Network for Ocean Worlds

https://oceanworlds.space

Established in 2019 (4 and now 5 co-Leads & Coordinator)

Alyssa Rhoden

Chris German

Alison Murray

Jackie Grebmeier

Dustin Schroeder

Kathryn Pietro

Goal: to accelerate ocean worlds research by facilitating communication among active research teams across NASA divisions and by expanding community-wide engagement.

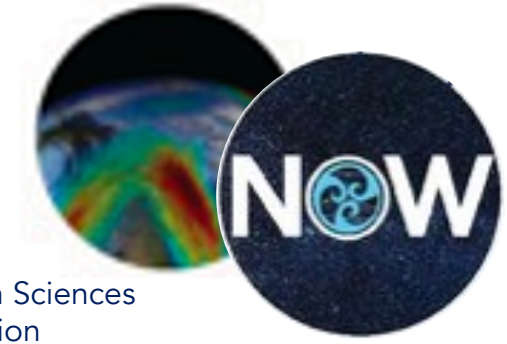
NASA RCNs – broad expertise across all of astrobiology facilitating science communication

Prebiotic Chemistry and Early Earth Environments
PCE3

NASA Astrophysics Division
NASA APD

The Nexus for Exoplanet System Science
NExSS

LIFE: Early Cells to Multicellularity
ECM

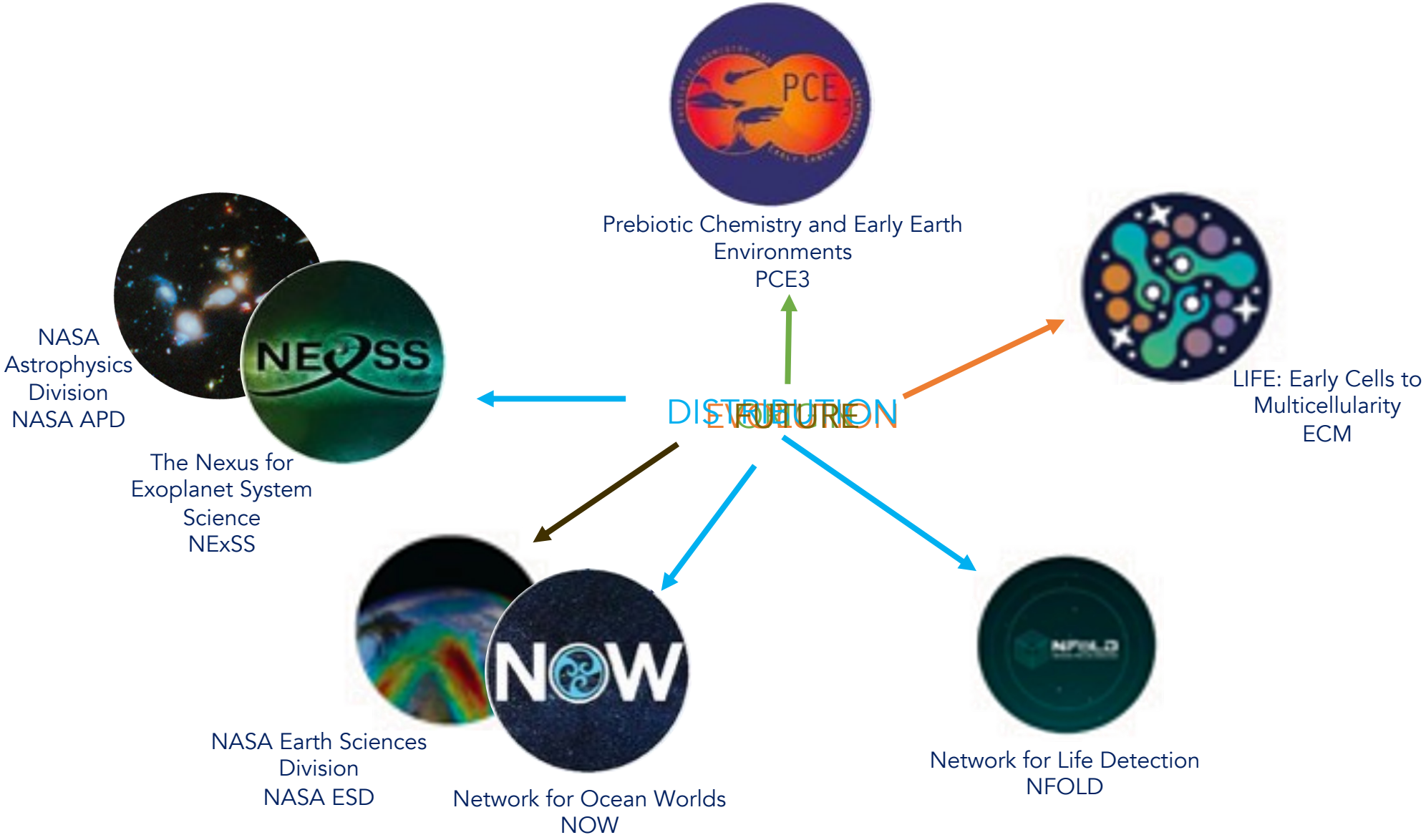


NASA Earth Sciences Division
NASA ESD

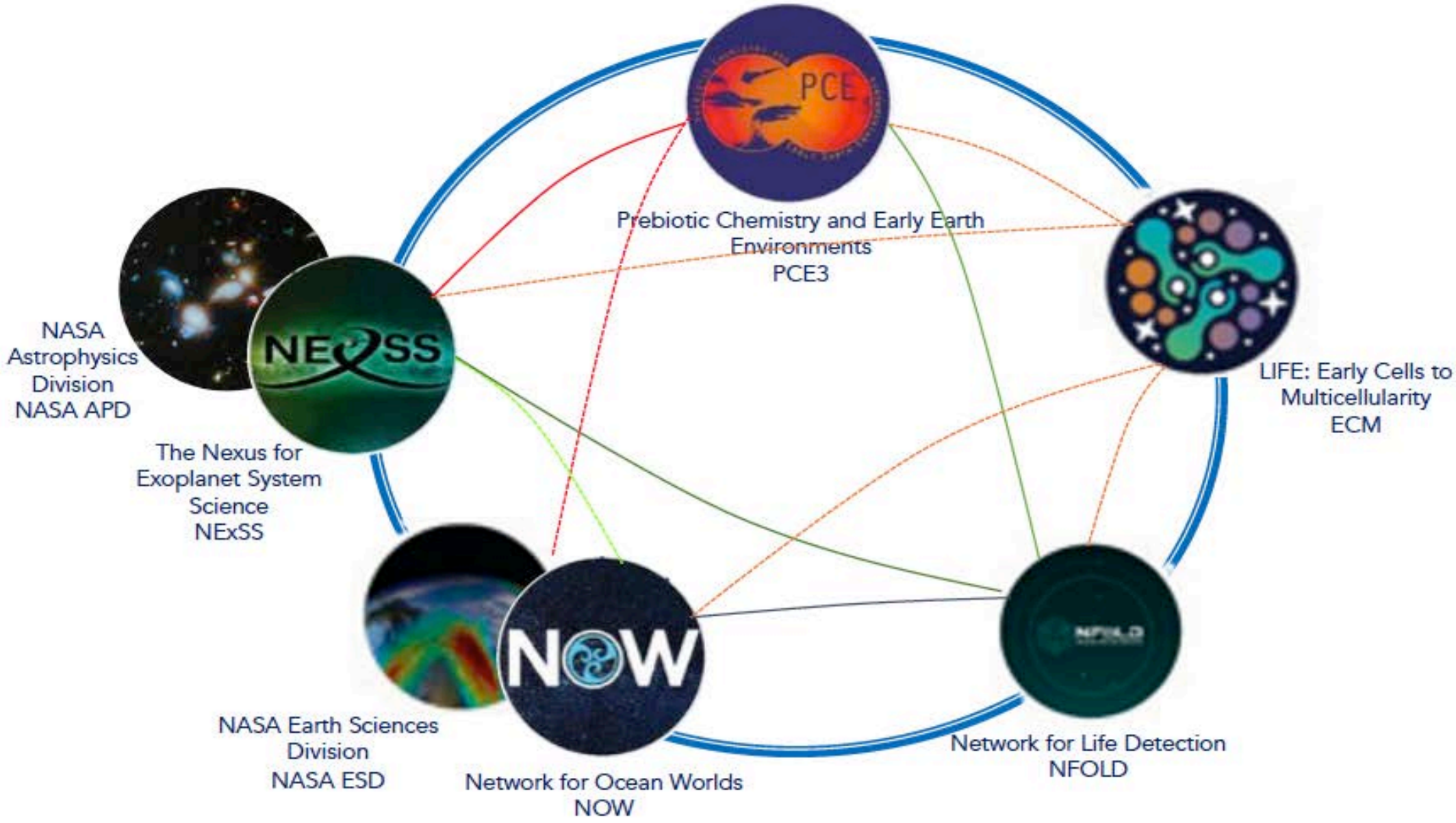
Network for Ocean Worlds
NOW

Network for Life Detection
NFOLD

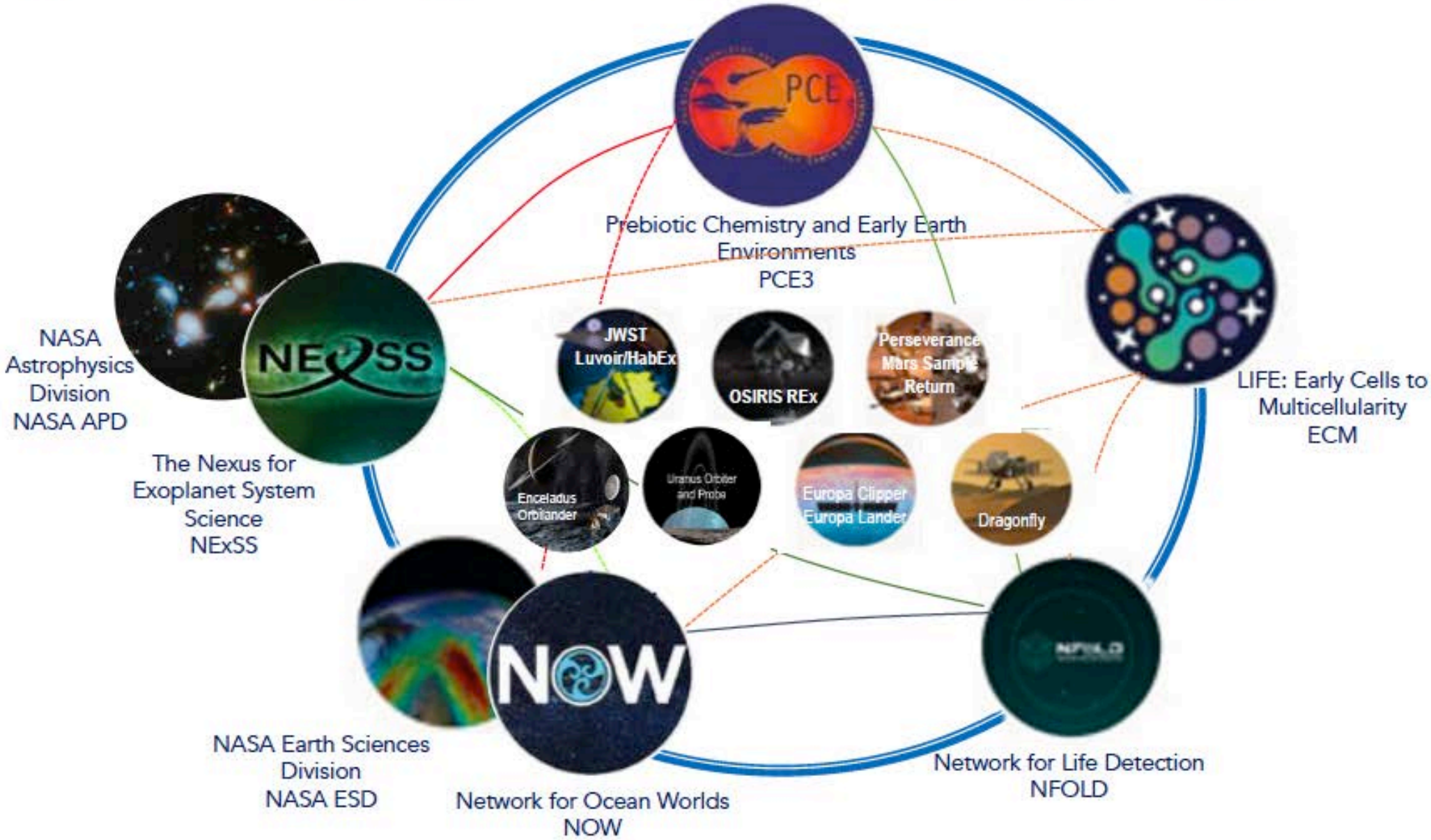
Connected by Astrobiology's central tenet



