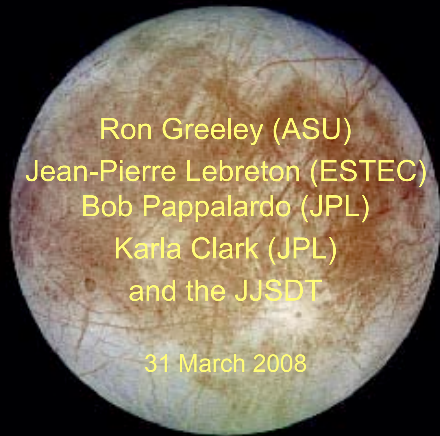
Preliminary Report of the Joint Jupiter SDT



Ron Greeley (ASU)
Jean-Pierre Lebreton (ESTEC)
Bob Pappalardo (JPL)
Karla Clark (JPL)
and the JJSDT

31 March 2008

Joint Jupiter Science Definition Team

US JJSDT Membership

Ron Greeley	**Co-Chair**
Bob Pappalardo	**Study Scientist**
Anbar, Ariel	astrobiology
Bills, Bruce	geophysics
Blaney, Diana	composition
Blankenship, Don	radar/geophysics
Christensen, Phil	composition
Dalton, Brad	composition
Deming, Jody	astrobiology
Greenberg, Rick	geophysics
Hand, Kevin	astrobiology
Hendrix, Amanda	satellites
Khurana, Krishan	fields & particles
McCord, Tom	composition
McGrath, Melissa	satellites
Moore, Bill	geophysics
Moore, Jeff	geology
Nimmo, Francis	geophysics
Paranicas, Chris	fields & particles
Prockter, Louise	geology
Schubert, Jerry	Jupiter
Senske, David	satellites
Showman, Adam	Jupiter
Sogin, Mitch	astrobiology
Spencer, John	satellites
Waite, Hunter	fields & particles

ESA JJSDT Membership

Jean-Pierre Lebreton	**Co-Chair**
Blanc, Michel	**Lead Scientist**
Drossart, Pierre	Jupiter
Grasset, Olivier	geology
Huβman, Hauke	geophysics
Krupp, Norbert	fields & particles
Prieur, Daniel	astrobiology
Tosi, Federico	origins
Wurz, Peter	origins/instruments

ESA Cross-Disciplinary

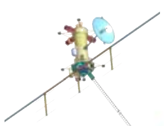
Lorenzo Bruzzone	radar/geophysics
Paolo Tortora	radio science
Ingo Mueller-Wodarg	fields & particles
Frank Sohl	geophysics
Olga Prieto-Ballasteros	astrobiology
Michele Dougherty	fields & particles

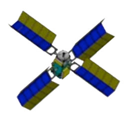
JJSDT Meetings

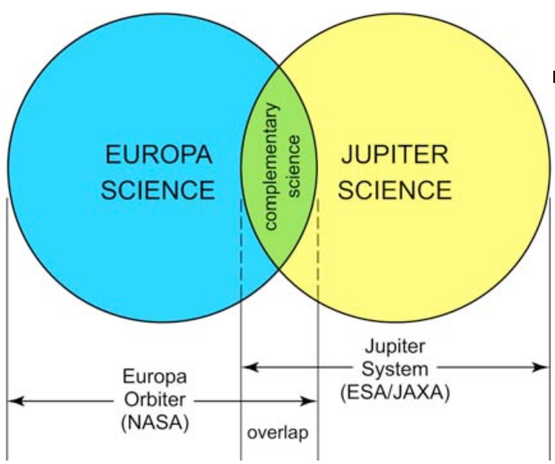
- Feb. 27-29, JPL: Europa Orbiter objectives
- March 26-28, JPL: US-EU science integration
- April 23-24, Rome: EO-JPO complementary payloads
- May 26-29, JPL Outstanding issues

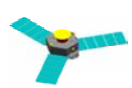
Europa-Jupiter System Mission

Over arching Goal (TBD)

