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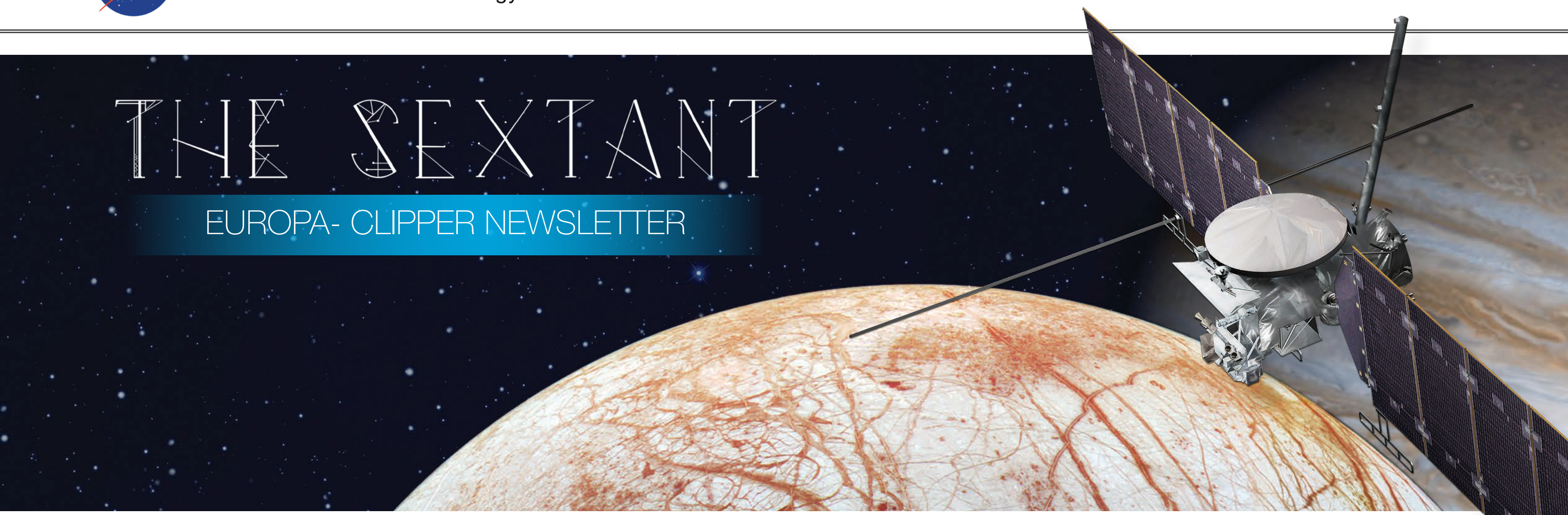


