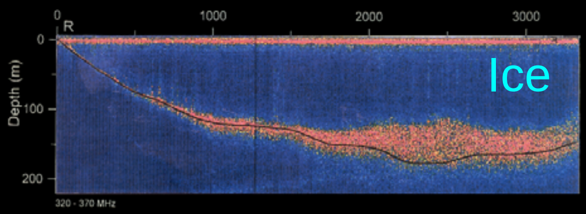
Goal: Explore Europa to Investigate Its Habitability

Ocean



A. Characterize the extent of the ocean and its relation to the deeper interior.

B. Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange.

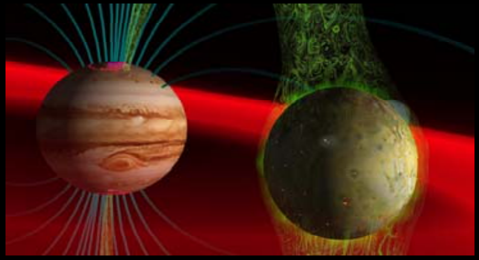


Chemistry

C. Determine global surface compositions and chemistry, especially as related to habitability.

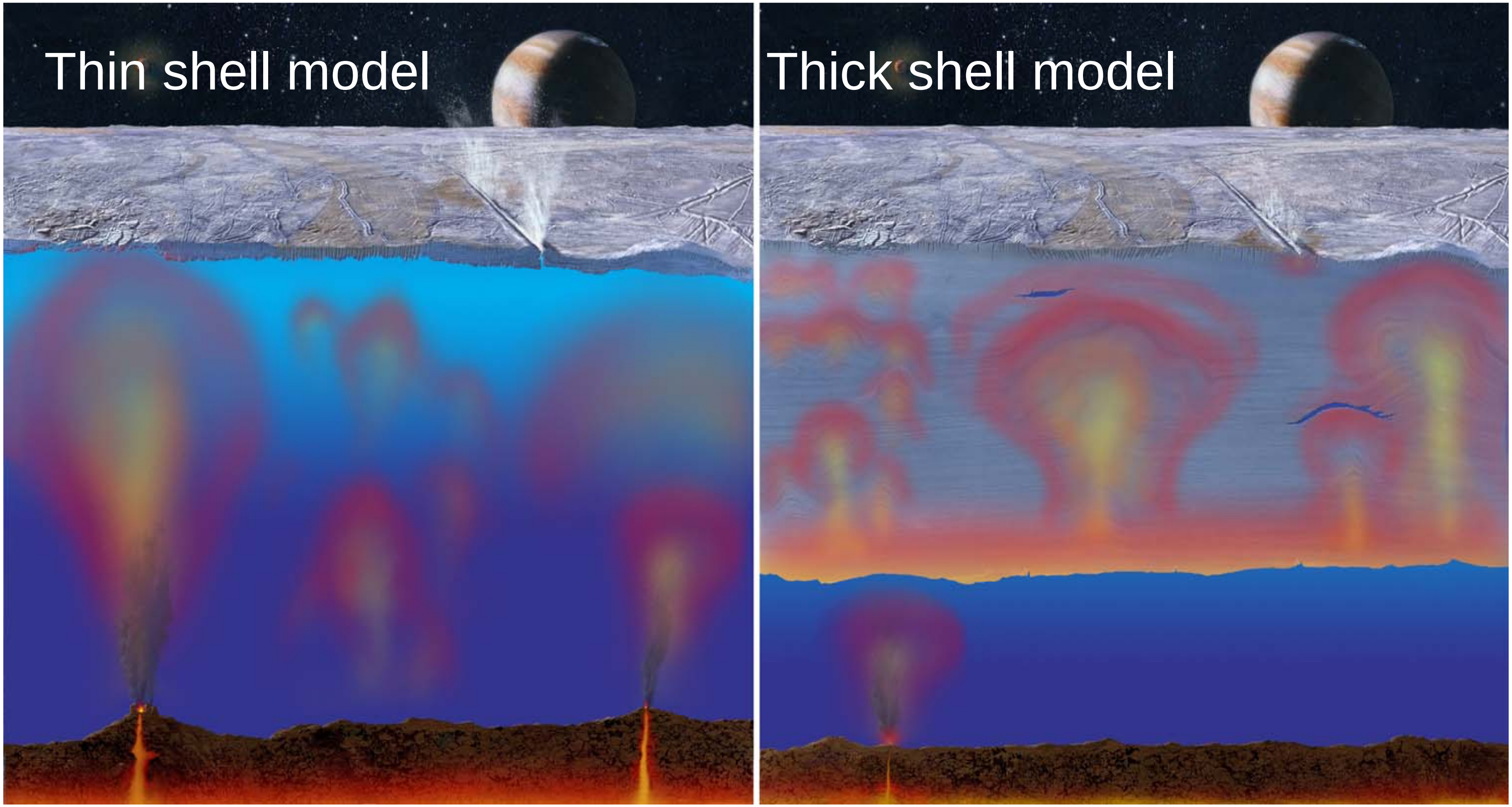
D. Understand the formation of surface features, including sites of recent or current activity, and identify and characterize candidate sites for future *in situ* exploration.

Jupiter system



E. Understand Europa in the context of the Jupiter system.

Example of Europa Hypothesis Testing: Thin vs. Thick Ice Shell



Data from multiple instruments combine to test fundamental hypotheses: gravity, altimetry, radar sounding, magnetometry, imaging, thermal

Rating JEO to the Decadal Survey's Steering Group Recommendations

DECADAL SURVEY STEERING GROUP "EUROPA GEOPHYSICAL EXPLORER" SCIENCE	Core JEO	Sweet Spot	Decadal JEO
Determine the presence or absence of an ocean.	5	5	5
Characterize the three-dimensional distribution of any subsurface liquid water and its overlying ice layer.	4	5	5
Understand the formation of surface features, including sites of recent or current activity, and identify candidate landing sites for future lander missions.	3	5	5
Characterize the surface composition, especially compounds of interest to prebiotic chemistry.	3	4	4
Map the distribution of important constituents on the surface.	3	5	5
Characterize the radiation environment in order to reduce the uncertainty for future missions, especially landers.	2	5	5

5	Definitely addresses full science.
4	May address full science.
3	Definitely addresses partial science.

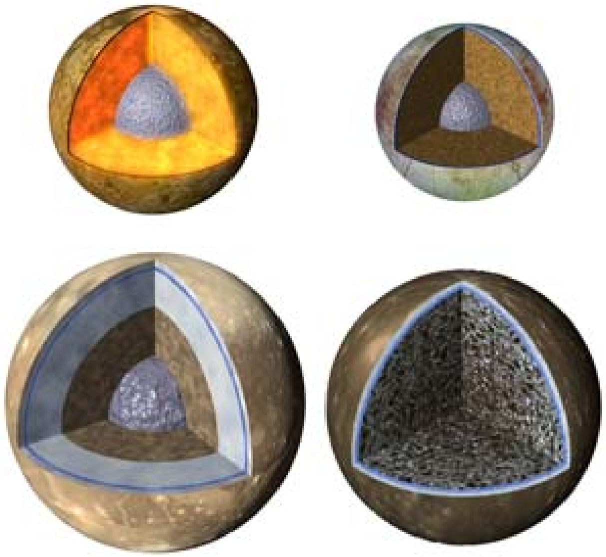
2	May address partial science.
1	Touches on science.
0	Does not address science.

Rating JEO to the Decadal Survey's Large Satellites Panel Recommendations

	Core JEO	Sweet Spot	Decadal JEO
Theme 1. Origin and Evolution of Satellite Systems			
1. How do conditions in the protoplanetary nebula influence the compositions, orbits, and sizes of the resulting satellites?	1	2	3
2. What affects differentiation, outgassing, and the formation of a thick atmosphere? (Why is Titan unique?)	2	3	3
3. To what extent are the surfaces of icy satellites coupled to their interiors (chemically and physically)?	4	5	5
4. How has the impactor population in the outer solar system evolved through time, and how is it different from the inner solar	3	5	5
5. What does the magnetic field of Ganymede tell us about its thermal evolution, and is Ganymede unique?	2	3	3
Theme 2. Origin and Evolution of Water-Rich Environments in Icy Satellites			
1. What is the chemical composition of the water-rich phase?	2	4	4
2. What is the distribution of internal water, in space and in time?	3	4	4
3. What combination of size, energy sources, composition, and history produce long-lived internal oceans?	3	4	4
4. Can and does life exist in the internal ocean of an icy satellite?	2	3	3
Theme 3. Exploring Organic-Rich Environments			
1. What is the nature of organics on large satellites?	2	3	4
4. How do atmospheric processes affect organic chemistry?	1	2	3
Theme 4. Understanding Dynamic Planetary Processes			
1. What are the active interior processes and their relations to tidal heating, heat flow, and global patterns of volcanism and tectonism?	3	4	4
2. What are the currently active endogenic geologic processes (volcanism, tectonism, diapirism) and what can we learn about such processes in general from these active worlds?	3	4	5
3. What are the complex processes and interactions on the surfaces and in volcanic or geyser-like plumes, atmospheres, exospheres, and magnetospheres?	2	4	5
Large Satellites Panel overall high-priority questions:			
1. How common are liquid-water layers within icy satellites?	2	4	4
2. How does tidal heating affect the evolution of worlds?	3	4	4

5	Definitely addresses full science.
4	May address full science.
3	Definitely addresses partial science.
2	May address partial science.
1	Touches on science.
0	Does not address science.