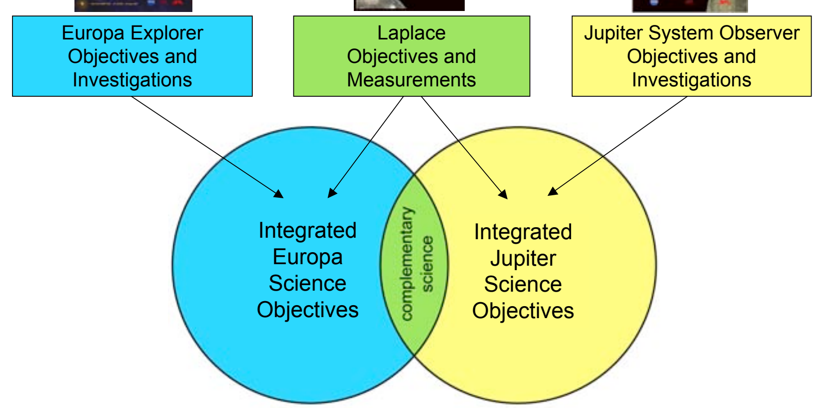








JJSDT Science Integration Process



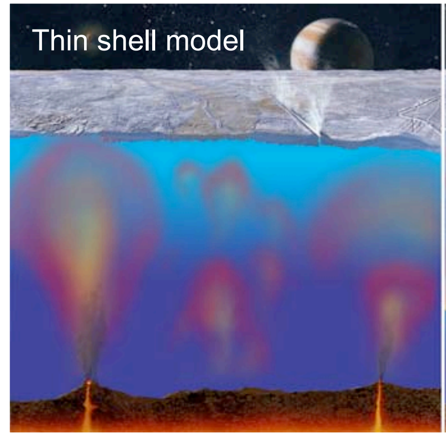
Europa Orbiter: Prioritized and Integrated Science

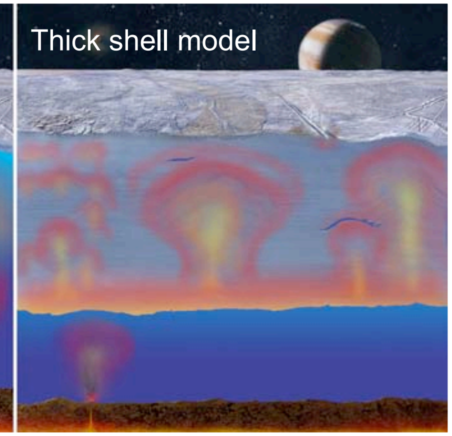
Goal		Science Objective	Science Investigation
Explore Europa to investigate its habitability.	A. Ocean	Characterize the extent of the ocean and its relation to the deeper interior.	A1. Determine the amplitude and phase of the gravitational tides.
			A2. Characterize the magnetic environment (including ionospheric current plasma effects) to determine the induction response from the ocean over multiple frequencies.
			A3. Characterize surface motion over the tidal cycle.
			A4. Determine the satellite's dynamical rotation state.
			A5. Investigate the core, rocky mantle, and rock-ocean interface.
	B. Ice	Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface ice-ocean exchange.	B1. Characterize the distribution of any shallow subsurface water.
			B2. Search for an ice-ocean interface.
			B3. Correlate surface features and subsurface structure to investigate processes governing communication among the surface, ice shell, and ocean.
			B4. Characterize regional and global heat flow variations.
	C. Chemistry	Determine global surface compositions and chemistry, especially as related to habitability.	C1. Characterize surface organic and inorganic chemistry, including abundances and distributions of materials, with emphasis on indicators of habitability.
			C2. Relate compositions to geological processes, especially communication with the interior.
			C3. Characterize the global radiation environment and the effects of radiation on surface composition, atmospheric composition, albedo, sputtering, sublimation, and redox chemistry.
			C4. Characterize the nature of exogenic materials.
	D. Geology	Understand the formation of surface features, including sites of recent or current activity, and identify and characterize candidate sites for future *in situ* exploration.	D1. Determine the formation history and three-dimensional characteristics of magmatic, tectonic, and impact landforms.
			D2. Determine sites of most recent geological activity, and evaluate future landing sites.
			D3. Investigate processes of erosion and deposition and their effects on the physical properties of the surface debris.
	E. Jupiter system	Understand Europa in the context of the Jupiter system.	E1.
			E2. In progress
			E3.
			E4.
			E5.

red = edits from JJSDT Meeting 1 blue = edits based on JJSDT Meeting 2 integration of US Europa Explorer - EU Laplace

- Objectives are now prioritized.
- Chemistry objective's traceability is receiving special attention.
- Former "External Environment" objective is folded into the others.
- Jupiter system science is elevated to Level 1 priority.
- US Europa Explorer and Laplace Europa objectives are now integrated.