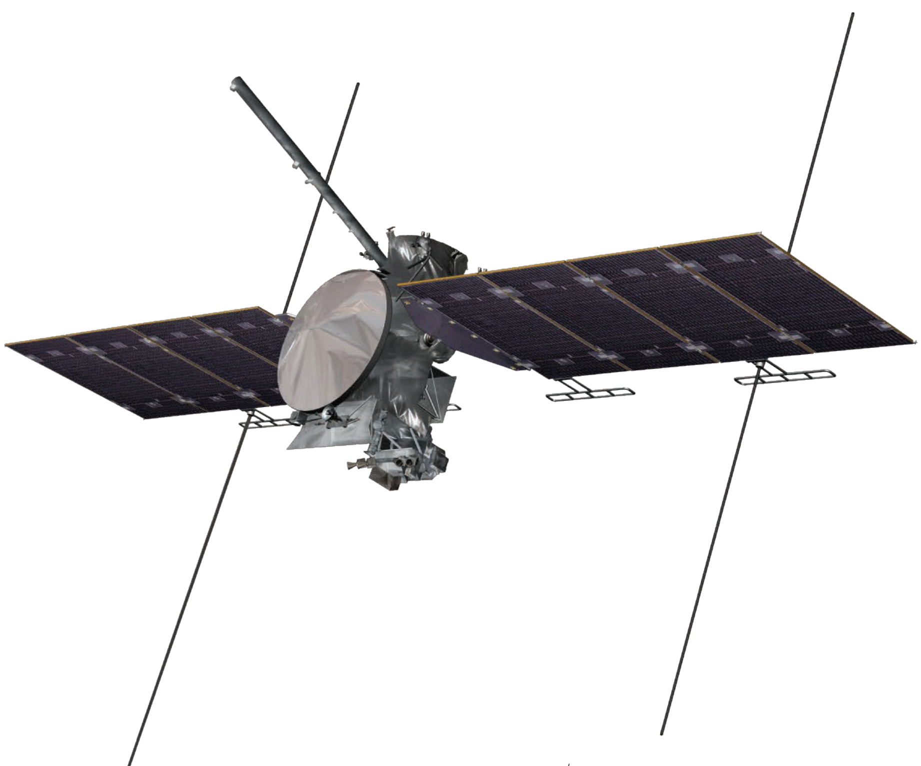

## Project News

The Europa Clipper project team continues to grow as we move into more detailed design of the equipment, and it is gratifying to see such a geographically distributed team work well together. The map below shows all the major organizations that are currently contributing to the project, not including the array of companies providing parts and components for the various instruments and subsystems.


We are a little over half way through Phase B of the project and, as Barry mentioned, PDR season is well under way. In 2017 we completed the PDRs for the Propulsion Subsystem, Propulsion Module Electronics, and the Propulsion Module on the spacecraft side, and the Europa UVS and PIMS instrument PDRs. After a brief year-end break, we jumped back in with the EIS and SUDA instrument PDRs and the Power Subsystem PDR. The systems engineers are busy updating the requirements flow down and interface control documents for each instrument and subsystem

as each approaches their review date.  Many PDRs remain as we go through the next several 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 |
|---|---|
| Mechanical | Feb 20 - 22 |
| Thermal | Feb 27 & 28 |
| RF | Mar 14 & 15 |
| REASON | Mar 26 & 27 |
| Mag Boom | Apr 9 & 10 |
| ICEMAG | May 23 & 24 |
| RadMon | Apr 17 |
| E-THEMIS | Apr 19 & 20 |
| MISE | Apr 24 & 25 |
| Avionics | May 7 - 10 |
| MASPEX | May 15 & 16 |
| Fault Mgmt | May 21 & 22 |
| Harness | Jun 15 |
| Mission System | Jun 19 - 21 |
| *Prop SS CDR* | *Jun 26 - 28* |
| Solar Array | Jul 10 & 11 |
| Project | Aug 20 - 24 |



## Spacecraft Highlights

**Sodern has been selected as the Clipper Stellar Reference Unit (SRU) supplier**

**The Power Subsystem successfully passed its PDR in January**

**A Requirements Review for the Solar Array was held in January to support the buy of the full solar array from a subcontractor, Airbus Defense and Space Netherlands (ADSN). ADSN is now on contract for the co-engineering phase of the solar array development.**

**Keystone was selected as the propellant tank supplier**

**Mario Mora has been appointed System Integration and Test (SI&T) Manager**

# "Weigh Your Options Carefully"

By Brent Buffington and Jason Kastner
Jet Propulsion Laboratory, California Institute of Technology

With the beginning of a new year comes the opportunity to set new goals and resolutions for the year ahead. One very common New Year's resolution is to lose weight. While the Europa Clipper project hasn't formally declared a similar goal, the mass of our flight system continues to be the top topic of conversation anytime a flight system configuration change is proposed. This is because the flight system is on strict orders to not exceed a very precise total mass, namely 6001 kg. The derivation of this number stems from the strategy for the entire Project System to be compatible with launching on either NASA's Space Launch System (SLS) rocket or a commercially available heavy lift Expendable Launch Vehicle (ELV) in launch years spanning from 2022 to 2025, inclusively. Due to the very different capabilities afforded by the different launch vehicles, vastly different interplanetary trajectories are needed to reach Jupiter with sufficient mass to successfully execute the planned scientific interrogation of Europa. The SLS provides the capability to travel directly to Jupiter, whereas the largest non-SLS ELVs would require our spacecraft to circumnavigate the inner solar system for an additional 4-5 years to attain enough energy (via Venus and Earth gravity assists) to reach Jupiter. For a given launch year, each interplanetary trajectory will have a maximum specific energy (C3) across a 21-day launch period to escape Earth's gravity well and place the flight system on a trajectory to ultimately reach Jupiter. Given this C3 value, the injected wet mass (the total mass of the launched spacecraft including on board propellant) can be determined directly from each launch vehicle's performance curve. Finally, to guarantee compatibility with all aforementioned launch options, a single "not-to-be-exceeded" injected wet mass value for the flight system would simply be the minimum value of the set of injected wet masses.