Recommendations and ratings relate to all outer planet satellites



Potentially Paradigm-Altering Science from JEO

The JEO "Sweet Spot" Mission would achieve ten historic firsts:

- **Confirmation and characterization of Europa's ocean**
- **Ability to characterize organic and other compounds on Europa at high spectral and spatial resolution**
- **Global mapping of Europa at resolution needed to identify full array of surface features**
- **Comprehensive search for current geological activity at Europa**
- **Topographic mapping of Europa's surface**
- **Characterization of the composition and dynamics of Europa's atmosphere and ionosphere**
- **Radar sounding of the icy shell of Europa, and those of the other Galilean satellites**
- **Systematic and detailed search for a future Europa lander site**
- **Direct sampling of Io's chemistry**
- **Integrated jovian system science in the context of Europa**

We know enough to ask the key questions, yet we anticipate being surprised by scientific discoveries!

2008 JEO Sweet Spot Mission Concept

- **Objectives: Jupiter System, Europa**
- **Launch Vehicle:** Atlas V 551
- **Power Source:** 5 MMRTG or ASRG
- **Mission Timeline:**
  - Launch: 2018 to 2022
  - Jovian system tour phase: ~24-33 months
    - 3-5 Io flybys
    - 8-10 Ganymede flybys
    - 4-6 Callisto flybys
  - Europa orbital phase: 9-12 months
  - Spacecraft final disposition: Europa surface Impact
- **5 Science Objectives**
  - 12 Instruments
  - Radio Science
- **Radiation Dose:** 2.9 Mrad (behind 100 mils Al)

Sweet Spot Analysis   Spacecraft & Technology

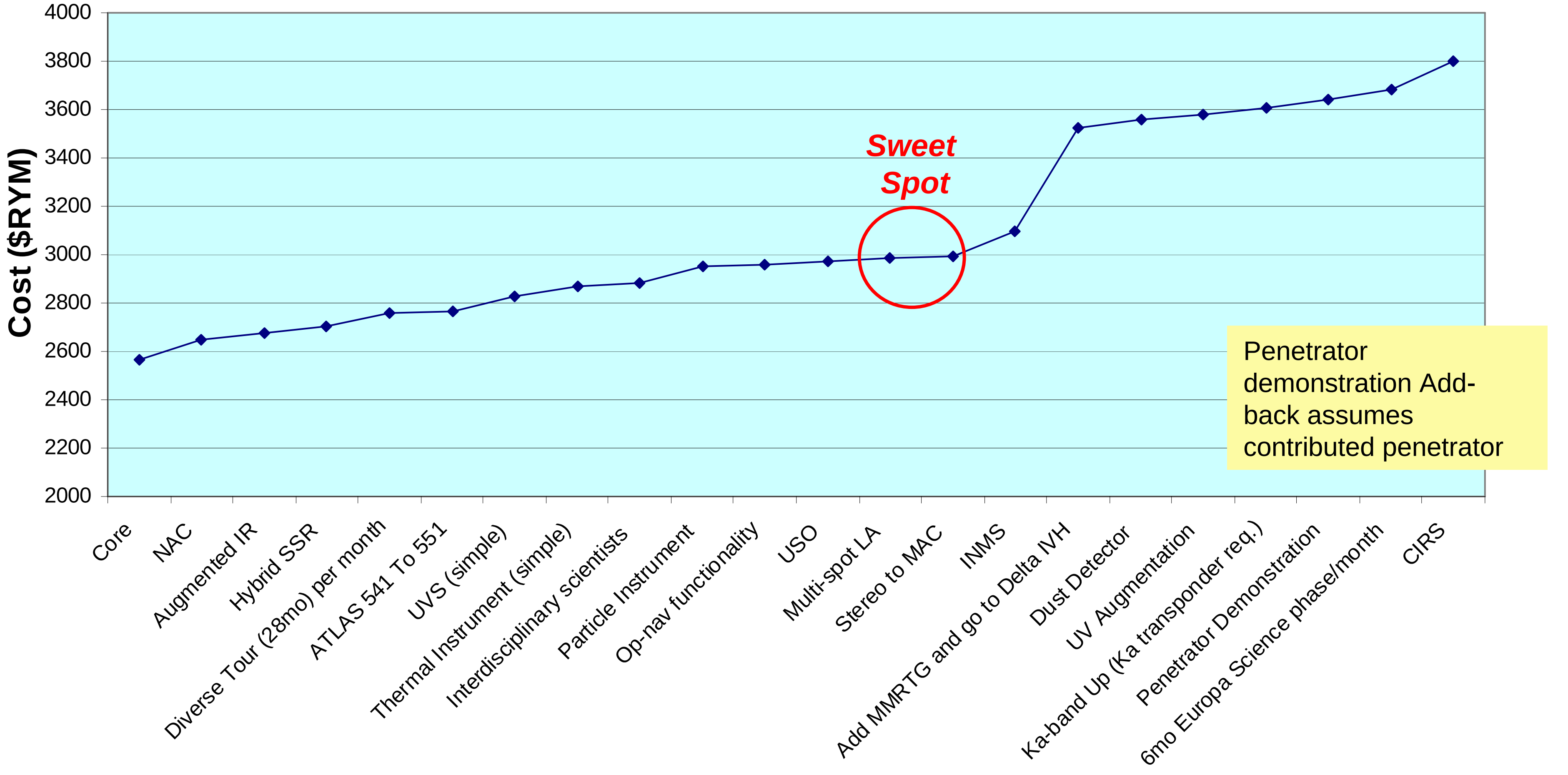
Plus Up Process

- JJSDT identified and prioritized instrument and mission capabilities
- Mass, power and data estimated to determine when additional MMRTG or LV capability was required
- Costs were obtained from estimated raw costs and obtaining fully integrated costs from Project cost estimate

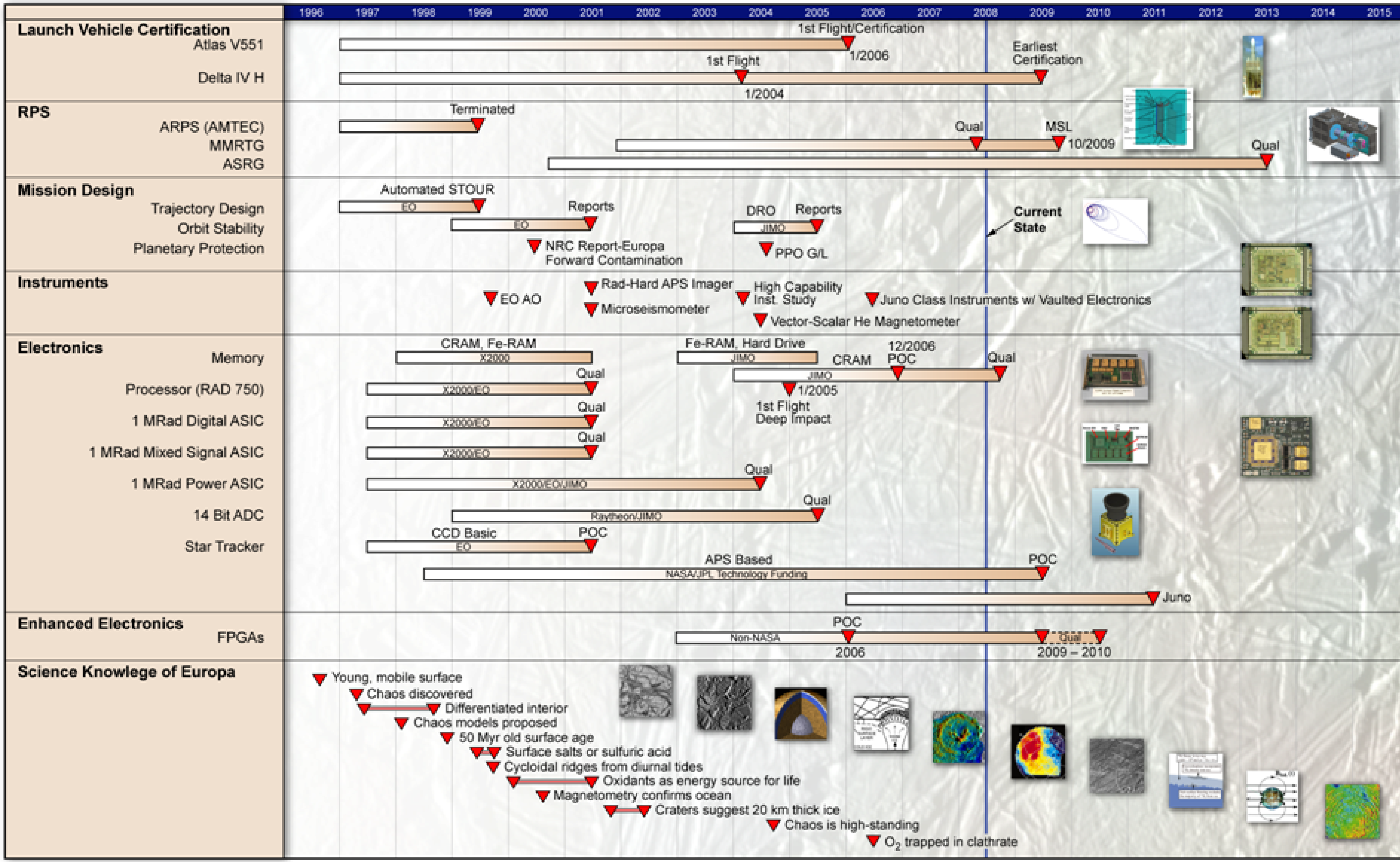
Priority	Add-backs	Science Benefit
	Core	
1	NAC	Detailed local geology; System Satellite, Ring & Jupiter Science
2	Augmented IR	Europa Surface Composition & System satellite Science
3	Hybrid SSR	System science--increased data volume return
4	Diverse Tour (28 mo)	Added satellite surface coverage; discovery follow-up
	ATLAS 541 to 551	
5	Simple UVS	Europa Surface Composition & System Science; Satellite Atmospheres
6	Simple Thermal Instrument	Europa & Satellite Thermal Anomalies; Space physics--sublimation and Sputtering
7	Interdisciplinary scientists	Multi-facetted/crosscutting science investigations
8	Particle Instrument	Space Physics--system interactions
9	Op-Nav functionality	Closer satellites flybys
10	USO	Atmospheric Science--Occultations
11	Multi-spot Laser Altimeter	Improved Lateral topographic resolution--quantitative morphology
12	Stereo to MAC	Improved Lateral topographic resolution--quantitative morphology
13	INMS	Composition of sputter material
	Add MMRTG and go to Delta IVH	
14	Dust Detector	Composition of sputter material
15	Augmented UV	Enhanced Europa Surface Composition studies & System Science
16	Ka-band Uplink	High fidelity Gravity data
17	Penetrator Demonstration	In situ assessment of organics
18	6 mo. Europa Science phase	Greater ability to follow-up on discoveries
19	CIRS	Jupiter Atmospheric Structure

