Jet Propulsion Laboratory
California Institute of Technology

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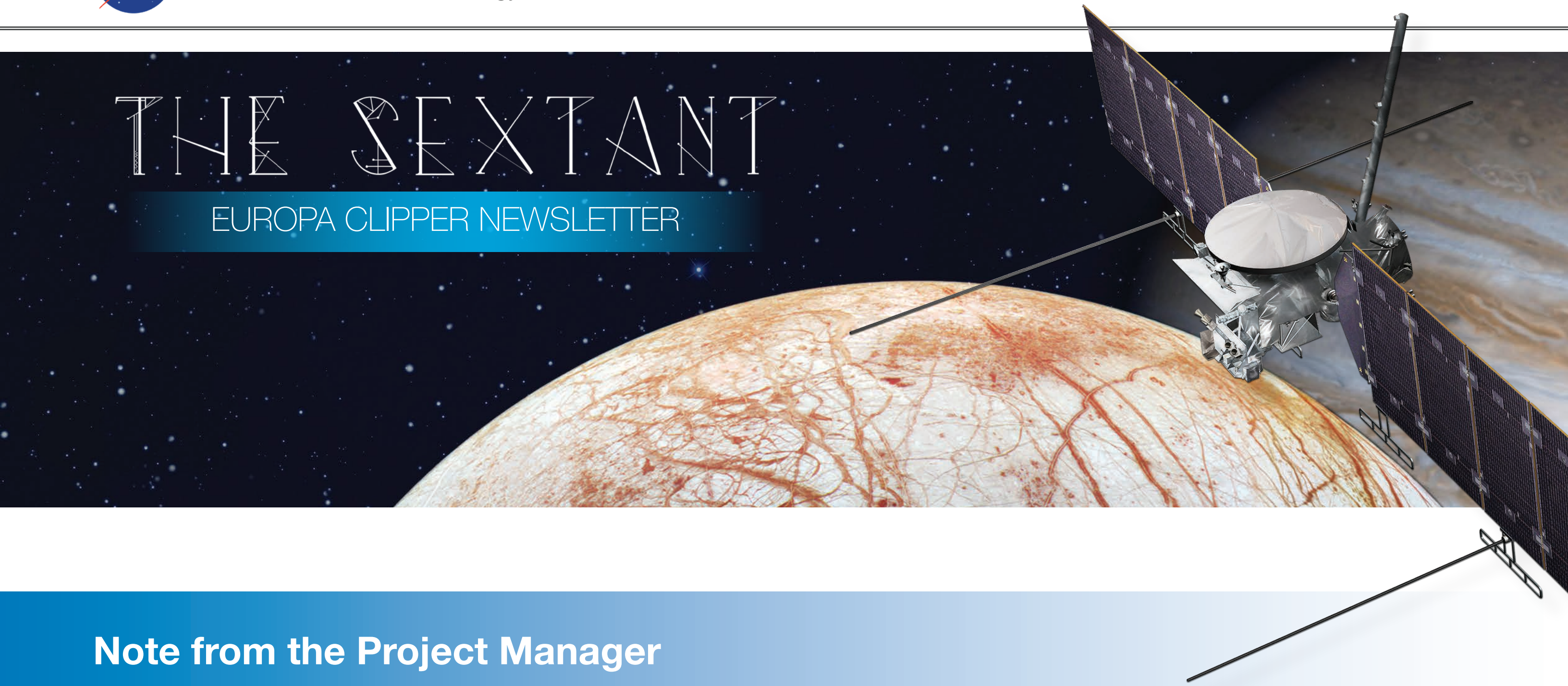


Note from the Project Manager

By Barry Goldstein

Friday, May 11th marks the T-100 day to our Project Preliminary Design Review (PDR). While this is only one in a litany of reviews that have been conducted over the past ten months, the milestone is significant. Successful completion of this review and concurrence from NASA headquarters will place us formally into our implementation phase. To celebrate the end of "PDR Season" we are planning a Project BBQ on the afternoon of Friday, August 24th after the conclusion of the PDR. Look for the announcement from Yvonne Chen in the coming weeks.