But of course, it's not quite this simple. This is because in late 2016, the project needed to select the size of the propellant tanks in order to move out on procuring the tanks and building the propulsion module to be ready for a 2022 launch. And here's the kicker: the selected tank capacity limits the injected wet mass of the flight system. That is to say, we are not fully taking advantage of the launch vehicle capabilities to maximize the flight system "dry" mass (i.e., without propellant) due to the fact that for a given Maximum Expected Value (MEV) ΔV budget, a flight system with fully loaded propellant tanks can only push a finite dry mass through that ΔV. Now, like many decisions in our business, things are rarely clear-cut and straightforward. While the Spacecraft and Payload offices would love to have much more dry mass, it comes at the cost of additional propellant to push it through the MEV ΔV budget. The more propellant mass we load, the larger the tanks need to be, and the larger the tank, the higher the amount of energy that is needed to keep the propellant tanks warm as the flight system extends its range to over 800,000,000 km from the Sun during the course of the mission. More energy requires larger solar arrays, and the larger the arrays the larger the Reaction Wheel Assembles (RWAs) need to be (which also would require more power!) and the more complicated and difficult (read: expensive and expensive) the design, fabrication, assembly, testing, deployment and the in-flight operations of the integrated flight system becomes.

In the end, the propellant tank capacity was selected to be 2750 kg. Given this capacity and the launch scenario with largest ΔV budget (this determines the single not-to-be-exceeded wet mass), a maximum wet mass of 6001 kg was derived. With 2750 kg of the 6001 kg already accounted for as propellant, the remaining 3251 kg is broken down into 3241 kg for the flight system dry mass and 10 kg for the propulsion system helium pressurant. The dry mass of the flight system has been further broken down, with 2616 kg allocated to the spacecraft, 352 kg allocated to the payload, and the remaining 273 kg (8.4% of the total dry mass) as project reserve from which the Project Manager can deploy as he sees fit. Finally, the spacecraft and payload allocations are broken down into allocations for each instrument and subsystem, and in some cases, even sub-allocated down to the individual box level. Figure 1 illustrates the breakdown of mass for the Europa Clipper mission.

JPL Design Principles dictate a specific mass margin profile as a function of time in the project lifecycle–based on decades of experience–in order to responsibly manage the risk of not exceeding the mass capabilities of the system such that the mission can't be launched. The Europa Clipper project tracks and manages these mass margins in part by monitoring the Current Best Estimate (CBE) and the MEV masses. The CBE is the engineer's best judgment of what the mass of the delivered item is, while the MEV adds on a contingency factor to the CBE. Contingency is based on historical trends, typically expressed as a percentage of the basic mass estimate and as a function of the design/verification maturity.

But what happens when, like now, the MEV (or even CBE) of a system or sub-system is larger than its allocation?

There are a few ways to address the problem, and these typically vary depending on the stage of the project. Of course, one way is to simply increase the allocation to the system of concern, but this is generally done as a last resort. Mass is precious and every gram disbursed in one area is a gram that can't be utilized on a potentially worse problem in the future. Another way is to examine the contingency factor more closely because it may be that the maturity of the item is such that the contingency for unknowns doesn't need to be as large. This particular approach is being done now and as part of the Preliminary Design Review process it is expected that each area examine their contingency factors and update (read: lower!) them to reflect the increased design maturity. Yet another approach is to change the design itself, which could entail options such as using lighter weight materials (titanium fasteners instead of steel), more efficient structures, or even just fewer parts.