Sweet Spot Determination

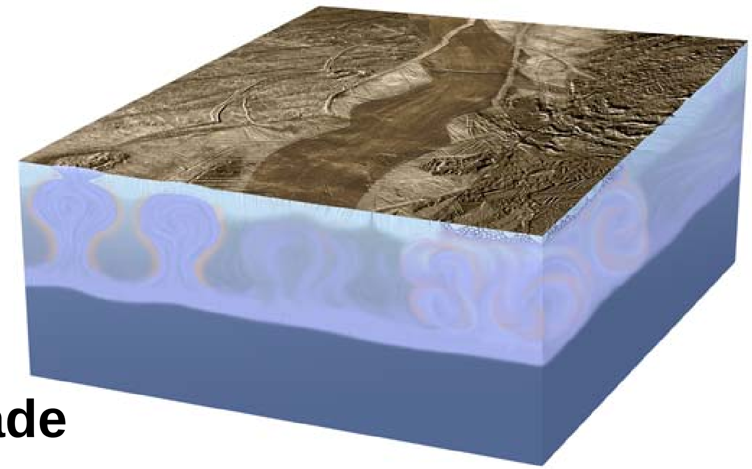
- **Stay on Atlas launch vehicle and within capability of 5 MMRTGs including 33% margin**
- **Increase resiliency to future changes in direction**



A Decade of Investment Has Reduced JEO Risk



EJSM-JEO Summary

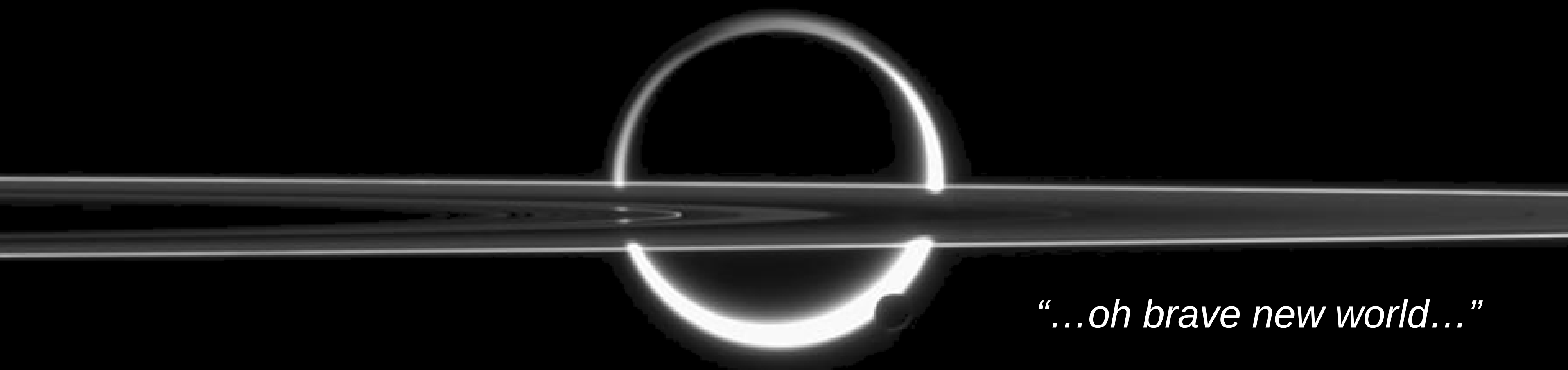


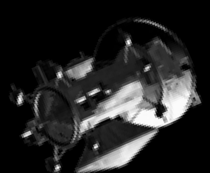
- **Science questions are mature:**
  - Clearly testable hypotheses have been honed
- **JEO Achieves Decadal Survey Recommendations:**
  - Top Recommendation for Flagship in 2003-2013
  - Reaffirmed by NRC's CASSE Report (2007)
- **Significant technical advances over decade**
  - Launch vehicle capability
  - Power source technology
  - Trajectory tools
  - Radiation hardened components
- **NASA-only mission is highly capable**
  - Sweet spot mission allows optimization of science, cost and risk
  - Synergy with ESA mission enhances science return
  - Programmatic flexibility allows mission launch independence

We know enough to ask the key questions,
yet we anticipate being surprised by discoveries!

TSSM

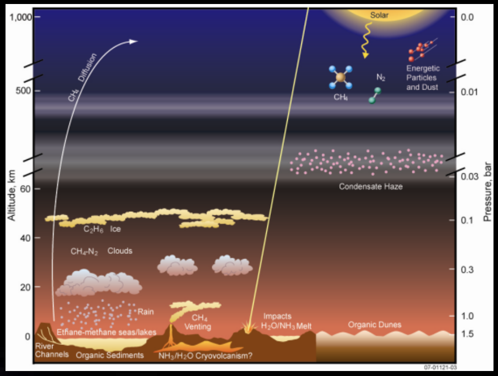
Titan Saturn System Mission





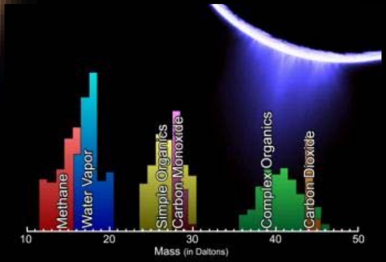
2008 Study Objectives

- *Dedicated Titan orbiter with ESA provided in situ elements*



- *Enceladus science and Saturn magnetospheric interaction with Titan*
- *Advancement in understanding Titan system well beyond the high bar set by Cassini-Huygens*

- *Balance science, cost and risk in achieving "Decadal " Science*



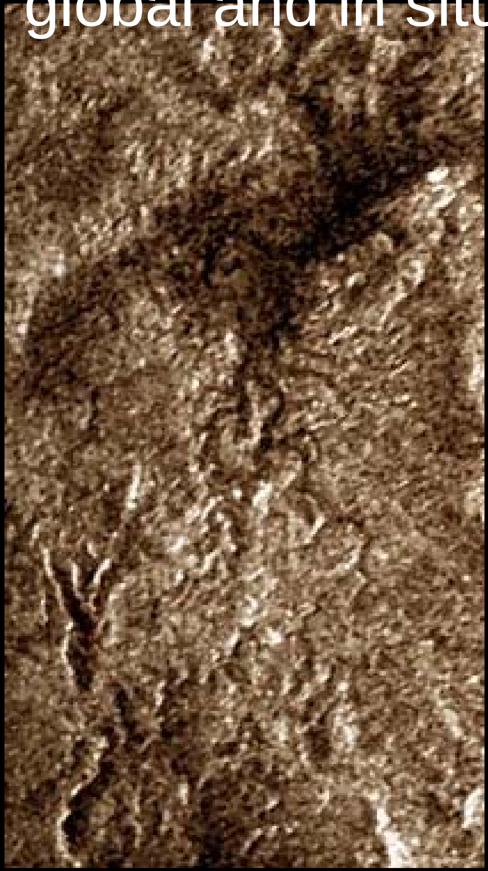
Titan - What We Have Learned

- **Planet-sized moon with an atmosphere: the world in the solar system that most closely resembles Earth in terms of the balance of geological and meteorological forces.**
- **Active hydrologic cycle, with methane replacing water, and surface lakes, seas, and rivers of methane and its sister molecule ethane.**
- **Internal ocean of water and external hydrocarbon lakes and seas, providing the potential for two distinct kinds of environments for different forms of life (those using water as the universal solvent and those using ethane/methane).**
- **Organic chemistry ongoing over billions of years over a surface larger than that of the planet Mercury provides what may be the solar system's best natural laboratory for the steps leading to the origin of life as we know it.**
- **Titan's neighbor, Enceladus, has strong evidence for liquid salty water in its interior in contact with rock. Plumes contain water ice and organic molecules.**