We continue on the path for a 2022 launch with the launch period opening in a little more than four years, on June 4th, 2022. A mere 1,487 days from the time I am typing this note (35,688 hours or 2,141,280 minutes including leap days, for those who are counting). Several events have increased our likelihood of holding that date. Locally, our funding for fiscal 2018 has been received, and it was in excess of our requests for the current year. This excess, which will roll into 2019, increases the probability, however not the guarantee, that next year's funding request for the 2022 launch will be received as well. This is significant in that fiscal 2019 is our peak funding year for the 2022 launch. In addition, things look more promising on the launch vehicle front. While it is true that we have not been assigned a vehicle, two events brighten the horizon for us. First, the successful launch of the Falcon Heavy has now added a second EELV to NASA's inventory which is capable of sending us to Jupiter, albeit on the long cruise. While the Delta-IV Heavy has been an option for some time, this second vehicle removes some of the selection constraints from headquarters with only one vehicle. Even more encouraging is the projected performance improvements we have seen from the SLS Block-1 vehicle. Prior to this increase we needed the SLS Block-1B to send us on a direct trajectory to Jupiter. The Block 1B however, relies on the development of a new upper stage, which would pose schedule risk for our 2022 launch. This development along with increased commitment to multiple launches of the Block-1 brighten our path to 2022.

Of course, we have our own development challenges to hold schedule. However, even in some of our more difficult areas, significant progress has been made in the past few months. After a slow start, the integration of the REASON antennas on the Solar Arrays now have a path, albeit a difficult one, forward. No one on the Project team is blind to these challenges, and it is likely to remain our most difficult issue for some time to come. The results of a tiger team have garnered significant maturity of the design and architecture of the ICEMAG / ICEMAG Boom, and while their pending PDRs will no doubt reveal other issues, there is a strong baseline with which to move forward. On the very near horizon (now) are issues of contamination control. Our in-situ investigations are state of the art science instruments. As such, they will drive our cleanliness requirements to endeavors perhaps never taken on any previous planetary spacecraft. I expect that closing on this significant goal will take patience, understanding and compromise on many fronts to make our way forward.

Overall, congratulations to all of you, as while no Project is ever in perfect shape for PDR, I think we are doing extremely well. Looking forward to seeing you at the BBQ!!!!

Project News

By Tim Larson

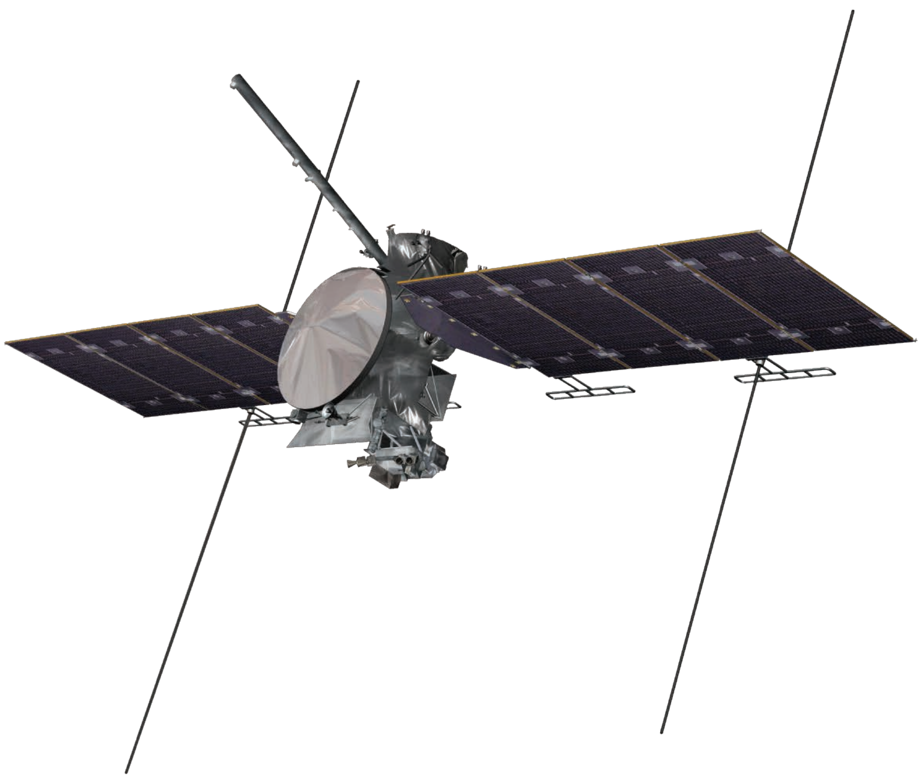
The Preliminary Design Phase of the project continues at full speed. It seems like every week hosts either a peer review or a PDR. Most of the subsystems and instruments have already held their PDRs, and as usual, the review boards provide plenty of helpful feedback (and Requests for Actions). At the project level, the teams are very busy, finalizing all the gate products that are due prior to the project PDR. In the process, we are updating requirements as the subsystems and instruments continue to mature their requirements and designs for their own reviews.

