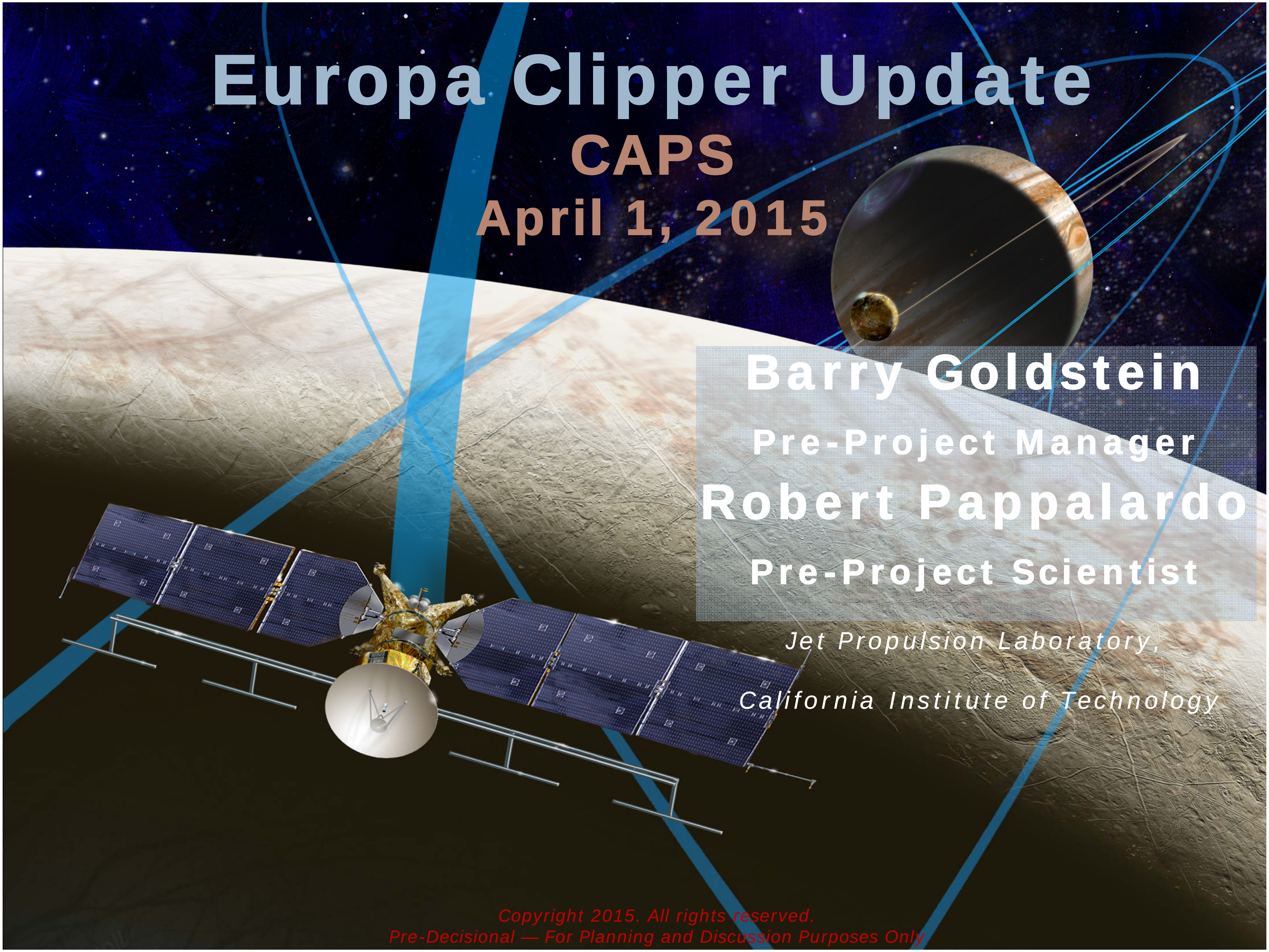

Europa Clipper Update

CAPS

April 1, 2015

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Pre-Project Manager

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Europa SDT Members, 1999 – 2014

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Dale Winebrenner
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Highlights Since March ’14

- Preliminary Concept Review : March 2014
- Instrument AO released June 2014
  - Evaluations In Process
- Plume workshop : June 2014
- **Project Baseline switched to Solar Arrays : July 2014**
- **Mission Concept Review September 2014**