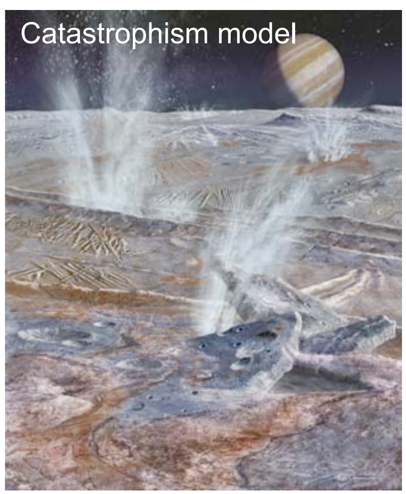
Example of Europa Hypothesis Testing: Thin vs. Thick Ice Shell





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

Example of Europa Hypothesis Testing: Catastrophic vs. Steady-State Evolution



90% of Europa remains unseen at resolution needed to recognize key units.

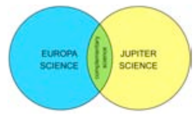
Jupiter Polar Orbiter: Prioritized and Integrated Science

III. Study the Jovian magnetodisk/magnetosphere

Science Objective	Required Measurements
Jupiter as a fast magnetic rotator	
1. Magnetodisk structure, dissipation of rotational energy, transfer of angular momentum	1.1 Characterization of the 3D properties of the magnetodisk
	1.2 Analysis of the influence of the various plasma sources on its structure (including composition measurements)
	1.3 Response to mass loading variability (Ionian space weathering)
	1.4 Characterization of the different modes of transport
	1.5 Determination of the plasma loss processes
	1.6 Boundary layers: Investigate the important boundary layers of the magnetosphere (Bow shock, magnetopause, plasma sheet boundary layer, high energy particle radiation belt boundaries, equatorial plasma disk)
2. Global energy regulation in a complex magnetosphere	2.1 Characterization of the Magnetosphere/Ionosphere/thermosphere coupling processes
	2.2 Morphology & modulation of the auroral/radio emissions (multi-λ) and modulation of particles and fields
	2.3 Magnetospheric mapping of auroral/radio features/regions
	2.4 Response to solar wind variability (Jovian space weather)
Jupiter as a magnetized binary system	
3. Satellites/Magnetosphere interactions	3.1 Characterization of the local electrodynamics interaction
	3.2 Observations of the moon auroral magnetic footprints
	3.3 Study of pick-up & charge-exchange processes in plasma/neutral tori
	3.4 Analysis of plasma/surface sputtering processes/surface weathering
	3.5 Investigation of Ganymede's magnetosphere
Jupiter as a giant particle accelerator	
4. Origin & effects of its harsh radiation environment	4.1 Characterization of high-energy electron, proton and heavy ion properties
	4.2 Identification of high-energy particle acceleration processes (reconnection)
	4.3 Determination of high-energy particle loss processes
	4.4 Analysis of moon micro-signatures to quantify fundamental processes
	4.5 Analysis of high-energy electrons synchrotron emissions
	4.6 Radiation effects in the inner magnetosphere on ring system and dust population
	4.7 Particles from Jupiter in interplanetary space

- US Europa Explorer and Laplace Europa objectives are being integrated.

Jupiter System Science *(in progress)*



- Jupiter System Science Objective for EO:
  - ➢ Understand Europa in the context of the Jupiter system.
- Overall Jupiter System Science Philosophy:
  - ➢ EO adopts investigations which fit under its "Europa habitability" goal.
  - ➢ JPO adopts all relevant Jupiter System Science investigations.
  - ➢ Each spacecraft might achieve investigations "bookkept" by the other.
- Candidate EO Investigations:
  - ➢ Understand the sources and sinks of Io's crustal volatiles and atmosphere.
  - ➢ Characterize the composition, variability, and dynamics of Europa's atmosphere and ionosphere.
  - ➢ Identify the dynamical processes that cause internal evolution and near-surface tectonics of Ganymede vs. Callisto.
  - ➢ Characterize the abundance of Jupiter minor atmospheric species to understand the origin of the Jovian system.