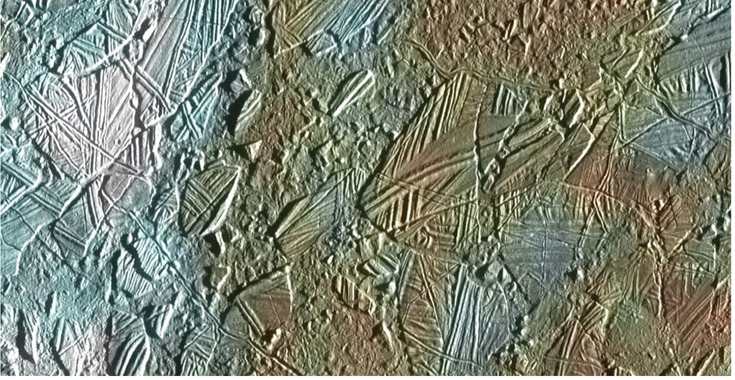
The accommodation of the REASON antennas on the edge of the solar array continues to be a technical challenge. There are the usual issues of understanding the loads imparted by having the four large VHF antennas attached to the edge of the panels - a concern mainly during launch, and the associated design to account for the CTE difference between the metal fittings and the composite panels. The solar array team is also studying how to deal with the stiffness of the coaxial cables that carry the radar signals between the body of the spacecraft and each antenna. The panels themselves need to be designed so they are conductive enough to not interfere with the radar signals. And finally, the performance of this large and complex arrangement needs to be verified. All of these are complex, cross-cutting challenges, and the teams are working diligently to address them. The Integrated Product Development Team pulls all the affected areas together into a combined working group. These key design challenges have resulted in moving the Solar Array PDR to September (yes, that is after the Project PDR). This will be followed in a few weeks by the Integrated Wing Review that will combine the results of the previous REASON PDR and the SA PDR to address the cross-cutting issues. This approach will allow the project time to incorporate the results into the plan forward prior to the KDP-C gate to Phase C.

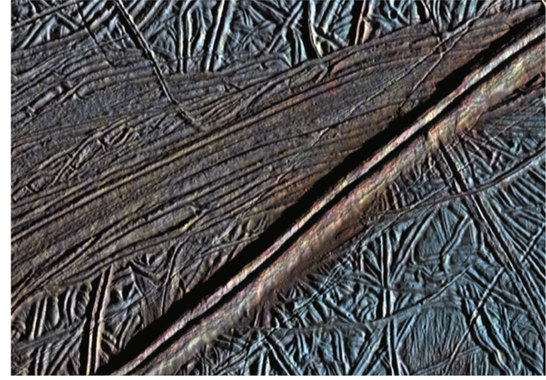
This is just one example of many issues that various teams are addressing in the process of designing a large and complex flight system headed to a very hostile environment. The 'Hot Topic' article addresses the interesting challenge of the thermal control of this large vehicle and the 'One Science Team' article describes how the science team is addressing the scientific complexities of exploring our exciting destination.

Several PDRs remain as we go through the next few months leading to the Project PDR. The current dates for these are shown in the following table. Note that there is an early Critical Design Review (CDR) in the list due to the long lead needs of the Propulsion Subsystem. Just a few months after the Project PDR we kick off the bulk of the CDR season, starting up in November of 2018 culminating in the Project CDR a year later.