"Solar" Study Chronology

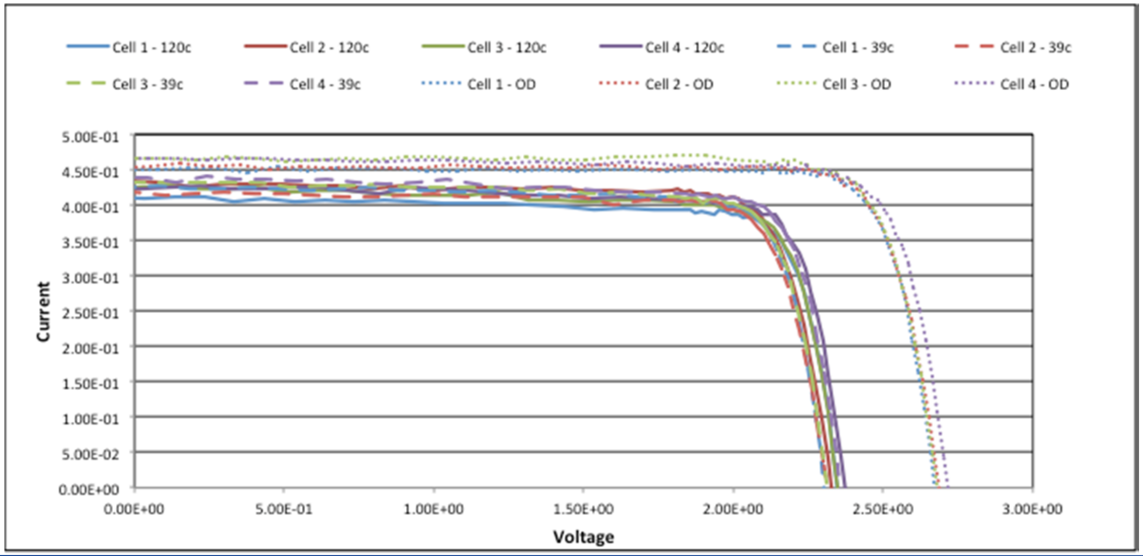
- Preliminary Solar Option Study (March 2012 – August 2013)
  - Clipper mission concept opened possibility of solar
  - Active thermal control added further realism
  - Leveraged heavily off of work done by Juno
  - Engineering team evaluated key risks and worked a plan to retire
- Held independent solar feasibility review (August 2013)
  - Is solar power for Clipper Feasible? ("**Yes"**)
  - Have the critical risks been identified? ("**Yes"**)
  - Do we have a comprehensive risk mitigation Plan? ("**Too high a bar, but all risks have been identified"**)
- Aggressively worked detailed technical trade & risk mitigation tasks (August 2013 – July 2014)
  - Key driver was to complete evaluation and establish MCR baseline
- Held independent review to do in-depth assessment of trade study and risk mitigation results (August 19-20 2014)

The Questions We Set Out To Answer

- What are the arrays radiation performance?
- Can the arrays survive Jovian eclipses?
- What are the long life considerations (potential for an extended mission)?
- Do the large arrays adversely affect vehicle stability for instrument pointing?
- Is it overly aggressive to develop and/or to deploy solar arrays of this size?
- Is there is any concern about flying through the potential plumes?
- What is the impact on power margin?
- What is the impact on mass margin?
- What is the impact on cost?
- What is the impact on schedule?

Survival of Jovian Eclipses?

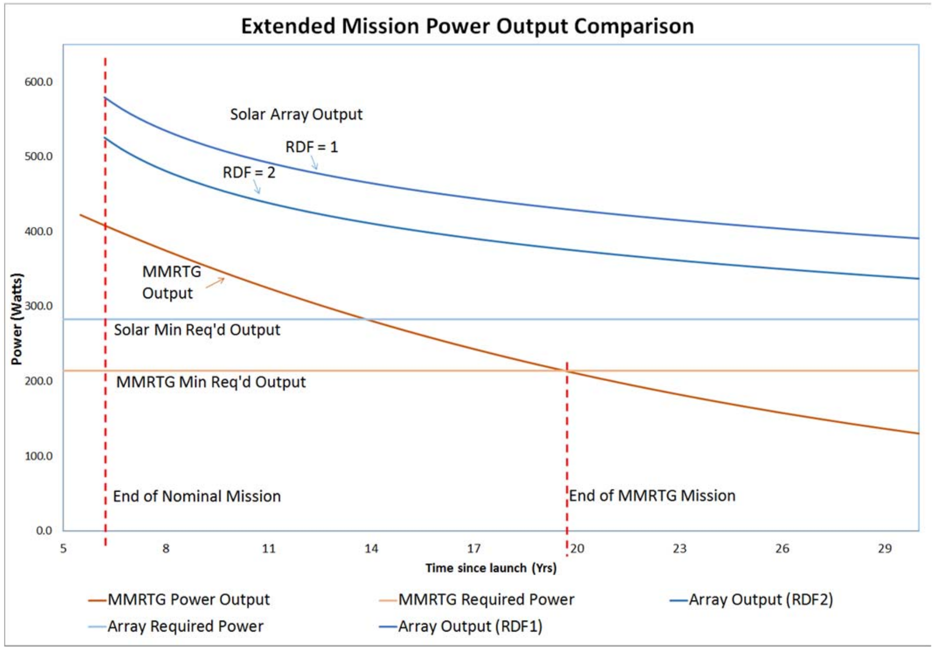
- Clipper makes several passes behind Jupiter over the course of its 45 prime mission orbits
- Thermal model predicted temperature cycles: Does that lead to materials and/or performance issues?
  - Radiated (2.6 x mission dose) cells, and executed thermal cycle tests, with performance checks after 39 and 120 cycles
  - Performance was very stable after ‘qualification number’ of thermal cycles
  - No materials issues identified from the harsh thermal excursions