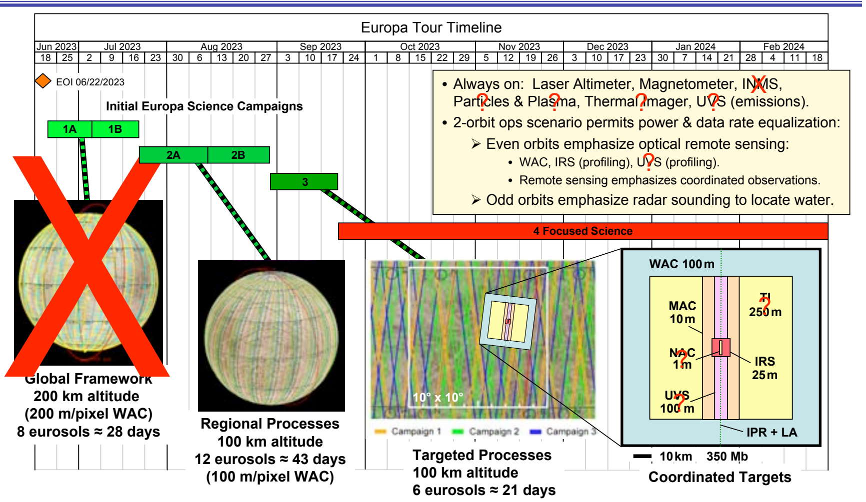
- Possible EO Implementation:
  - ➢ Io campaign (3 - 4 Io fly-bys).
  - ➢ Perijove on Jupiter's sunlit side.
  - Ganymede fly-bys (~8 - 10).
  - Polar Callisto fly-by (≥1).

EO Planning Payload to fit $2.1B Cost Box

CORE PAYLOAD	Mass (kg)	Power (W)	Change from EE07 Floor
Ocean			
Radio Science (RSS)			Ka + X bands
Laser Altimeter (LA)	7	15	
Ice			
Ice Penetrating Radar (IPR)	31	45	Two dipoles
Chemistry			
Near-IR Spectrometer (IRS)	20	20	increased mass for realism
Geology			
Wide- + Med-Angle Camera (WAC+MAC)	10	12	Both have color filters
Mag & Plasma			
Magnetometers + Plasma (MAG + Langmuir Probe?)	5	3	Dual mags on a 10 m boom
TOTALS:	73	95	
2007 Floor TOTALS:	77	106	

NOT IN CORE PAYLOAD			
Thermal Instrument (TI)	5	5	
Particle Instrument (PI)	6	3	10s keV - ~1.5 MeV (e-) - 10s MeV (ions)
UV Spectrometer (UVS)	5	10	1 channel only
Narrow Angle Camera (NAC)	15	12	
Ion & Neutral Mass Spectr. (INMS)	15	28	

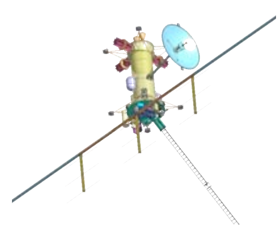
Implications of Only 60 Days In Europa Orbit



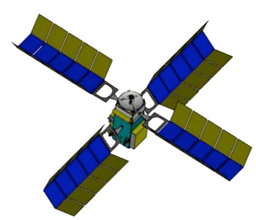
- Campaign 1 is lost, with corresponding loss to science and increased risk.
- Second-order optimizations are possible, e.g. reducing polar overlaps.

Europa-Jupiter System Mission

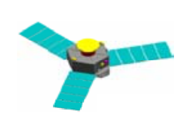
- Joint NASA/ESA Mission Study
  - ➢ Multi element architecture
  - ➢ Independent launches allow decoupled development schedules
  - ➢ Possible JAXA contribution being evaluated



Europa Orbiter – NASA-led



Jupiter Planetary Orbiter/Ganymede Orbiter – ESA-led

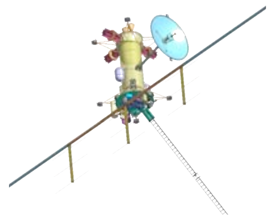


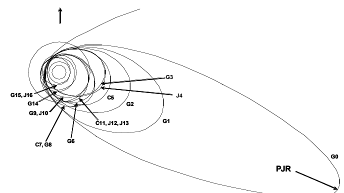
Jupiter Magnespheric Orbiter – JAXA-led

- Rest of discussion is on Europa Orbiter portion of Study

2007 Europa Explorer Floor Mission Concept Updated for 2008 Key Ground Rule Changes

- Concept: Europa orbiter with Galilean Satellite Tour
- Launch Vehicle: Atlas 531 => Atlas V551
- Power Source: 5 ASRGs => 5 MMRTG
- Mission Timeline:
  - ➢ Launch: ~6/2015 (VEEGA) => 2016/7 (TBD trajectory)
  - ➢ Jupiter arrival: ~7/2021 => 2021-2024
  - ➢ Galilean satellite tour science: ~2 yr
  - ➢ Europa orbital science: ~ 6 months => 60 days
    - 70m stations for 92 days 24/7, then single pass/day
      => 34m, no arraying, continuous
  - ➢ Spacecraft operates until loss of control; final disposition: Europa surface Impact
- Instruments: 8 ; 77 kg, 106 W
- Modified Reserves Base
- Cost: $2.4B => $2.45B