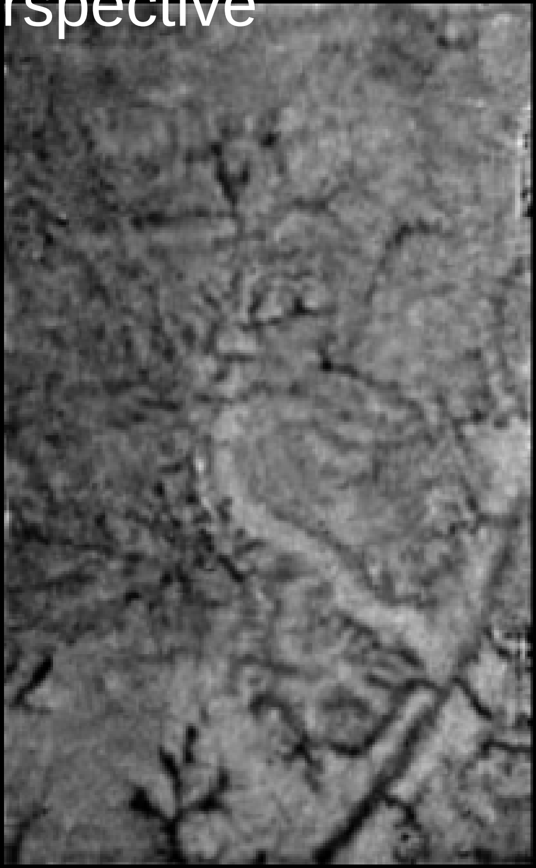
Besides Earth, Titan is the only body in our solar system with an organics laden atmosphere, hydrocarbon lakes and sub-surface ocean.

Cassini-Huygens View of Titan

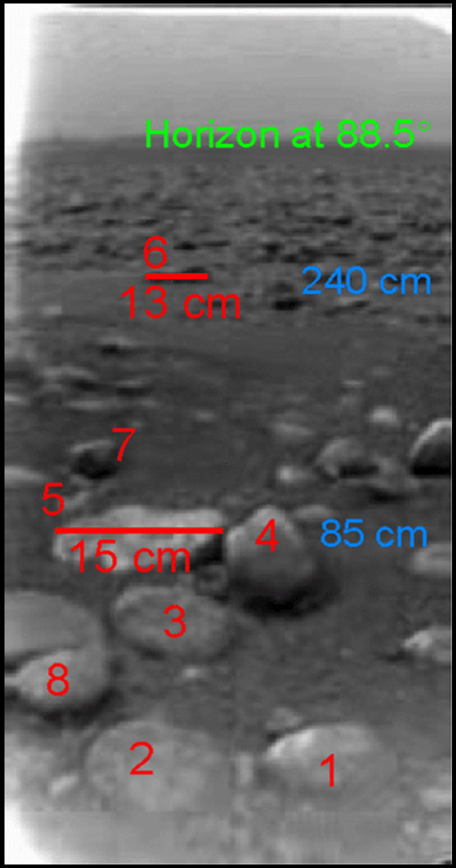
A mystery unveiled but not solved – TSSM will achieve global and in situ perspective



500 meter resolution
Broad fluvial channels
(Cassini Radar)



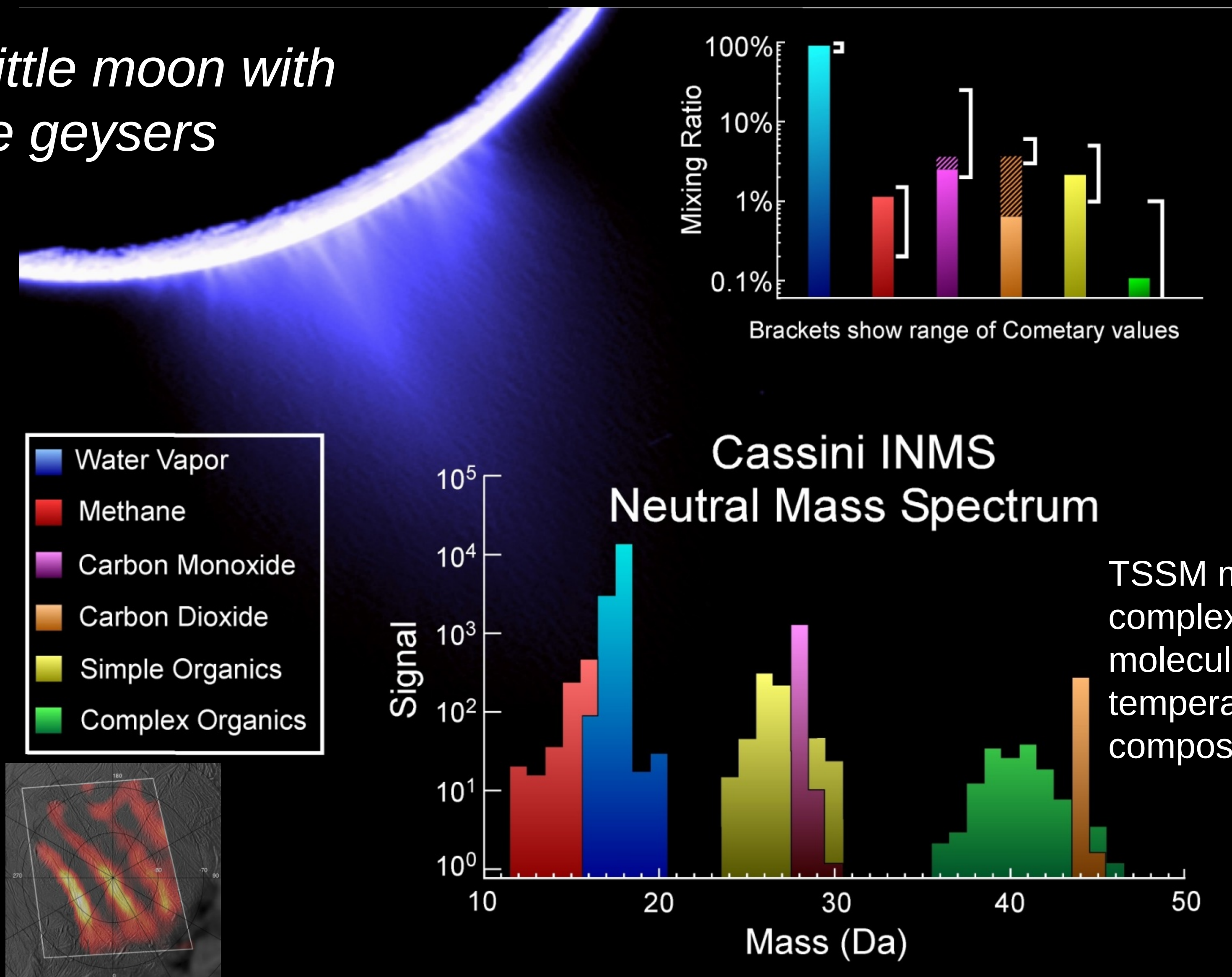
50 meter resolution
Small-scale sapping
(Huygens DISR)



5 cm resolution
Fluvial outflow
(Huygens DISR)

Enceladus from Cassini Perspective

The little moon with active geysers

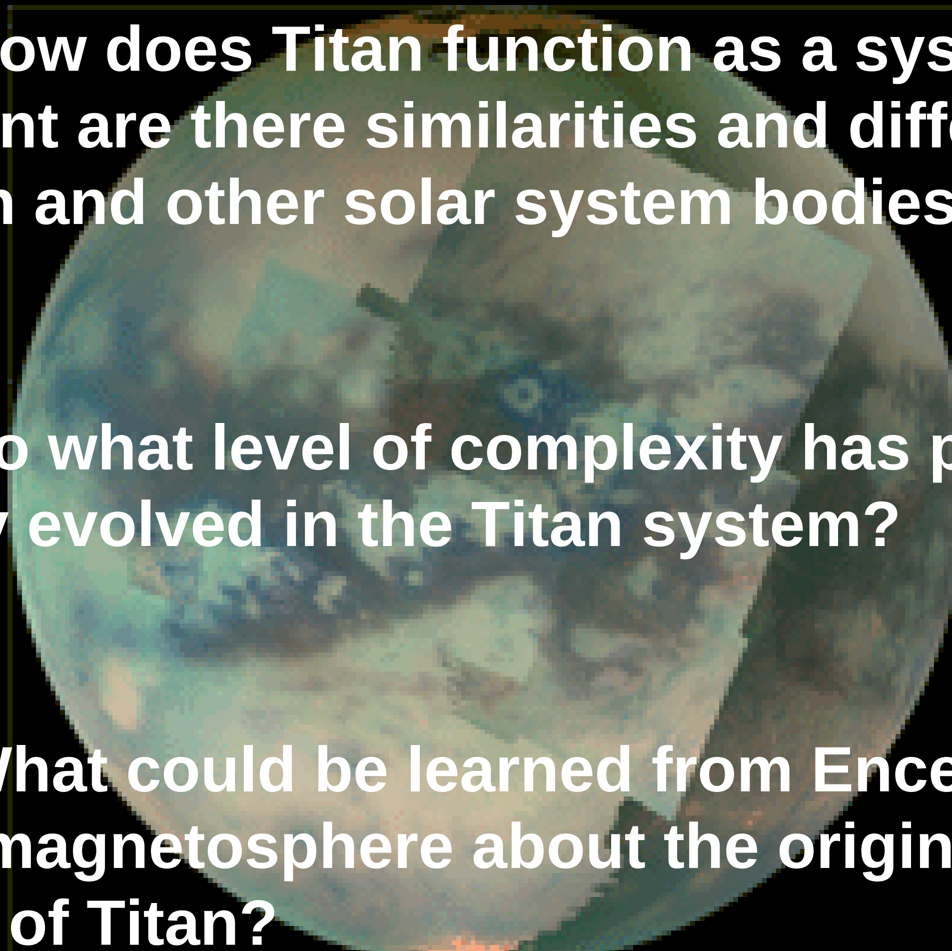


TSSM measure complex molecules, temperature and composition

Tiger stripes are >100 K hotter than background

What We Seek to Know

TSSM Science Goals



- **Goal A: How does Titan function as a system; to what extent are there similarities and differences with Earth and other solar system bodies?**
- **Goal B: To what level of complexity has prebiotic chemistry evolved in the Titan system?**
- **Goal C: What could be learned from Enceladus and Saturn's magnetosphere about the origin and evolution of Titan?**