Long Life?
(Potential for Extended Mission)

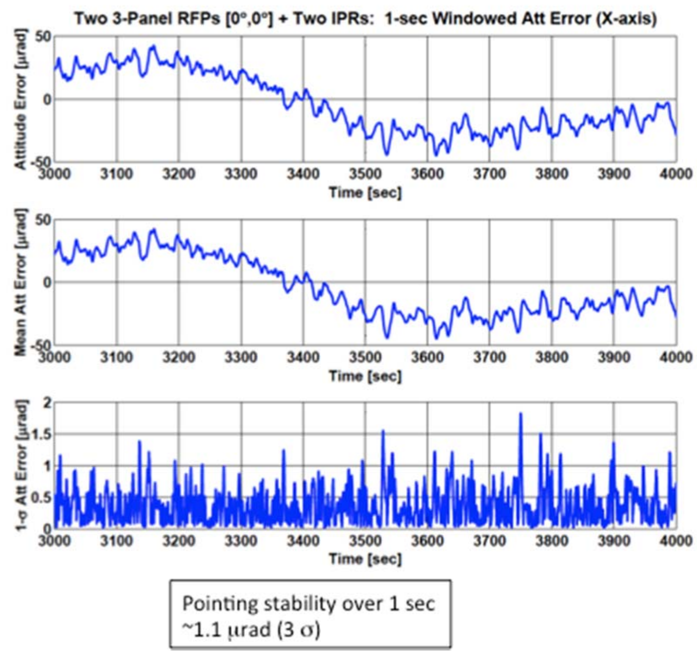
- Both MMRTGs and Solar Option provide for significant extended missions
- Unlikely that power output will be mission limiting resource, however ➔

  - If power were to determine mission duration, solar would outlive MMRTG



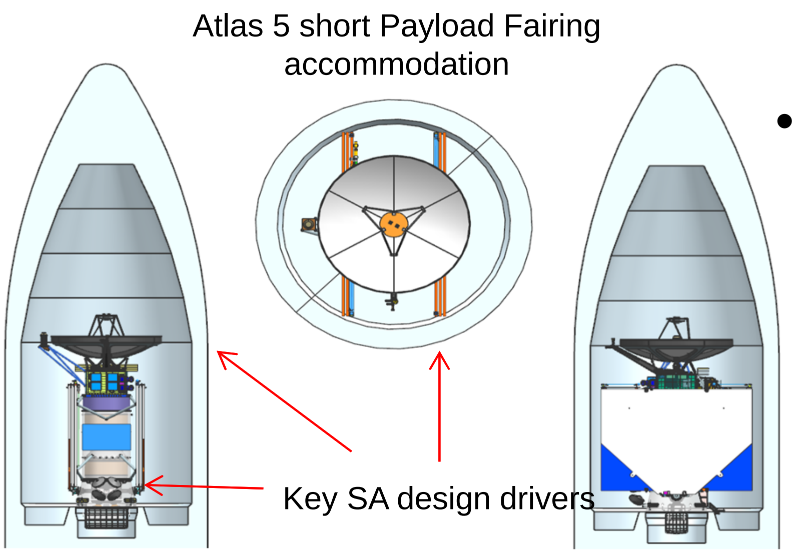
Vehicle Stability for Instrument Pointing?

- Clipper pointing and stability requirements are derived from inputs of the Europa Science Definition Team
- Pre-Project plan holds solar arrays fixed during Europa flybys
- Conducted significant modeling of spacecraft stability
  - The payload elements with the most stringent pointing requirements are easily met:
    - Pointing stability over 1 sec (3 σ): [1.1, 1.4, 0.9] urad
      - **Recon Camera requirement (50 urad/s)**
    - Pointing stability over 3 sec (3 σ): [3.1, 2.8, 2.5] urad
      - **SWIRS requirement (75 is urad per-axis over 3 sec)**
  - Should selected payload requirements be more stringent we have over an order of magnitude stability margin