PDR	Date
Fault Management	May 21–22
ICEMAG	May 23–24
Magnetometer Boom	May 30–31
Radiation Monitor	May 31
Harness	Jun 15
Mission System	Jun 19–21
Prop SS CDR	Jun 26–28
Project	Aug 20–24
Solar Array	Sept 3–4
Integrated Wing Review	Nov 13–14







One Science Team

By Bob Pappalardo, Europa Clipper Project Scientist

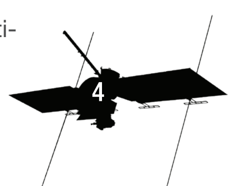
Europa is an enigmatic world. To understand whether Europa is potentially habitable, we need to disentangle the complex and interrelated processes that can reveal whether it has the "ingredients" for life. We need to know the location and properties of liquid water, including its relationship to tidal heating, the movement of melt, and the composition of brines. Whether Europa's chemistry is suitable for life can come from detailed measurements of the surface and tenuous atmosphere, including remote and in situ measurements of the surface, gases, particles, and plasma. Whether Europa's ocean has the chemical energy to support life requires understanding the geological, geochemical, and radiolytic processes that create surface oxidants and seafloor reductants and transport them to the ocean. For humans to discern Europa's secrets, synthesis is key.

If a friend were to come down with mysterious flu-like symptoms, you'd probably offer advice to visit their doctor. Perhaps the next steps would be to visit an allergist, an immunologist, an endocrinologist, a rheumatologist, a gastroenterologist, a pulmonologist, an otolaryngologist.... Each specialist might prod and poke the patient in different ways, recommending detailed exams via blood tests, X-rays, ultrasound, MRI, fluoroscopy, or even biopsy. A specialist has the skills to provide critical clues as to the bigger problem, but if symptoms are especially interrelated and complex, they need to mutually communicated, analyzed, and synthesized into an integrated picture. Only then can there be comprehensive understanding, and holistic plans prepared for the future.

Each of the nine Europa Clipper instruments will poke and prod Europa and its environs, each finding critical clues about how that planetary body works. In combining and assessing the details, limitations, and datasets from each instrument's experiments, we can collectively gain clarity into the multi-disciplinary mysteries of Europa. To achieve our mission's goal of exploring Europa to understand its habitability, we are compelled to step beyond the comfort zone of our own scientific discipline, to celebrate and engage the expertise of our colleagues. As is often true in science, it is at the overlapping boundaries of our sub-fields that the greatest insights and discoveries will be made.

Integrated science is promoted by visibility across the science team. Visibility includes understanding each other's processes, techniques, data sets, analyses, caveats, and results. Integration and its associated visibility also provide holistic solutions to problems that could arise. If in the future some Europa Clipper investigation is at risk of not achieving its contribution to a science objective, then informed representatives of other instruments will be more readily motivated to offer resources, tangible or intangible, to ensure success for the at-risk technique's contribution to the greater whole. Our Europa Clipper science team's Rules of the Road codify visibility and integration, for example through the sharing of collaborative data among all of the science team members and by calling for coordination of manuscripts in preparation. These rules are meant as a common covenant—an ethos shared among partners in exploration.

Integrated science celebrates our individual expertise, challenges our assumptions, breaks through our limitations, and expands our intellectual boundaries. Associated visibility brings trust, promotes partnerships, and enhances personal relationships. These aspirations are the inherent basis for functioning as one science team. They say "it's all about the journey," so let's make this a great one, for the good of our science, and our mission.



A hot topic: The Europa Clipper Heat Redistribution System

By Jason Kastner and A.J. Mastropietro

The core function of the thermal subsystem is very easy to understand: its purpose is to ensure all the hosted components stay within an acceptable temperature range despite the widely varying thermal environments experienced by the flight system as it travels close to and far from the Sun. Making sure that the flight system temperatures are correct is a complicated task that involves applying, collecting, redirecting, and rejecting heat at all levels.

The key to enabling an efficient thermal control system for Europa Clipper is the Heat Redistribution System (HRS). The HRS can be thought of as the heart and circulatory system of the warm-blooded Europa Clipper spacecraft. The HRS consists of tubes filled with a refrigerant (in this case CFC-11, colloquially called Freon) that reclaims waste heat from the vault components and moves it to the propulsion module to keep it warm. Heat is transferred to and from the CFC-11 via special flanged aluminum tubing extrusions that are bonded to the structure supporting the equipment that is dissipating or needing heat. This fluid is pushed through the ~100m of tubing by a brushless DC centrifugal pump with a 1.5 liter per minute capacity. A similar pump was used on the Mars Science Laboratory Cruise Stage and Rover, and the testbed for both of those setups was taken over by Europa Clipper. As of this writing, the testbed pump has been operating for over 100,000 hours, while the pump onboard Curiosity's Rover has been in operation for over 50,000 hours!