Decadal Survey Satellite Objectives

DECADAL SURVEY STEERING GROUP p. 137-139

LARGE SATELLITES PANEL THEMES AND KEY QUESTIONS:

	Orbiter only	Orbiter + lander	Orbiter + lander + ball-oon
Theme 1. Origin and Evolution of Satellite Systems			
1. How do conditions in the protoplanetary nebula influence the compositions, orbits, and sizes of the resulting satellites?	3	4	4
2. What affects differentiation, outgassing, and the formation of a thick atmosphere? (Why is Titan unique?)	4	5	5
3. To what extent are the surfaces of icy satellites coupled to their interiors (chemically and physically)?	3	4	4
4. How has the impactor population in the outer solar system evolved through time, and how is it different from the inner solar system?	4	4	4
5. What does the magnetic field of Genymede tell us about its thermal evolution, and do other large satellites have intrinsic magnetic fields?	1	3	4
Theme 2. Origin and Evolution of Water-rich environments			
1. What is the chemical composition of the water-rich phase?	5	5	5
2. What is the distribution of internal water, in space and in time?	4	4	4
3. What combination of size, energy sources, composition, and history produce long-lived internal oceans?	5	5	5
4. Can and does life exist in the internal ocean of an icy satellite?	1	2	3
Theme 3. Exploring organic-rich environments			
1. What are the chemistry, distribution, and cycling of organic materials on Titan?	4	5	5
2. Is Titan internally active, producing water-rich environments with potential habitability?	4	5	5
3. What are the current state and history of Titan's surface?	5	5	5
4. What drives the meteorology of Titan?	2	3	4
5. Has there been climate change on Titan?	4	5	5
6. Could Titan support life forms that do not require liquid water?	1	2	3
Theme 4. Understanding dynamic planetary processes			
1. What are the active interior processes and their relations to tidal heating, heat flow, and global patterns of volcanism and tectonism?	4	4	5
2. What are the currently active endogenic geologic processes (volcanism, tectonism, diapirism) and what can we learn about such processes in general from these active worlds?	4	4	5
3. What are the complex processes and interactions on the surfaces and in volcanic or geyser-like plumes, atmospheres, exospheres, and magnetospheres?	5	5	5
	3.5	3.9	4.4

5	Definitely addresses full science investigation
4	May address full science investigation
3	Definitely addresses partial science investigation
2	May address partial science investigation
1	Touches on science investigation
0	Does not address science investigation

Decadal Survey Satellite Objectives

LARGE SATELLITES PANEL THEMES AND KEY QUESTIONS:

Theme 1. Origin and Evolution of Satellite Systems	Orbiter only	Orbiter + lander	Orbiter + lander + ball-oon
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3. To what extent are the surfaces of icy satellites coupled to their interiors (chemically and physically)?	3	4	4
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Theme 2. Origin and Evolution of Water-rich environments	Orbiter only	Orbiter + lander	Orbiter + lander + ball-oon
1. What is the chemical composition of the water-rich phase?	5	5	5
2. What is the distribution of internal water, in space and in time?	4	4	4
3. What combination of size, energy sources, composition, and history produce long-lived internal oceans?	5	5	5
4. Can and does life exist in the internal ocean of an icy satellite?	1	2	3

Decadal Survey Satellite Objectives

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6. Could Titan support life forms that do not require liquid water?	1	2	3
Theme 4. Understanding dynamic planetary processes			
1. What are the active interior processes and their relations to tidal heating, heat flow, and global patterns of volcanism and tectonism?	4	4	5
2. What are the currently active endogenic geologic processes (volcanism, tectonism, diapirism) and what can we learn about such processes in general from these active worlds?	4	4	5
3. What are the complex processes and interactions on the surfaces and in volcanic or geyser-like plumes, atmospheres, exospheres, and magnetospheres?	5	5	5
	3.5	3.9	4.4

Expected "Firsts" from TSSM

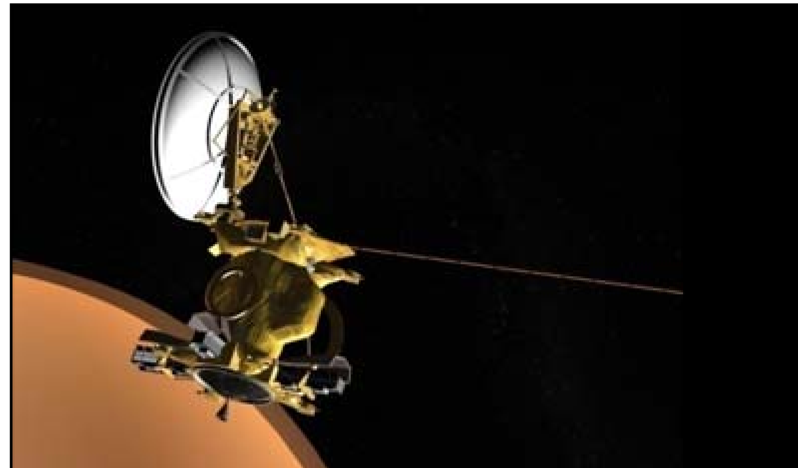
- Global mapping of Titan at Mars-Odyssey resolution
- Global topographic information
- Chemical information on heavy polymers in atmosphere
- Identification of complex organics on surface
- High repeat rate sensing for clouds and surface activity
- High spatial resolution spectral mapping of surface
- Subsurface characterization
- Chemical analysis of a northern lake and atmosphere
- Mapping of complex polymers and detailed temperature and composition at Enceladus tiger stripes

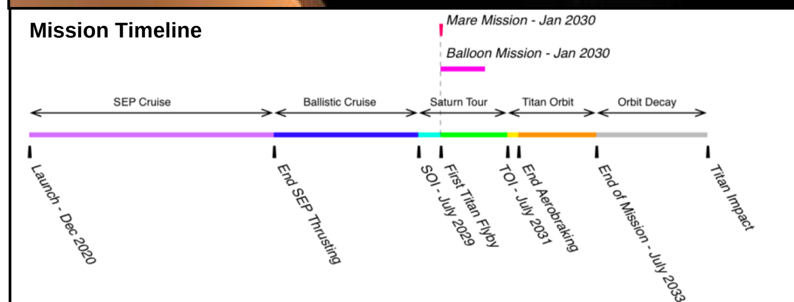
The Titan Saturn System Mission would provide a giant leap in understanding beyond Cassini-Huygens

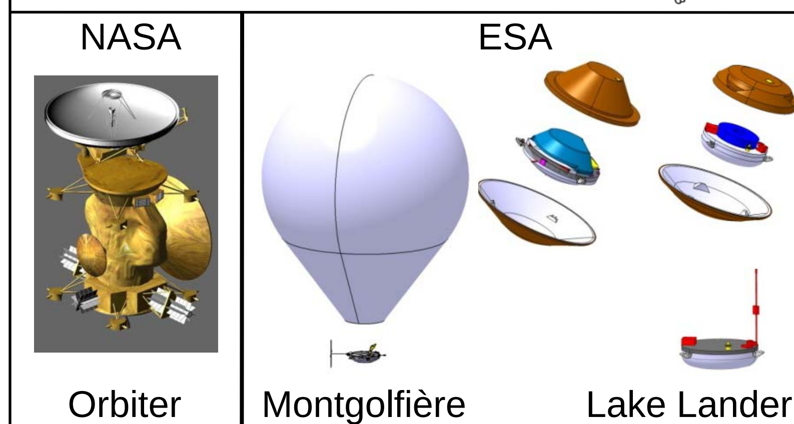
TSSM Baseline Mission

- **Titan Orbit, Saturn system, Enceladus**
- **NASA Orbiter with ESA in situ elements**
  - Chemical orbiter + Solar Electric Propulsion (SEP) stage
  - Lake Lander and Montgolfière Balloon
  - NASA provided Launch Vehicle and RPS
- **Mission Design**
  - 2020 Earth Gravity Assist SEP trajectory
  - 8.8 yr to Saturn arrival
  - SEP stage released 5.8 yr after launch
  - Balloon released on 1st Titan flyby, Lander on subsequent flyby
  - ~4 year prime mission: 2 year Saturn tour, 2 mo Titan aerosampling; 18 mo Titan orbit
- **Orbiter payload; 6 Inst. + Radio Science**