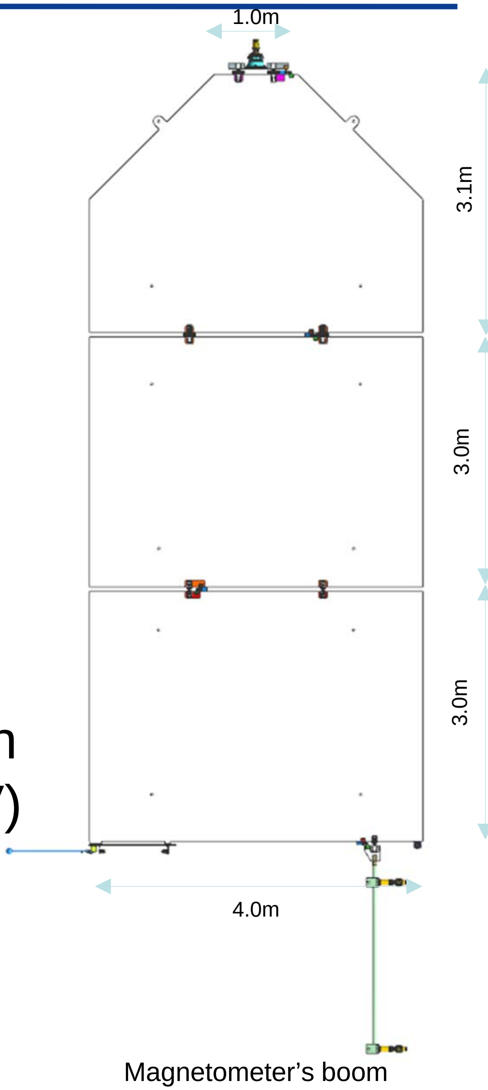


Development/Deployment Of Large Arrays?

- Array size and deployment mechanisms in family with previous NASA missions (e.g. Juno, Dawn) as well as several ESA missions



- Driving fairing accommodation case (ATLAS-V) still allows growth if necessary



Mass and Power Impacts?

- Mass:
  - Driving mass case is SLS direct trajectory
    - Mass margin with 5 MMRTGs ➔ 42%
    - Mass margin with Solar ➔ 38%
      - JPL Design Principles 30%
  - ATLAS margins significantly greater, however 4 ½ year longer cruise

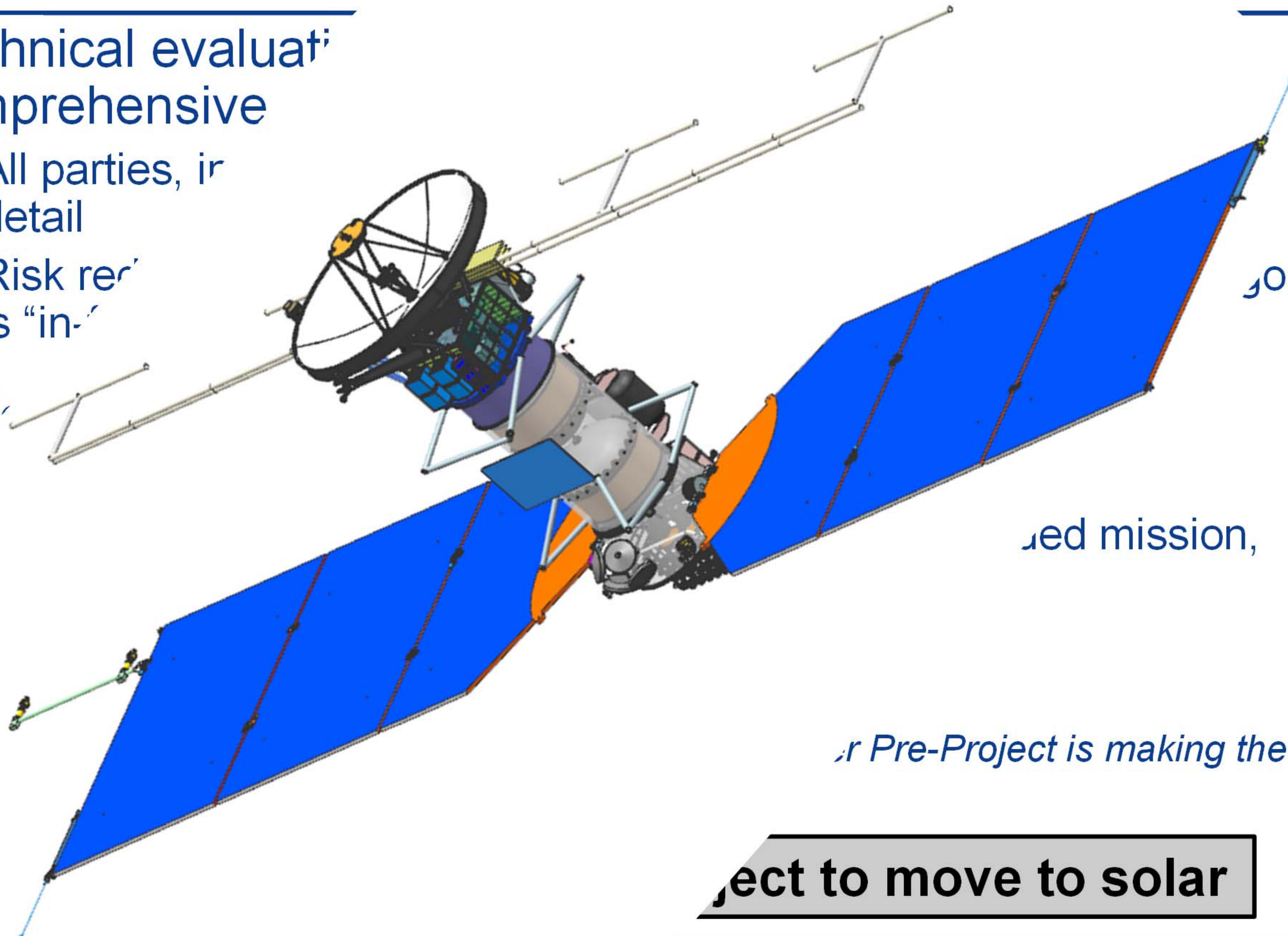
- Power:
  - Solar arrays sized to provide same end of prime mission power margin as 5 MMRTGs (40%)
  - Incremental impact of adding an MMRTG much more significant (cost, schedule, mass, etc.) than additional solar array area