Representative Tour Trajectory

The key challenge! Needs to be $2.1B

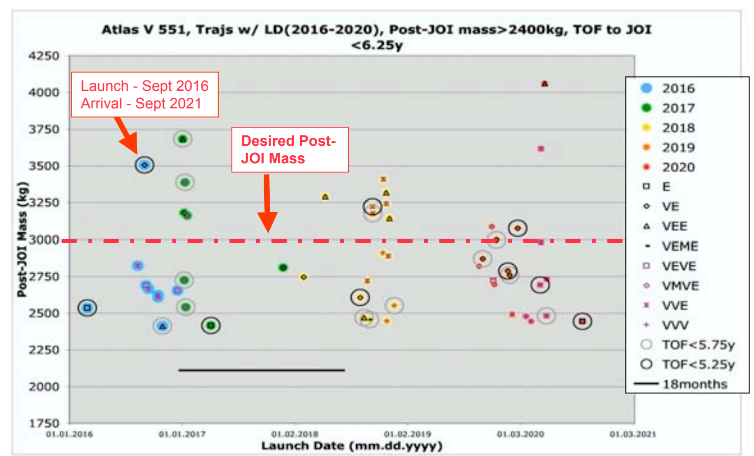
Europa Orbiter FY08 Mission Specific Tasks

- Incorporate *Jupiter System Science* as Level 1 Objective
- Refine the *chemistry* science objective especially in relation to habitability
- Perform analyses concerning radiation induced effects on instrument measurement quality and mitigation strategies
- Investigate opportunities for *international partnerships* within the $1B for contributions
- Design and characterize the sensitivity to the design point of a *60 day orbital* mission in terms of cost, mass, science return and other factors
- *Refine radiation plan* in 2007 report
- *Execute* the revised *radiation plan* including:
  - ➢ Establishment of all acceptable radiation related lifetime or performance criteria
  - ➢ Demonstration of the ability to reach these goals on representative parts including detectors
- Develop a specific *Preferred Parts list* for all hardware and permit only highly justified and well mitigated exceptions

Challenges for 2008

- Fitting into the $2.1B box
  - ➢ Re-evaluating required management and system engineering workforce
    - Comparison to other missions
    - Evaluating alternate approaches
  - ➢ Potential options for Phases B/C/D
    - Simplify spacecraft design
    - Delete MMRTG
  - ➢ Potential options for Phases E/F
    - Shorten flight times
    - Simplify operational scenarios to reduce required staff
- Mitigating Radiation Risk
  - ➢ Created and began executing radiation plan
  - ➢ Identifying, evaluating and testing potential parts and materials
- Preparing potential instrument providers for Announcement of Opportunity (AO)
  - ➢ Workshops
  - ➢ Design guidelines
  - ➢ On-line tutorials

Chemical Trajectory Performance
(by launch year and trajectory type)



2016 and 2017 launch opportunities exist which would allow arrival at Europa ~ 7 years after launch

Arrival Strategy Options

	Ganymede		Io Once		Io Campaign
Post-JOI Period (days)	200		200		200
Number of Io flybys	0		1		4
Perijove @ JOI (Rj)	12.5	9.0	5.2		5.2
Post-PJR Perijove (Rj)	12.5	9.0	12.0	9.0	5.2
JOI + PJR ΔV (Rj)	1010	910	920	820	675
ΔTID over EE07 (krad)	-		~50		~300
ACS sensor high dose-rate accommodation impacts (kg)	-		10-20		10-20
ΔV-EGA compatible?	N		N		2016 only

ACS - Attitude Control Subsystem
JOI - Jupiter Orbit Insertion
PJR - Perijove Raise Maneuver
Rj - Jovian radii
TID - Total integrated dose

- Major dose-rate increase at Io over that at Europa
- The tour duration is independent of moon assist
- Mass trade looks favorable for conducting an Io campaign