Items that are not part of the HRS fluid loop are controlled via more traditional passive means (like blankets and thermal control coatings) and may employ survival and operational heaters. While a valid architecture approach is to use only local heaters to warm all the colder areas, numerous trade studies and architecture reviews for Europa Clipper have concluded that the HRS requires much less power, while still being compatible with a volume constrained vault with a dense packing ratio of equipment.

There are times when components within the vault are not turned on and supplying all the necessary heat required by the propulsion module. In this case a Replacement Heater Block (RHB) inserts heat into the CFC-11 which is then transferred throughout the rest of the propulsion module. On the flip side, excess heat is transported to and rejected overboard via a central radiator (~1.3m2) on the nadir side of the spacecraft. In order to conserve power, the HRS design uses two passive mixing valves in series to essentially cut off all fluid flow through the radiator circuit. This radiator turn-down capability will be especially important at Jupiter; when the spacecraft is over 5AU from the Sun, the system is power starved and every Watt is precious.

Instrument Highlights

EIS is moving ahead with an updated gimbal design after a successful review on May 4. The foundry run of the flight 4k x 2k detectors is complete and they are undergoing testing. Fabrication of flight filters is underway.

E-THEMIS successfully completed their PDR in April.

Europa-UVS received the EM detector and electronics and are integrating them into the EM unit.

ICEMAG team is conducting brassboard testing through Fall, 2018 and currently conducting radiation test on candidate fiber optic fibers. Instrument PDR is on track for May 23-24, 2018.

MASPEX successfully completed TRL maturation activities on their triode pump and vacuum door assemblies in preparation for their PDR

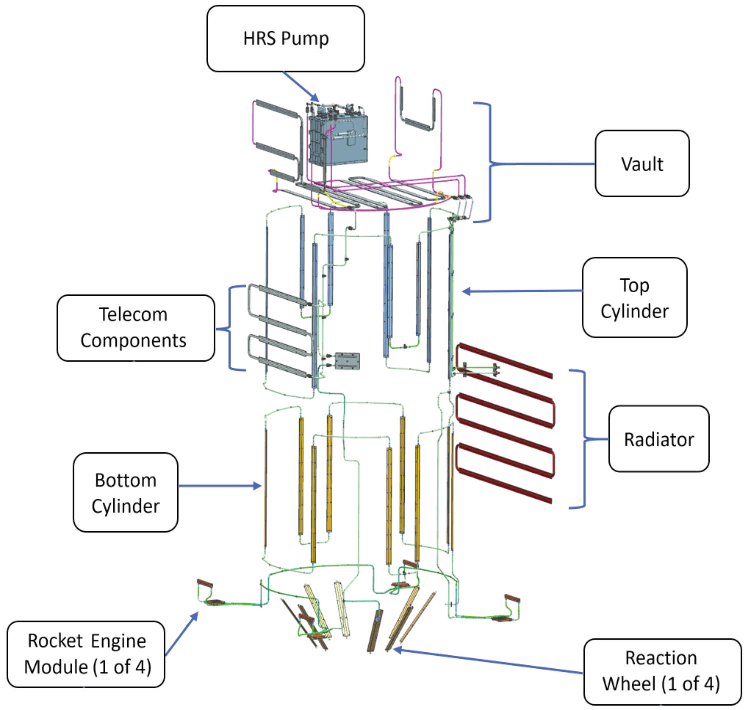
The **MISE** instrument PDR was held in April. EM development is proceeding with the first EM boards fabricated. MISE has also performed initial closed loop scan mirror testing.

PIMS has completed its Engineering Model design, which has been released and is in fabrication.

REASON matching network qualification testing at cryogenic temperatures has completed. Data analysis is ongoing; however, it is anticipated that heater power can be eliminated from these electronics. REASON held their instrument PDR in March.

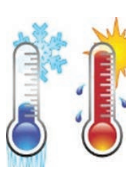
SUDA has finished another round of dust accelerator testing with the SUDA lab prototype instrument. "Clean" mass spectra were generated using a newly fabricated full-scale iridium target, which provides additional confidence in the in-house Ir coating process. Additionally, data from this test will be used to correlate ion optics performance models.

By being able to maintain both science and engineering equipment within safe operating and non-operating temperature limits throughout the life of the mission, the HRS will keep Europa Clipper not too hot and not too cold, but just right.