• Technical evaluati
comprehensive

– All parties, ir
detail

– Risk rec
is "in-

• Proj

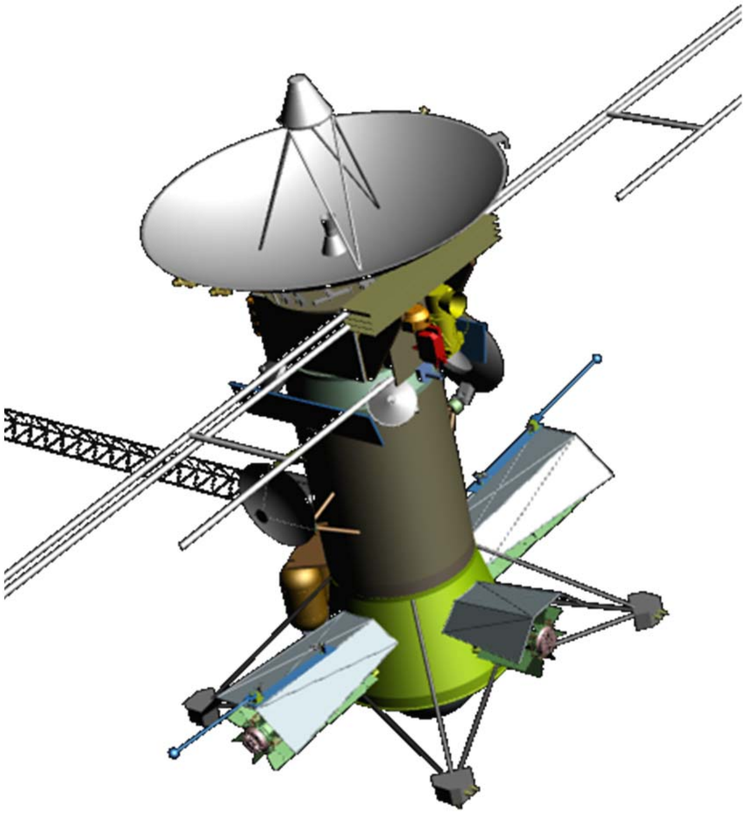


ued mission,

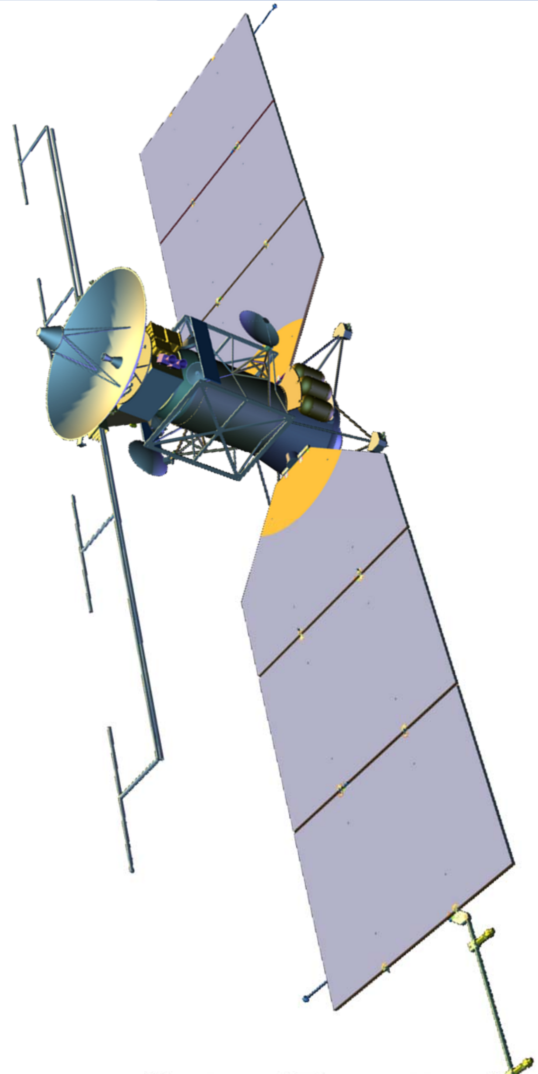
r Pre-Project is making the

ject to move to solar

Two Mission Concepts



MMRTG



Solar (Baseline)