-Optimizes science, cost and risk
-Leverages NASA-ESA collaboration

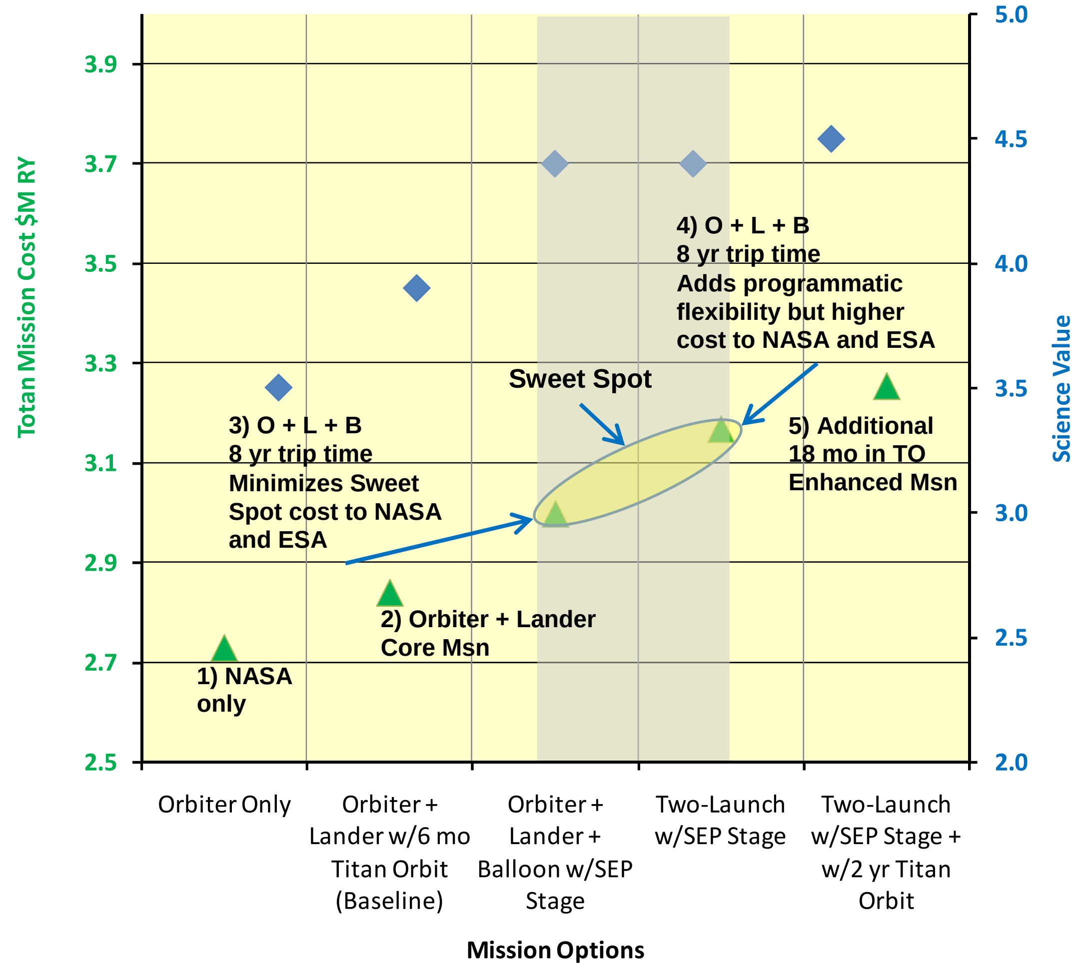






Sweet Spot

- Prioritization driven by decadal science
- Includes ESA full complement in situ payload
- In situ elements add considerable science value at limited accommodation cost to NASA
- Sweet Spot and enhanced decadal for NASA-only mission not shown in these charts



An orbiting mission that accommodates both an ESA lander and Montgolfiere balloon, while balancing cost, risk and science has an estimated cost ~$3.2 ($2.4B FY07)

International Mission Concept

- **NASA Titan Orbiter**
  - Would be launched in 2016-2017
  - Radioisotope powered
  - Would reach Saturn in ten years, spend one and a half to two years in Saturn orbit with 4 Enceladus and 15 Titan flybys before entering Titan orbit
  - Would conduct dedicated investigation of Titan and provide in situ accommodation

- **ESA In Situ Elements (Lander, Montgolfiere Balloon)**
  - Would be launched in 2016-2018 (depends on ESA launch availability)
  - Radioisotope Powered; RPS and launcher would be provided by NASA
  - Would reach Titan in ten years and spend one year at Titan in the lower atmosphere and on the surface -- potential for extended mission
  - Would conduct an intensive in situ investigation of Titan’s lower atmosphere, surface and interior

- **Single Launch of orbiter and lander on Atlas V is Core - Other architectures enable full suite of in situ elements but exceed study cost cap (e.g., SEP, Two Launch)**

ESA Provided *In situ* elements

- **Montgolfiere Balloon**
  - Release 6 months prior to arrival; <6km/s
  - Near equatorial to mid latitude location
  - Relay to orbiter and Direct to Earth (DTE) in Saturn tour; relay after TOI
  - Floats at 10km (+2 -8 km) altitude
  - Circumnavigates the globe
  - Lower atmosphere and surface science
  - > 6 months earth year life science reqmt

"Around Titan in 80 Days", Tokano

- **Capable Lander**
  - Would land in lake or dry lake bed at northern latitudes, or mid latitude
  - Very similar entry conditions to balloon
  - Similar relay options to balloon
  - Surface, hydrology and interior science
  - >1 earth month (2 Titan days) life for dry landing
    - >1 hours lake landing, battery power

ESA CDF efforts underway to define in situ elements

Summary

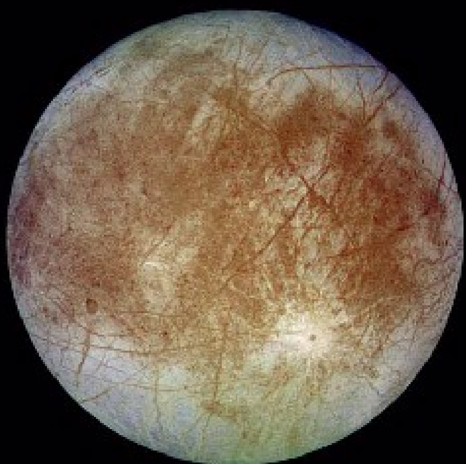
- **A mission to study Titan in depth is a high priority for exploration, as stated by the <u>2003</u> NRC Decadal Survey large satellites panel**

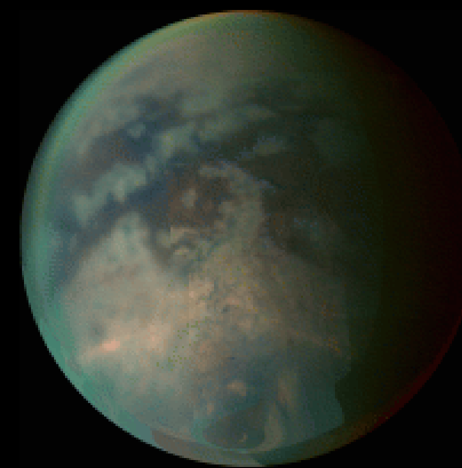
- **Since the Decadal Survey, Cassini-Huygens discoveries have further revolutionized our understanding of Titan and its potential for harboring the "ingredients" necessary for life. With these recent discoveries, the high priority of Titan is reinforced and a mission can now be planned.**

- **TSSM builds upon the following positive elements**
  - Dedicated remote sensing and extensive in situ investigations which Cassini cannot do
  - Major advance beyond Cassini-Huygens in accomplishing Decadal objectives
  - ESA success in landing Huygens on Titan, NASA success with Saturn orbiter & probe delivery
  - NASA-ESA collaboration: leverages resources, distributes risk, ensures technical readiness
  - Programmatic flexibility due to frequent launch opportunities

- **Launch in 2018-2022 ensures Titan arrival prior to winter solstice providing seasonal science complementary to Voyager & Cassini-Huygens including extended missions.**

We now know the important science questions and TSSM will answer them





Summary

Getting to Europa and Titan

- **Numerous opportunities for getting to Europa and Titan using inner planet gravity assist trajectories have been identified with no pronounced secular trends from 2016-2022**

- **Opportunities exist in all years in this time frame although more limited and/or less desirable opportunities exist in 2019 and (for Europa) in 2022**

- **Solar electric propulsion (SEP) can enable more mass and less trip time for the Titan Saturn System Mission**

Getting to Europa and Titan is not significantly constrained by launch date in the 2016 to 2022 time frame

NASA-ESA Interdependencies

- **Credible and scientifically exciting *Jupiter Europa Orbiter (JEO)* and *Saturn Titan Orbiter (STO)* missions have been defined**
  - They can be executed as **NASA-only** missions if ESA participation does not materialize
- ***JEO* and the *Jupiter Ganymede Orbiter (JGO)* are planned for launch on separate NASA and ESA LVs**
  - Later launch of JGO will only impact the subset of science that requires **simultaneous** observations in the Jupiter system
- **The *ESA Titan In Situ Elements* (lander and balloon) are delivered to Titan by STO.**
  - NASA also provides an RPS power system for the balloon

Cost Estimates

- **Preliminary cost estimates for the NASA elements of the baseline OPFM missions were presented at the 2nd Interim Review on June 20, 2006**
  - Europa Jupiter System Mission ($2.5B in $FY07, $3.0B in $RY)
  - Titan Saturn System Mission ($2.3B in $FY07, $3.0B in $RY)

- **These cost will be refined and updated for the 2020 launch opportunity in the study report completed on November 3, 2008**