A connected network of networks



A connected network of networks – supporting current NASA Mission Science



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Priority Research Themes

- Physical and Chemical Properties of Ocean Worlds
- Searching for Evidence of Life on Ocean Worlds.
- Analog Studies on Earth to inform Ocean Worlds research.
- Development of Technologies for future Ocean Worlds missions

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Priority Network Activities

- Expand NOW Membership & Provide Mentoring
- Catalyze Communications across our NOW Network
- Facilitate Meetings, Field-trips and Workshops
- Encourage Public Outreach & Education
- Pursue new Synergies beyond the NOW Network

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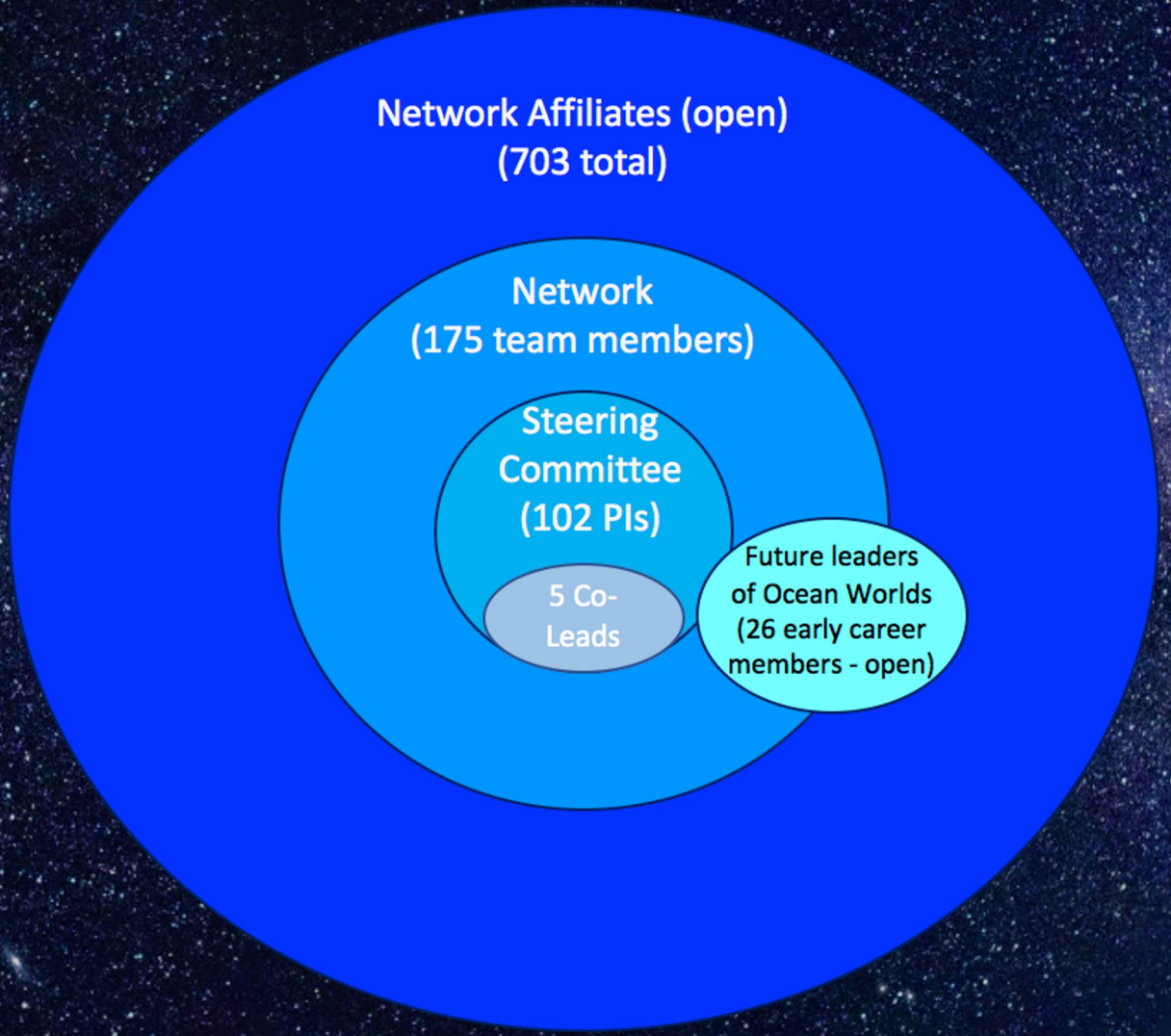
NOW Membership:



NASA Program Managers:
Mary Voytek
Laura Lorenzoni
Thorsten Markus

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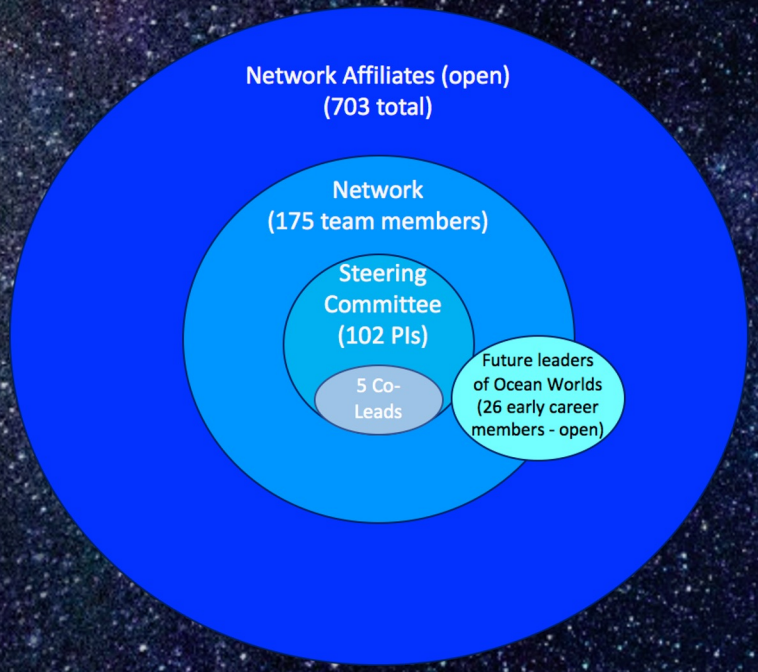
NOW Membership:



How to join? **Opt in once supported by NASA program related to Ocean Worlds**

Programs:

- Habitable Worlds
- Solar System Workings
- Exobiology
- ICAR
- PSTAR
- ColdTech
- ICEE2
- SESAME
- PICASSO
- MATISSE
- PSIE-PSD
- Cyosphere Science
- Ocean Carbon and Biogeochemistry
- Physical oceanography
- Interdisciplinary research in Earth Sciences (IRES-ESD)
- PACE Science Team
- Clipper Science Team
- Dragonfly Science Team
- … and more

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Communications - Network

• Website • Newsletter • Making Waves • Jobs Board • Steering Committee Meetings

http://oceanworlds.space

Phosphate Availability for Life on Ocean Worlds

NASA SILICON VALLEY AMES RESEARCH CENTER

Background:

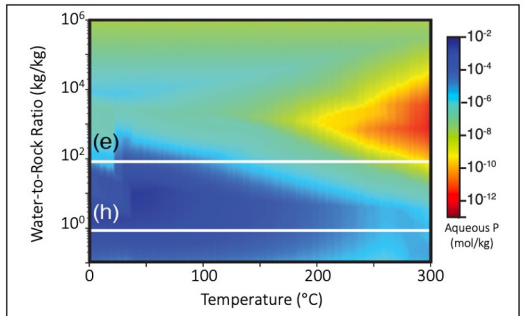
Phosphorus (P) is required by all known life and limits the abundance of life in many parts of Earth's oceans. The main source of P to Earth's oceans is continental weathering and runoff. Previous work suggested that, because this source does not exist on ocean worlds, P could be severely limiting to the abundance of life on some ocean worlds.

Main findings:

We conducted geochemical modeling to simulate the behavior of P during the reaction of water with silicate crustal rocks – a key control on the chemistry of ocean world oceans – for millions of unique combinations of temperature, rock composition, and water-to-rock mass ratio. In a large majority of those simulations, including the most plausible scenarios, the resulting aqueous P abundance is sufficient to support the establishment of cell populations larger than those typical of Earth's deep oceans.

Impact:

We show that, relative to the requirements of Earth-like microorganisms, P availability likely does not limit the abundance of life on icy moons, with positive implications for habitability and life detection on these worlds. This work directly addressed Planetary Science Decadal questions 10.5 and 11.2.

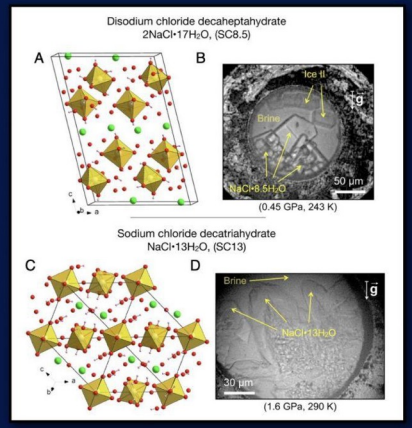


Heat map of model-predicted aqueous phosphate concentrations over a broad range of reaction temperatures and water-to-rock reaction mass ratios. Phosphate is abundant (cool colors) across most of the modeled conditions.

Reference:

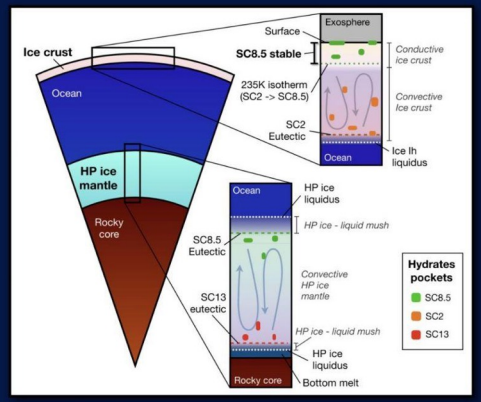
Randolph-Flagg, N.G., Ely, T., Som, S., Shock, E., German, C., Hoehler, T. (2023) Phosphorus availability and implications for life on ocean worlds, *Nature Communications,* doi:10.1038/s41467-023-37770-9

On the identification of hyperhydrated sodium chloride hydrates, stable at icy moon conditions



Journaux et al. 2023
PNAS,120 (9)
e2217125120

University of Washington



Results: Using experimental in-situ high pressure X-Ray diffraction, we report the discovery of 3 new NaCl hydrate structures, 2 of which are stable at icy moons conditions, including one, NaCl•8.5H_2O (SC8.5) stable at surface conditions (<1bar). We also report the first update of the H2O-NaCl phase diagram in over 150 years.

Significance: **i)** The SC8.5 hydrate stable at surface conditions has the good structure to explain the cryptic NIR spectral signatures found at the surface of Europa and Ganymede (high hydration and chlorinated); **ii)** The different pressure and temperature stability range suggests that detection of different type of hydrates at the surface could be used as a tracer for recent material surfacing; **iii)** The new structures are hyperhydrated due to pressure conditions (ions dissociated), suggesting that many other new and important mineral phases remain to be discovered at icy moons conditions.