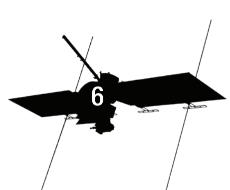


The Europa Clipper HRS Circulatory System

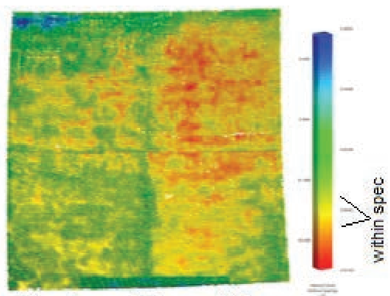
Fun Fact



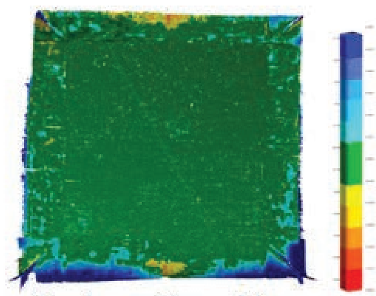
The typical electronic box inside the Europa Clipper spacecraft is required to function properly from 4°F to 122°F (-20°C to 50°C). This is the equivalent of expecting your laptop to work perfectly, whether outside in Fairbanks, AK in the middle of winter, or in Death Valley, CA on the hottest day of the summer.



Spacecraft Highlights



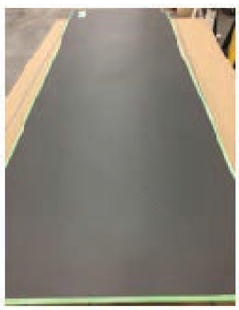
Surface Error Map (before sanding)



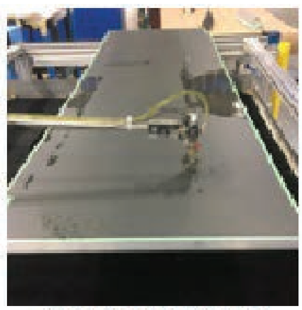
Surface Error Map (after sanding)

The radio frequency (RF) subsystem team is completing resurfacing of the reflector at the LaRC test range used for High Gain Antenna (HGA) testing. The images show the before and after surface measurements, illustrating the effectiveness of the "prime and sand process."

"Bagged" Sandwich Panel

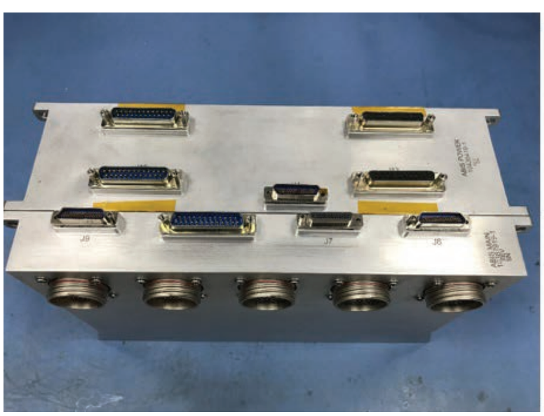


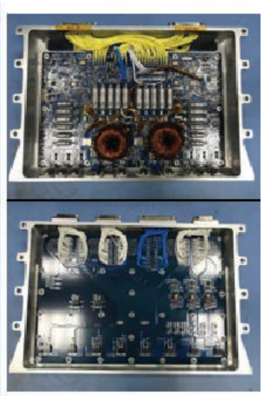
Post Cured Sandwich Panel



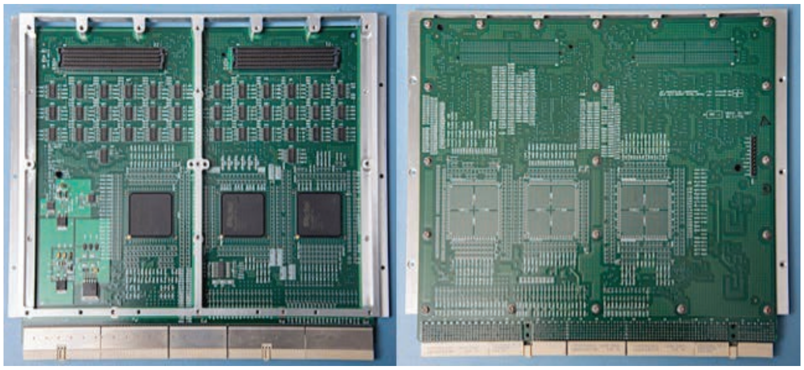
Sandwich Panel being inspected for Voids

The HGA vendor has completed initial fabrication of the composite coupons, with the various stages of fabrication and inspection shown in the photos.