Mission Concept Board Report

Review Team Membership

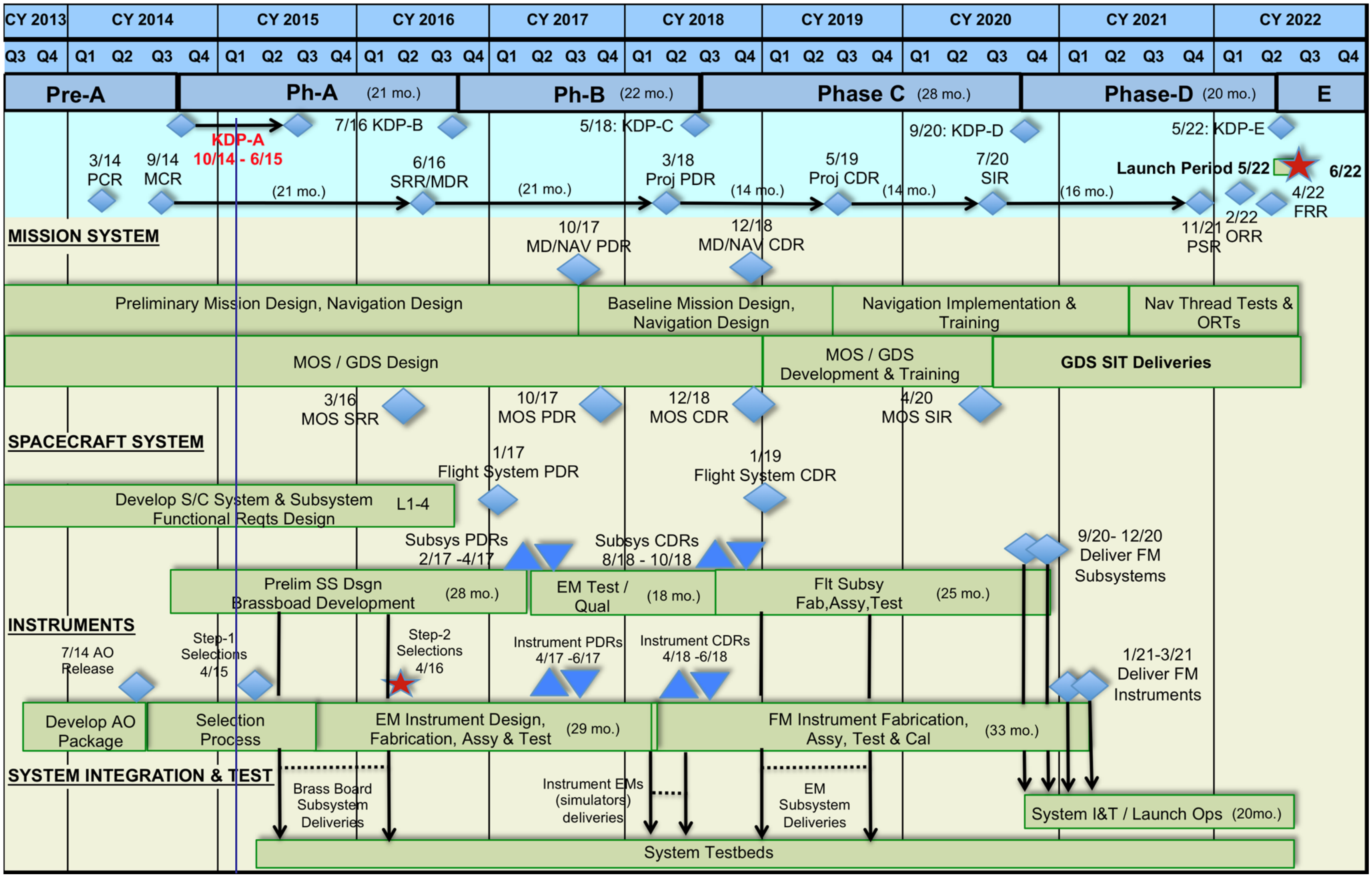
- A team of subject matter experts with decades of relevant hands on experience was assembled for the purpose of the review. The chair and membership was coordinated closely between JPL, APL, and the SMD Program Executive

Orlando Figueroa/Consultant - Chair	Steve Battel/Consultant
Gentry Lee/JPL	Richard Fitzgerald/APL
Tom Gavin/JPL-Ret	David Kusnierkiewicz/APL
Mark Brown/JPL	Will Devereux/APL - *Not present at review*
Jan Chodas/JPL	Larry Soderblom /AGU-Ret
Dara Sabahi/JPL - *Not present at review*	

Executive Summary

- The Europa Clipper Project team is to be commended for the level of maturity achieved to this point in the life cycle of the mission
  - The review and material presented and discussed exceeded all expectations for an MCR.
  - The presentations were clear, well organized and self-consistent.
  - It is evident that the technical design has benefited greatly from the substantial early funding, and the Project has been diligent in applying the resources smartly towards organization and planning, sound systems engineering, and addressing management, engineering (22 risk retirement activities) and science (11 risk reduction studies) areas.
  - The JPL/APL team commitment to building a strong team and to mission success was also evident by the quality and openness of the discussions at all levels.