Finally, an additional mechanism to relieve pressure on potential dry mass problems is to have Mission Design reduce the MEV

## Instrument Highlights

**The EIS team is moving ahead with detailed designs following their successful PDR in January. Testing of the EIS color filters shows good performance, and EIS has received the thinned, BSI (backside-illuminated) 4k x 2k detectors for testing. The detectors and filters are being packaged for the EIS Engineering Models (EMs), and the foundry run for the flight detectors is underway.**

**E-THEMIS completed its electronics design and configuration effort to accommodate the RVS detector and minimize radiation shielding and mass.**

**Europa-UVS passed its PDR last November 2017. The Europa-UVS is now developing its EM hardware with testing started on EM Command & Data Handling, Low Voltage Power Supply, and High Voltage Power Supply boards.**

**ICEMAG began testing optical fibers at low temperature to characterize their performance. The team confirmed operation of a flight-like fluxgate sensor at -125C° as the first step in exploring feasibility of a lower operating temperature. The team received helium cells for its brassboard instrument model.**

**The MASPEX team completed the fabrication and assembly of the EM mass spectrometer (MS) then performed pre and post vibration testing as a means of risk reduction for the proto-flight Flight Model (FM) development.**

**MISE successfully completed vibration testing of the cryocooler (part of the technology maturation plan for the cooler).**

**PIMS held a successful PDR in early December 2017 and is progressing into EM design.**

**The REASON matching network qualification testing is ongoing and is now starting thermal cycles to cryogenic temperatures. If successful, REASON will be able to eliminate heaters from extra-vault electronics. The team conducted a partially deployed test of the High Frequency (HF) antenna at the Keysight test range in Iowa. The contract to build the REASON Digital and Power Unit (DPU) is now in place with L3.**

**SUDA has achieved TRL-6 on both its technology maturation efforts: the iridium coated impact target and the electron multiplier detector. Both the target and the detector have been environmentally tested, integrated into the SUDA prototype sensor head and performance tested in LASP's electrostatic dust accelerator facility. The instrument PDR was successfully completed in late January 2018.**

ΔV for the driving case(s) that dictate the maximum flight system dry mass. By reducing the ΔV, more of the injected wet mass is available as dry mass. As such, the Mission Design team is constantly performing detailed trades and analyses to identify potential ways to decrease the MEV ΔV budgets for all relevant mission scenarios.

So, while many potential avenues to mitigated mass problems exists, extra mass cannot be plucked from the ether. That is why the most important approach is for each instrument and subsystem to create an efficient mass (and energy) design.