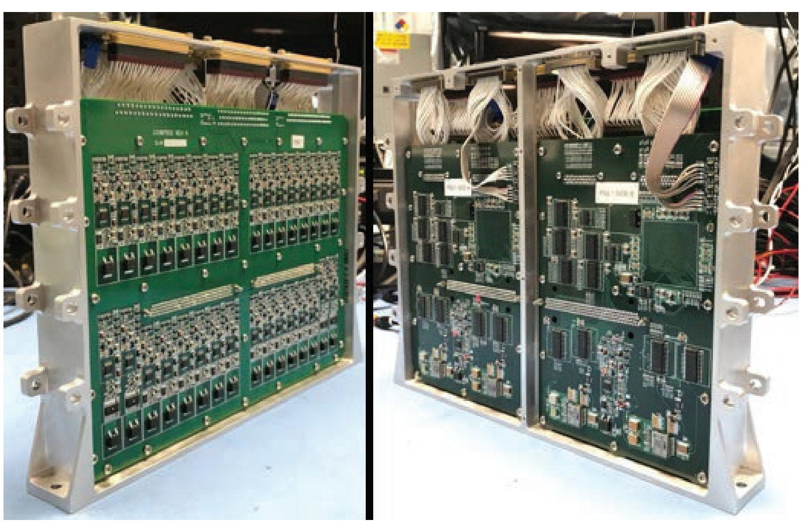


The Power subsystem team has completed testing of the Array Battery Interface Slice (ABIS) breadboard, showing good power sharing across the three regulators



We received the first prototype version of the Bulk Data Storage Manager (BDSM) board.

The Propulsion Module Electronics (PME) team has completed the build of the Mezzanine card for the PME, shown in initial bench top testing.



The Power subsystem team has completed the build and is proceeding with bench top testing of the Power Switch Slice assembly.

Fun Photos

U.S. Representative John Culberson (Texas), Chairman of the Appropriations Subcommittee on Commerce, Justice, and Science, wears a Europa Clipper shirt during a recent visit to JPL.

Brent Buffington chills his water bottle and explores an icy world during a recent heli-skiing trip in Alaska.

Team Member Profiles

Xianzhe Jia
Co-Investigator, ICEMAG and PIMS
University of Michigan

Sumita Nandi
Navigation Lead
Jet Propulsion Laboratory, California Institute of Technology

Bob Pappalardo
Project Scientist
Jet Propulsion Laboratory, California Institute of Technology

Samantha Walters
Mission Design
Johns Hopkins University, Applied Physics Laboratory

Team Additions and Changes

Brian Cooke (JPL) Project Chief Engineer
Michael Davis (SWRI) Europa-UVS, Instrument scientist
John Day (JPL) Acting Project Systems Engineer
David Humm (APL) EIS, Calibration lead
Laura Jones-Wilson (JPL) REASON-Solar Array, Integrated Product Team Systems Engineer
Caroline Racho (JPL) REASON, Instrument Engineer
Ujjwal Raut (SWRI) Deputy Instrument Scientist
Vanessa Sanders (JPL) Lead Project Cost Analyst
Marsha Schwinger (JHU/APL) Deputy Project System Engineer
Christine Walker (JPL) Spacecraft Lead Cost Analyst

Events Calendar

A Ticket to Explore JPL	June 9-10	JPL
Europa Clipper Project Science Group (PSG) #6	June 12-14	JPL
Committee on Space Research (COSPAR)	July 14-22	Pasadena, CA
JUICE Europa Clipper Science Workshop	July 14-22	Pasadena, CA

Recent Awards and Publications

Dr. Rachel Klima, project staff scientist on Europa Clipper at Johns Hopkins University, Applied Physics Laboratory, earned NASA's Susan Mahan Niebur Early Career Award.

The Sextant Editorial Team includes Brent Buffington, Jason Kastner, Roger Kuch, Tim Larson, Courtney O'Connor, and Cynthia Phillips.

The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.