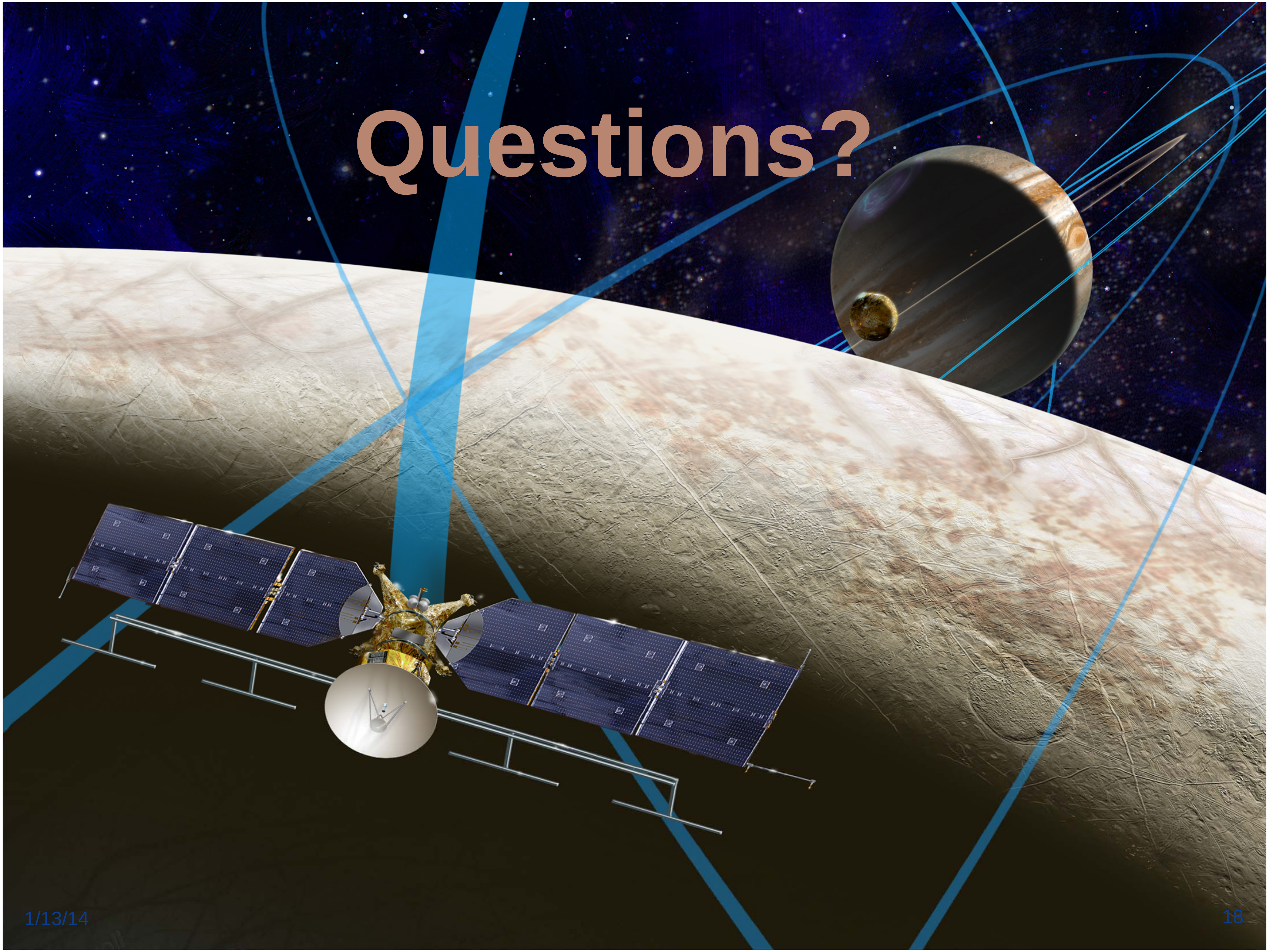
Top-Level Development Schedule



Plans Forward

- Key Decision Point A meeting : June 2015
  - Authority to proceed as official NASA Project
- Solar Array Technology Selection : Summer/Fall 2015
- Project Science Group (PSG) meeting #1 : August/September 2015
- Spacecraft Avionics Testbed : Fall 2015
- Mission Design Review / System Requirements Review : June 2016

Questions?