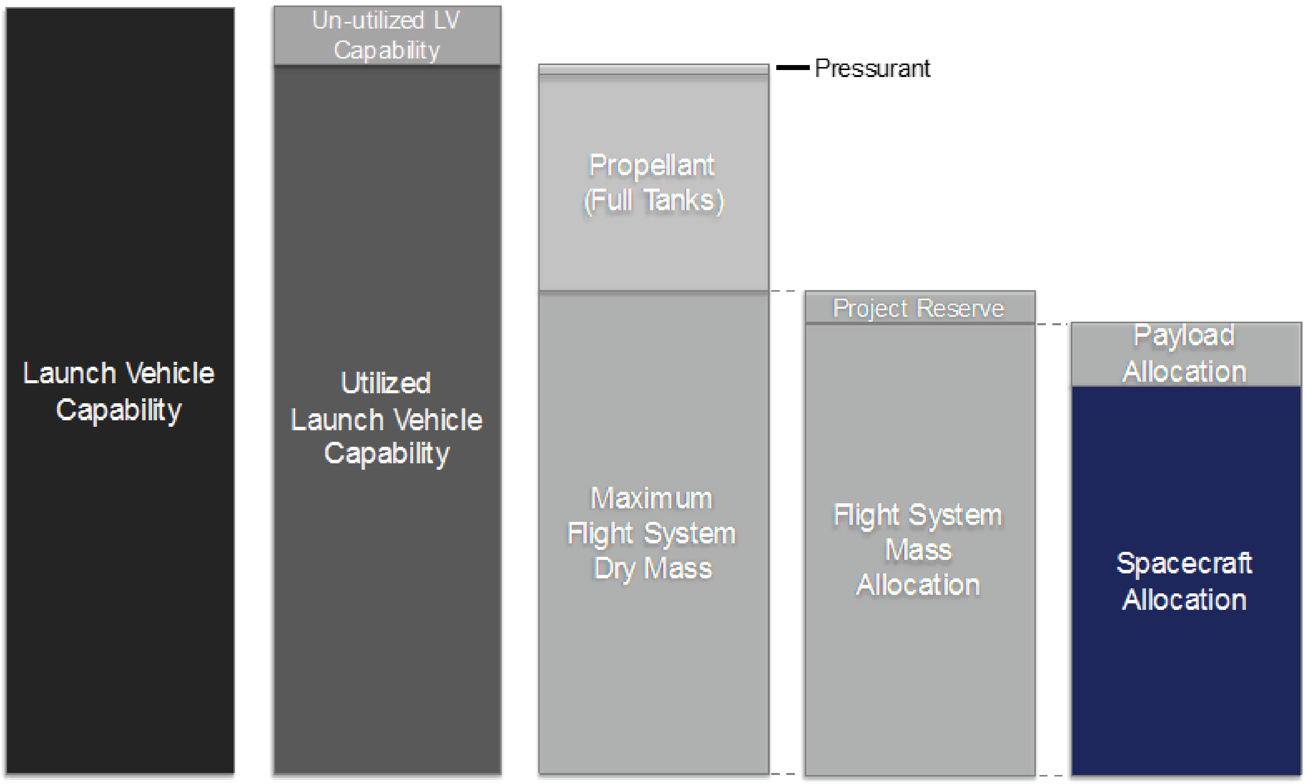



**Figure 1**: Compositional breakdown of the total injected wet mass.

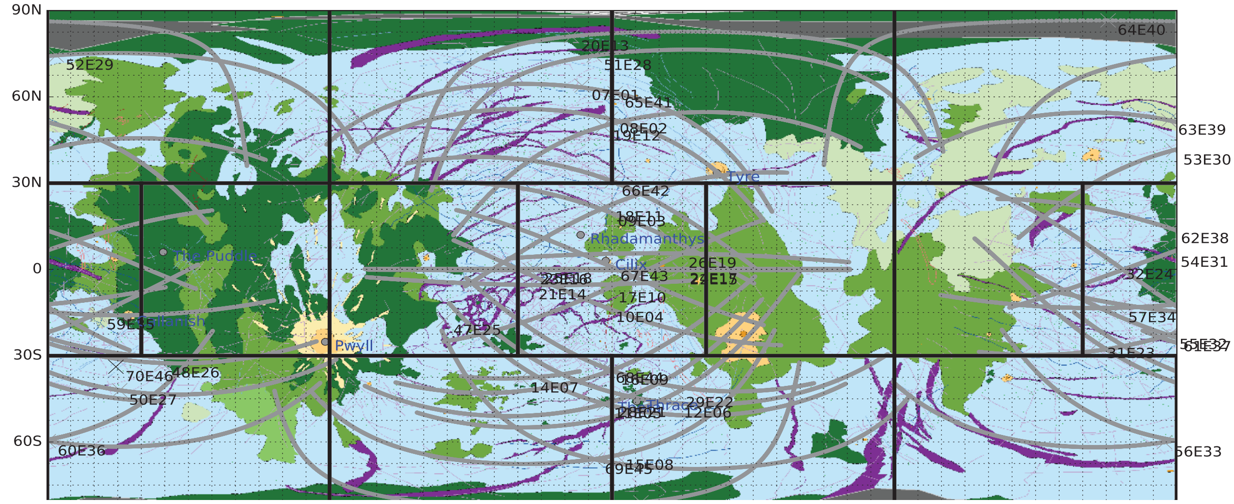
## New Europa Geologic Map


By Cynthia Phillips

Jet Propulsion Laboratory, California Institute of Technology


Deputy Project Scientist Dave Senske, along with graduate student Erin Leonard (UCLA) and JPL affiliate Alex Patthoff (Planetary Science Institute), have recently completed a new global geologic map of Europa, which is currently in peer review. This new geologic map is being used by the Europa Clipper Geologic Thematic Working Group (TWG), co-chaired by Geoff Collins and Julie Rathbun, to evaluate the current Europa Clipper trajectory and its coverage of representative landforms (Collins, G. C., et al., LPSC 2018, abstract #2625). The image below shows the geologic map overlaid by the 17F12_V2 Europa Clipper ground tracks at <1000 km altitude (gray curves). In the geologic map, blue areas are plains that are dominated by ridges, while purple areas are bands, and orange and yellow colors are associated with impact craters. Chaos, pits, domes, and dark plains are most strongly concentrated in the green areas, but small examples are also found outside these regions. Along the highlighted ground tracks, the remote sensing instruments will obtain pixel scales of: Europa-UVS <1 km, EIS- NAC <10 m, EIS-WAC <220 m, MISE <250 m, and E-THEMIS <340 m. REASON obtains along-track profile spacing of <10 km on these ground tracks.