- **The costs will be reviewed as part of NASA's Technical Management and Cost review to be carried out in the six week period following completion of the report**

Outer Planet Flagship Mission - Summary

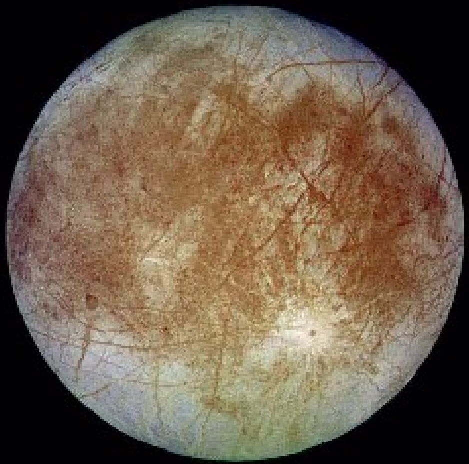
- **The NRC Decadal Survey Satellite panel determined in 2003 that**
  - *"Europa and Titan stand out as the highest priority targets among the satellites of the outer solar system. Together they address all the major themes and scientific questions that have been identified for future satellite exploration"*

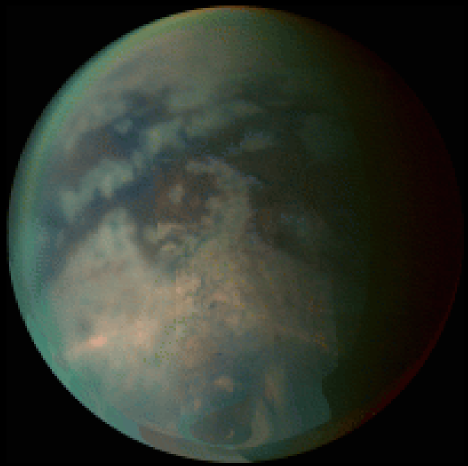
- **Excellent missions to both Europa and Titan are viable in the next decade. The readiness of each mission to move forward will be assessed by a NASA Review Panel in December 2008**

- **Outer planet exploration continues to be a field of unquestioned U.S. leadership because of our capabilities for coping with the severe environments & unique challenges of outer solar system exploration**

- **Participation of ESA and other international partners in the missions to the Jupiter and Saturn systems would enrich the scientific return**

- **From the extensive base of studies conducted so far, the study teams have developed a comprehensive grasp of the key scientific and technical issues for the further exploration of both Europa and Titan, positioning the agency to move forward at the earliest opportunity**

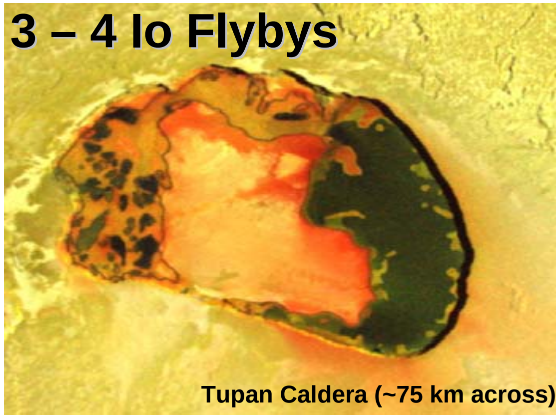


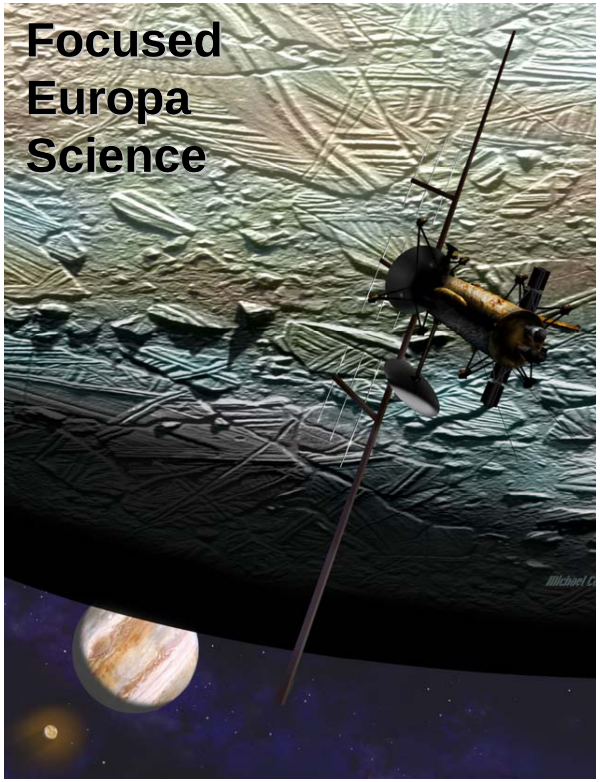


Backup

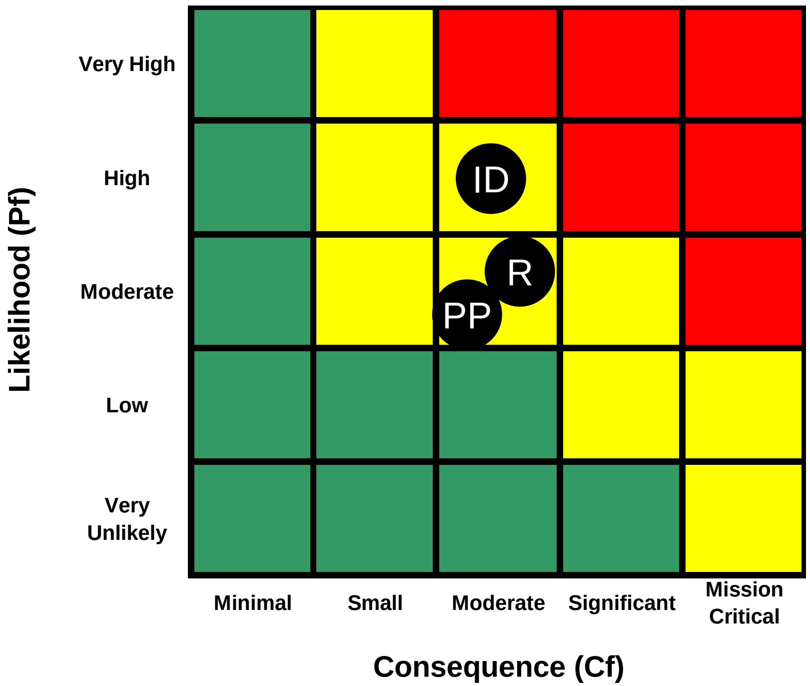
2008 JEO Core Mission Concept

- **Objectives: Jupiter System, Europa**
- **Launch Vehicle:** Atlas V 541
- **Power Source:** 5 MMRTG (530 W EOM)
- **Mission Timeline:**
  - Launch: 8/2016 (VEGA)
    - Many options available in later years
  - Jupiter arrival: 9/2021
  - Jovian system tour phase: ~21-28 months
    - 3-4 Io flybys
    - 8-10 Ganymede flybys
    - 4-6 Callisto flybys
  - Europa orbital phase: 105 days
    - Expected lifetime up to a year
  - Spacecraft final disposition: Europa surface Impact
- **5 Science Investigations**
  - 6 Instruments
  - Radio Science
  - 68 kg, 101 W





JEO Risk Analysis



Risk Area	Components	Mitigation
Radiation (R)	a) Dose rate effects b) Sensor impacts (SNR) c) FPGA qualification d) Non-Volatile Memory capability e) Internal Electrostatic Discharge f) Design techniques	a) Quantify dose rate effects b) Replace FPGAs with ASICs *c) Component radiation testing* *d) Document and disseminate design techniques and guidelines* e) Early subject matter expert (SME) engagement
Planetary Protection (PP)	a) Sensor sterilization b) Design techniques	*a) Document design techniques and guidelines* b) Early SME engagement
Instrument Development (ID)	a) Information availability b) Potential provider experience c) Development schedule	*a) Document design techniques and guidelines* *b) Instrument provider workshops - early SME engagement* c) Early and streamlined AO with confirmation review