Major Operations Cost Driver Categories

- Capture relevant lessons learned from the past and present operational missions (Cassini, MRO, New Horizons, MESSENGER), in the area of Phase E cost drivers and operations.
- Each of the following categories are being further expanded with metrics defined for each:
  - Operational processes and architectures
  - Flight system interface complexity (bus and Payload)
  - Ground system interface complexity
  - Flight resource limitations
  - Science observation density and complexity
  - Mission design complexity

Results of analysis will be used to lower operating costs for Europa Orbiter Mission

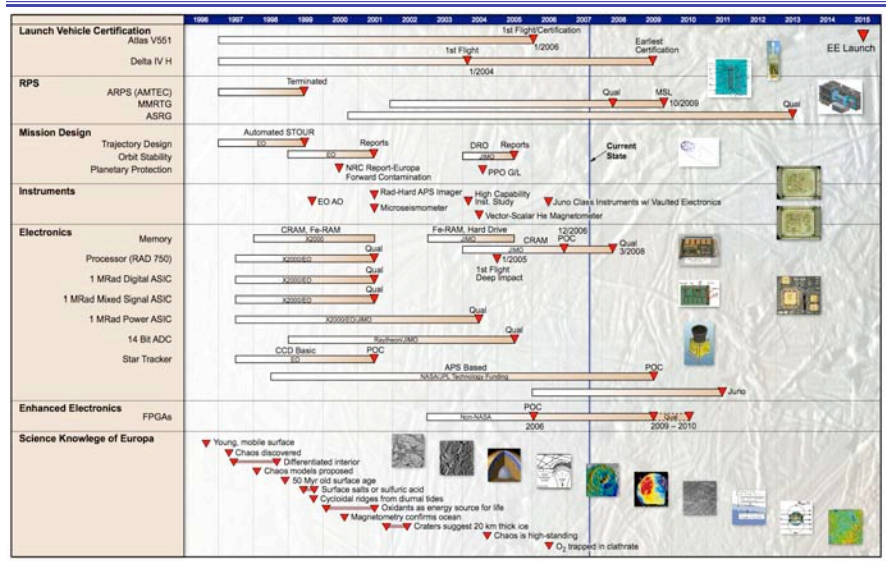
Risk Assessment: Early Focus Areas

Key Risk: Impact of radiation and planetary protection on design

Risk Area	Components	Mitigation	Impact
Radiation	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) Use ASICs in place of FPGAs c) FPGA, memory and sensor radiation testing d) Document and disseminate design techniques and guidelines e) Early subject matter expert engagement	a) Reduced cost risk and uncertainty
Planetary Protection	a) Sensor sterilization capability b) Design techniques	a) Document design techniques and guidelines b) Early subject matter expert engagement	a) Reduced cost risk and uncertainty
Instrument Maturity	a) Level of information available for potential providers b) Inexperience of potential providers c) Development schedule	a) Document design techniques and guidelines b) Instrument provider workshops - early subject matter expert engagement c) Early and streamlined AO with confirmation review	a) Maximize time instruments can work with experts b) Reduce cost risk and uncertainty at "commitment"

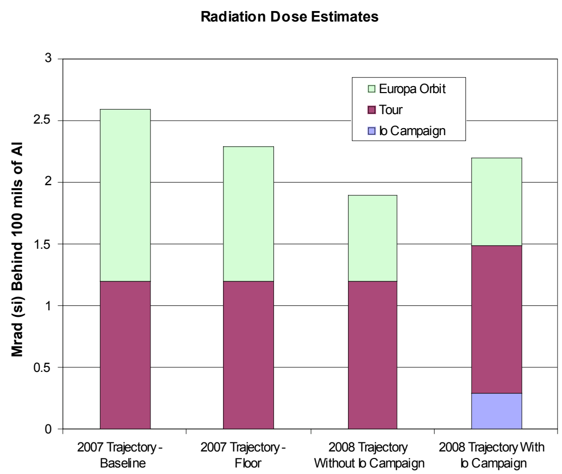
Analogous design/development approaches will be assessed and redesigned to meet radiation and planetary protection requirements

A Decade of Investment Has Reduced EO Risk



What's Changed for EE Radiation?