The initial evaluation by the Geology TWG shows that the planned Europa Clipper ground tracks offer a robust and diverse selection of terrain related to our current understanding of Europa geology. Features not covered by these close-range nadir observations will be observed by more distant remote sensing observations, outside of the close-approach time period. As the Europa Clipper trajectory continues to evolve, this analysis can be updated as well.




## Staff Member Update

The Europa Clipper project is pleased to announce the following new staff members:

**Shawn Brooks** joins us as the new Investigation Scientist (IS) for the Europa-UVS. Shawn did his undergraduate work at Rice University, and his graduate work in planetary science at the University of Colorado; he is an IS on Cassini and is an Instrument Operations Systems Engineer for Juno. (Note that former Europa-UVS IS and Cassini Deputy Project Scientist Scott Edgington is devoting his energies to leading the Saturn portion of the Cassini mission close-out.)

**Roger Kuch** joins us as a Staff Assistant for Europa Clipper. Roger received his undergraduate degree from UCSD and obtained a Master of Fine Arts in Theatre from Harvard University. His background extends from Bioengineering and Law to Theatre Production and Event Management.

**Ocean Mcintyre** joins us as a Europa Clipper Science Assistant. Ocean has a background in science writing and outreach, and she has previously worked for the Planetary Society.

**Mario Mora** joins us as the System Integration and Test (SI&T) manager. He has served in deputy section manager roles, group supervisor roles, and has worked on various flight and technology projects. Major areas of expertise are in Integration and Testing (I&T), Verification and Validation (V&V), and Operations. His experience spans the Formulation, Implementation, and Operations phases for both technology and flight projects.

**Sylvain Piqueaux** joins us as the new Investigation Scientist (IS) for E-THEMIS. Sylvain did his undergraduate work at the University of Paris and his graduate work in planetary science at Arizona State University; he is an expert in thermal infrared data analysis and thermophysical modeling with experience in observation planning for the THEMIS instrument on Mars

Odyssey. (Note that former E-THEMIS IS, Paul Hayne, has taken a faculty position at the University of Colorado so can no longer serve as IS, but he continues as a Co-Investigator on E-THEMIS.)

**Christina Richey** joins us as a Project Staff Scientist, specifically devoting her energies to Project Science Group meetings and Thematic Working Group activities. Christina did her undergraduate work at Wheeling Jesuit University and her graduate work in physics at the University of Alabama, and she previously worked as a Program Officer at NASA Headquarters. In 2015, Richey received the prestigious Harold Masursky Award for Meritorious Service to Planetary Science from the Division for Planetary Sciences, for her significant contributions to fostering equal opportunity, diversity, and inclusion in planetary science.

## Events Calendar

Your guide to upcoming conferences, meetings, and public events.
Submit calendar items by email to oconnor@jpl.nasa.gov

| | | |
|---|---|---|
| Lunar and Planetary Science Conference (LPSC) | March 19–23 | The Woodlands, TX |
| Europa Clipper Mini-PSG at LPSC | March 23 | The Woodlands, TX |
| USA Science & Engineering Festival | April 7–8 | Washington, D.C. |
| A Ticket to Explore JPL | June 9–10 | JPL |
| Europa Clipper PSG #6 | June 12–14 | JPL |
| Committee on Space Research (COSPAR) | July 14–22 | Pasadena, CA |
| JUICE-Europa Clipper Science Workshop | July 22 | Pasadena, CA |

## Team Profiles

| | | |
|---|---|---|
| Barry Goldstein | Project Manager | Jet Propulsion Laboratory, California Institute of Technology |
| Dr. Serina Diniega | Investigation Scientist (MISE) | Jet Propulsion Laboratory, California Institute of Technology |
| Nori Laslo | Payload Accommodation Engineer | John Hopkins University, Applied Physics Laboratory |
| Kelli McCoy | Project Systems Engineering Analysis Lead | Jet Propulsion Laboratory, California Institute of Technology |

## Awards

Corey Cochrane – Instrument Developer and Investigative Scientist for the Europa Clipper mission recently received The Edward Stone Award for Outstanding Research Publication from the NASA's Jet Propulsion Laboratory.

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