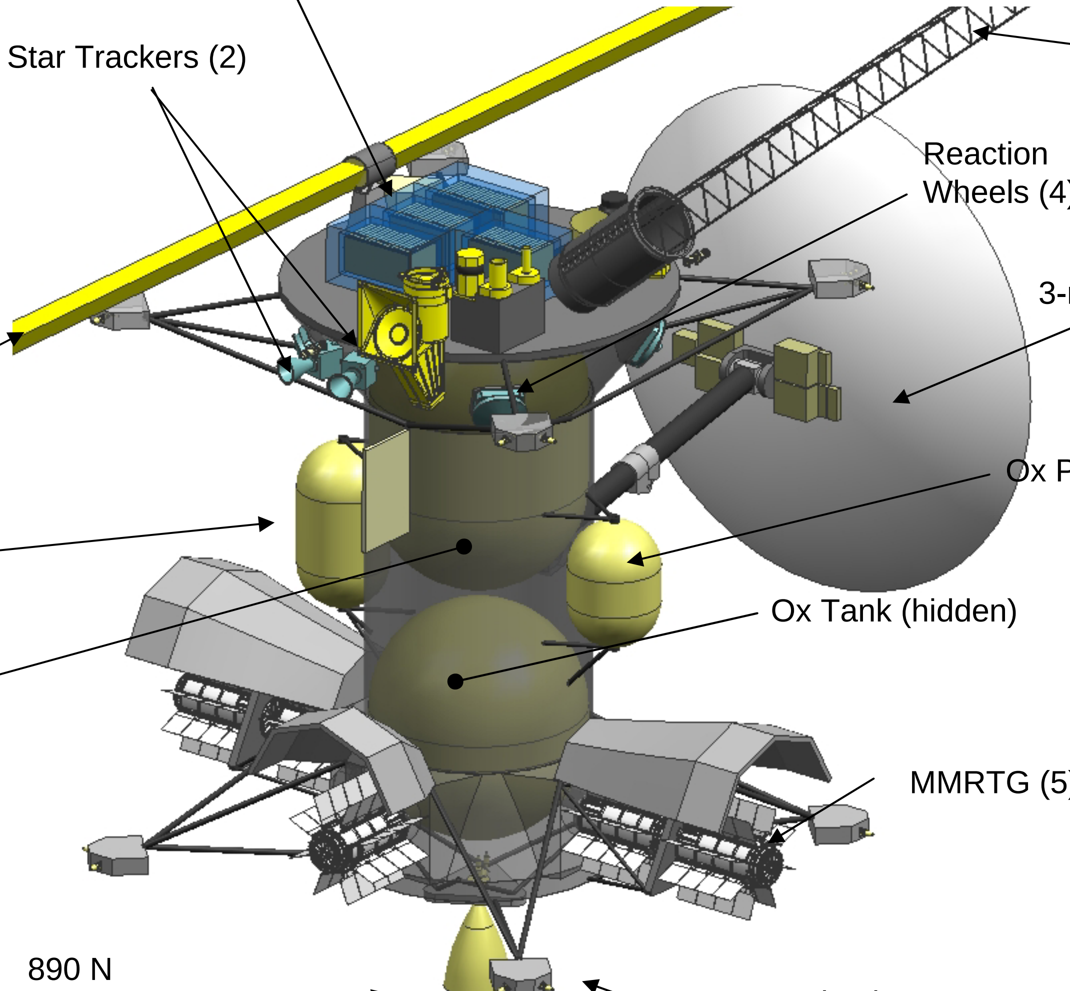
- Cost is recognized as a risk, 33% cost reserves on Phases B-D along with funded schedule margin

- Risks are currently being addressed:
  - ~$1.8M committed this year to help mitigate radiation risk (bold areas above)
    - ~$0.8k HQ, ~$1M JPL
  - First Instrument workshop held

Radiation environment and planetary protection requirements require early and focused attention to mitigate risk

JEO Core Spacecraft Configuration

- 37% mass margin on Atlas 541
- 42% mass margin on Atlas 551



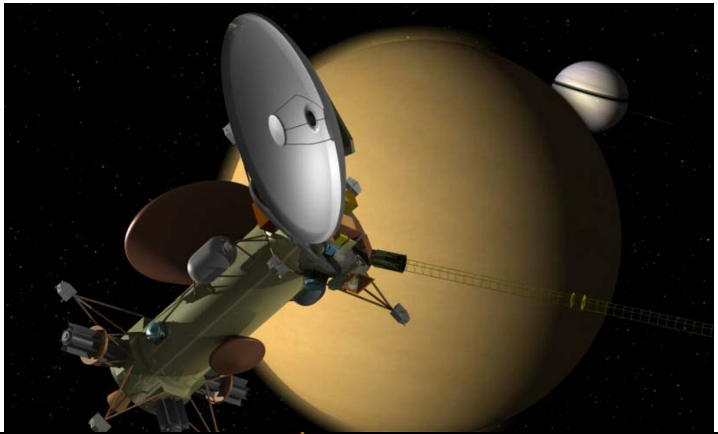
Core Mission Overview

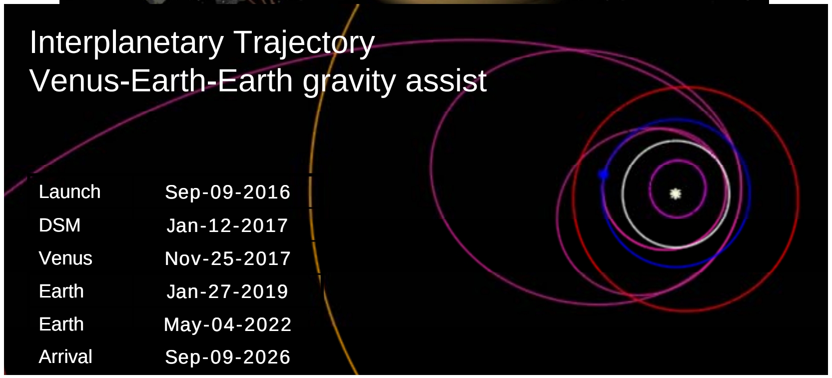
- **Objective: Titan orbit, Saturn system and Enceladus**

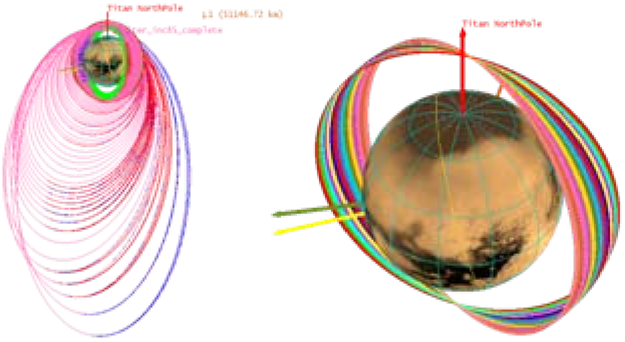
- **Orbiter accommodates ESA provided in situ elements;**
  - Core mission includes lander
  - Sweet spot and Enhanced missions include both lander and Montgolfiere but exceed study cost cap

- **Mission Timeline:**
  - Launch 9/2016
  - Saturn Arrival 9/2026
  - Saturn Tour; includes 4 Enceladus and 15 Titan flybys
  - Dedicated Titan aerosampling and mapping Orbit

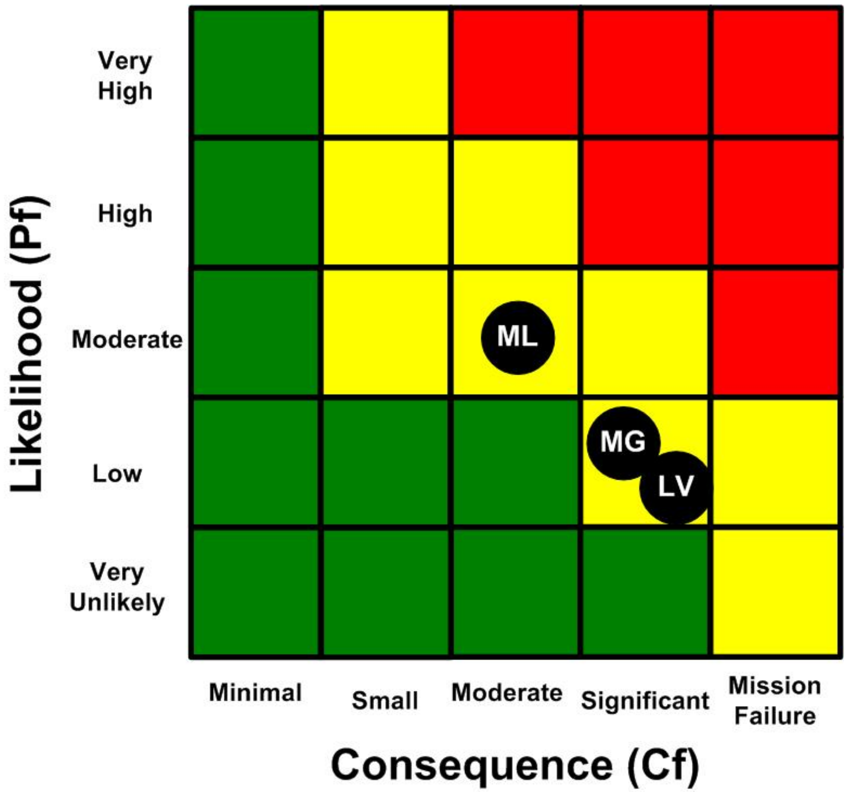
- **Focused payload; 6 inst. + RSA**







Core Mission Risk Assessment



Cost growth is recognized as a risk that is currently mitigated in 33% cost reserves and costed schedule margin

- **LV – integration of in situ element RPS adds complexity**
  – Early coordination planned for both orbiter and ESA contribution including "Trailblazer" exercise
  – JPL & APLs recent/current experience with RTG integration incorporated in plans
- **MG - Mass growth leading to larger LV or SEP**
  – System-level mass accounting necessary to address risk areas early in development
  – Healthy margins in place
  – The ESA provided in situ element study is just underway. Once the design is understood, there will likely be mass growth risk, but current spacecraft capability allows 100% mass growth above allocation
- **ML – Compatibility of design to operate for mission life of 13 years**
  – Long life design rules used on Voyager, Galileo, Cassini are incorporated
  – Additional parts screening and testing

Core Spacecraft Configuration

- **Configuration represents a balance of science, mass, cost & risk**

- **Orbiter dry mass ~1636 kg including 33% margin**
  - 150 kg allocated to orbiter instruments
  - Current *in situ* mass capability delivered to Titan orbit ~150 kg
    - Equates to 300 kg pre-SOI release
    - ESA currently designing to 150 kg allocation

- **Total Mission Dose estimated at ~21 krad (behind 100 mil Al)**