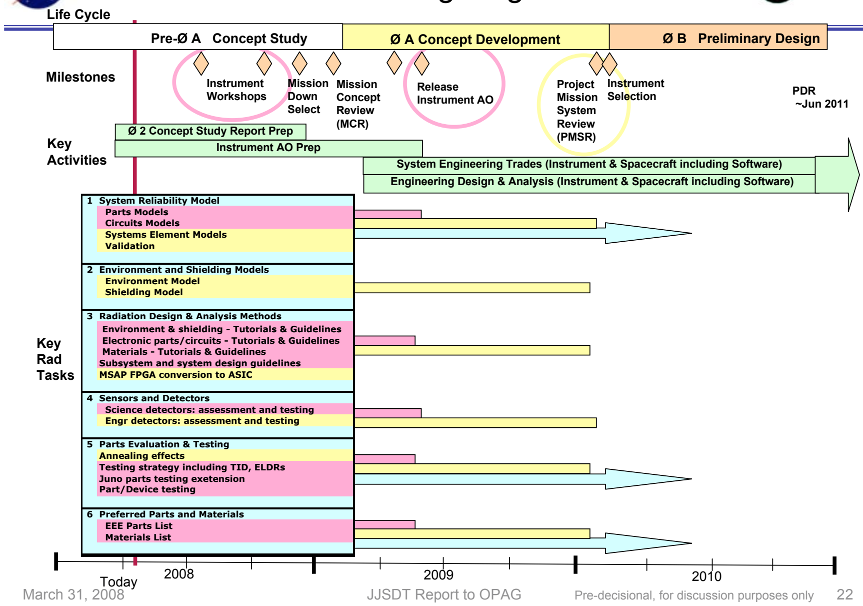
- 2007 baseline mission total => *~2.6 Mrad**
  - ~1.2 Mrad* when enter Europa orbit
  - ~1.4 Mrad* for @ Europa
- Reducing to 60 days at Europa reduces radiation estimate
- Io campaign would add ~0.3 Mrad*



* Radiation levels normalized to behind 100 mils of Al

Radiation level estimates will be ~2.2 +/- 0.3 Mrad*

Near Term Plan for Mitigating Radiation Risk



Instrument Workshops

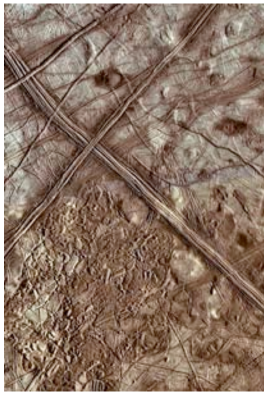
- AO release target ~April 2009
- Issues:
  - Europa radiation levels pose significant challenges to the performance of the scientific payloads
  - Planetary protection requirements will demand dry heat microbial reduction
  - Parts/material selection & circuit design for these harsh environments are not business as usual
  - Detectors will suffer performance degradation w/time and are susceptible to transient noise during science operations
- Need to communicate environmental & PP issues before the release of the AO. Benefits include:
  - Proposals with more cost & schedule realism
  - Ensure high-quality science return for the mission

Instrument Workshops - continued

- Communication strategy
  - Hold community workshops as information becomes available
  - e-tutorials on a community website based on the workshop content
- Current plans are to hold 3 workshops over the next year
- Outer Planet Flagship Instrument Workshop (6/3–5/08)
  - Joint EJSM/TJSM workshop
  - Overviews of mission architectures, science, notional payloads, science scenarios, etc
  - Split sessions that address Europa- and Titan-specific payload issues
  - Poster sessions for instrument providers
- EO Radiation & Planetary Protection Design Guidelines Workshop
  - ITAR restricted to allow for discussion of design details
- Final EO workshop to update design guidelines just prior to AO release

The Technical Maturity of Europa Orbiter

- Fruitful technology investments:
  - Launch vehicles, RPS, Mission Design, Instruments, Electronics.
- Radiation challenges have been met:
  - State-of-the-Art technology and comprehensive system engineering design approach identified, validated and being executed
  - Plan for communicating approaches to potential instrument providers formed
- New Study Guidelines require changes to mission concept and implementation to reduce estimated cost
  - Challenge previous assumptions
  - Simplify mission implementation
  - May require descopes to science as last resort
- Mature and successful operations plan:
  - Updates for shorter Europa Orbital mission being explored
  - Tour science being incorporated.
- Rich science return:
  - For Europa, Jupiter, and the Galilean satellites.
- The first icy satellite orbiter mission is ready to begin!



The technical capability is mature, and the inspirational goal of the first icy satellite orbiter is within our reach.