BACKUP

MCR Findings (1 of 7)

- The mission concept and design is brilliant, enabled by an in-depth knowledge and close collaboration between science and engineering, two highly capable organizations, and analytical tools not available in years past
  - The scientific goals and objectives are among the highest priority laid out in the Decadal Survey for Solar System Exploration, addressing nearly all Jupiter Europa Orbiter (JEO) science objectives for Europa exploration (excepting the deep ocean interface with the rocky interior)
  - The model payload, measurement plan and science traceability matrix all illustrate that these high level objectives are fully achievable by the Europa Clipper Mission as presented.
  - The science is resilient with several investigations supporting each of the key objectives, and fits credibly within the scope and programmatic envelope identified for the mission.
  - The mission concept meets the level 1 requirements presented, with science priorities clearly understood and flowed down to the mission and reflected in the system design

MCR Findings (2 of 7)

- Addition of Radiation Monitors to the spacecraft is an orphan requirement, not traceable to any of the Level 1 requirements as presented
  - The severity of and state of understanding of the radiation environment around Europa warrants that NASA consider adding radiation monitoring as part of the environmental reconnaissance measurements
  - They have science and engineering value to inform the conduct of the Clipper and for follow on missions

- Project comments on finding:
  - Project completely concurs with this finding, and endorses the inclusion of radiation monitors as part of the level-1 requirements
  - Intelligent design and placement of radiation monitors will allow the Project to not only feed forward important engineering and science data, it will allow us to deal with radiation dose as a vehicle consumable.

MCR Findings (3 of 7)

- The partnership between JPL and APL is working very well, with roles, accountability and authority clearly defined, and based on mutual respect for each other's contributions
  - The work is allocated across lines that make best use of the talents on both sides, and where they complement and reinforce each other
  - There was evidence of the partnership providing checks and balances, and therefore risk reduction

MCR Findings (4 of 7)

- A Class A risk classification for the mission may be overly constraining the system designs and trades, and not truly being applied consistently across the board, a Class B classification is recommended
  - Applying such risk classification to its full extent may be an expensive proposition in mass and cost, and not appropriate for the Europa Clipper mission

- Project comments on finding:
  - Project completely concurs with this finding, and will begin working with HQ to establish concurrence prior to KDP-A

MCR Findings (5 of 7)

- The schedule is adequate to complete the development with acceptable risk. The Project's estimated cost of $2.0B (FY15$, excluding launch vehicle) is within the range of Independent Cost Estimate Predictions of $1.8B to $2.3B.
  - The confidence level for the project cost estimate represents 58% in "S-Curve" (70% is $2.1B)
  - The Project planned profile and cost posture is realistic and proper for the MCR milestone in the life cycle

MCR Findings (6 of 7)

- The review team is particularly concerned about the risk areas listed below, because they may not be captured properly and/or be fully appreciated:
  - Integration (system integration, education and interactions with the science payload providers) of the payload may not yet be fully appreciated, with an Announcement of Opportunity still open, unknown payload providers, possibility of over selection, and the complexity of constrained communications;
  - Each of the low altitude flybys will potentially leave the spacecraft on an impact trajectory, and any significant anomaly affecting the spacecraft's propulsive capability will need to be quickly resolved, in order to avoid impact at the subsequent flyby, which would occur approximately 14 days later;
  - Keeping the options for launch vehicles open for longer than Preliminary Design Review (PDR) drives design, and carries cost and schedule risks.

MCR Findings (6 of 7) Continued

- Project comments on finding:
  - The Project is very concerned about the possibility of a two-step instrument selection and the strain it will put on the existing team, as well as consequences of attempting to integrate payload teams while they are themselves embroiled in a competition.
    - In addition to the payload system engineering team, which grows to approximately 7 at the step-1 selection, the Project System Engineering team has allocated 8 FTE’s, Spacecraft team has allocated 11 FTE’s and the Mission Assurance team has allocated 2 FTE’s to support this activity
  - The Project recognizes the need to have a more holistic set of autonomy requirements addressing system safety which will integrate into the planetary protection planning
    - We have been working these issues independently and will integrate and present them at MDR
  - Selection of the final launch vehicle sooner is better, however the Project does not want that to eliminate the SLS prematurely
    - The ELV options are more demanding, thus the work to leave the SLS on the table is mainly borne by the Mission Design Team
    - Currently it is unclear if the Project could take advantage of the Delta IV Heavy shorter cruise without significant S/C modification. If that is the case, unless the Atlas 5 is removed, we will maintain one S/C design reducing the time of flight advantages of the Delta.

MCR Findings (7 of 7)

- The SLS launch vehicle is a far superior and the optimal solution for the Europa Clipper mission, followed by the Delta IV-H and the Atlas V551
  - The SLS reduces time of flight by ~3 years, and reduces complexity in system design and operation considerably by eliminating the need for multiple gravity assists and Venus flyby
  - The review team therefore recommends that a detailed plan be developed to specifically address each of the individual issues associated with space policy and certification towards an SLS solution