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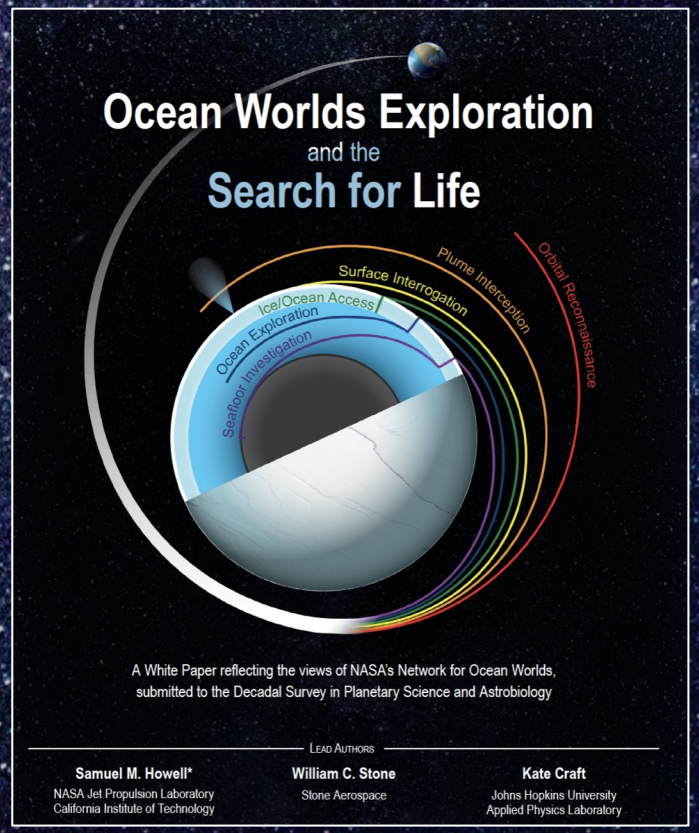
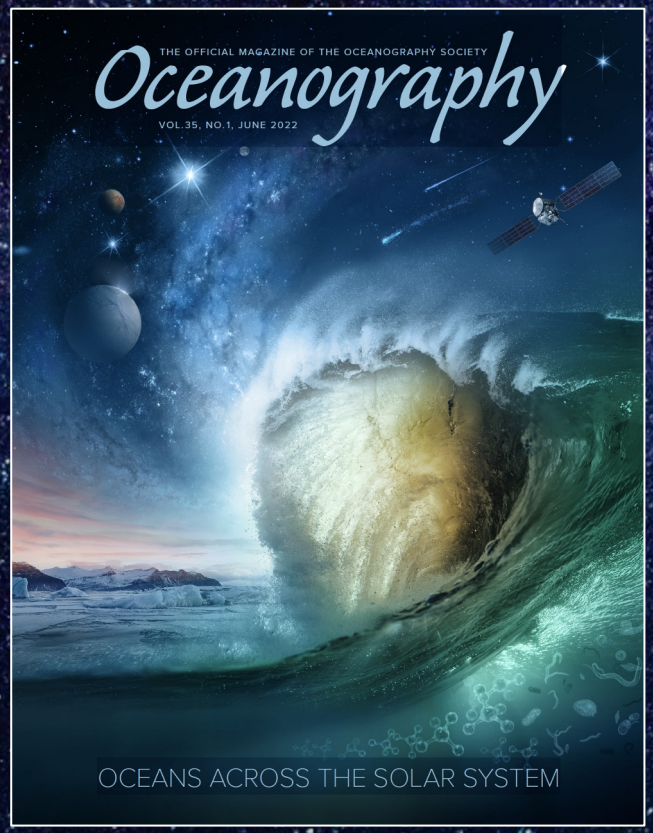
Communications - Scientific Community

- Decadal Survey



- Special Issue



- Popular Science

Recent Activities - Facilitating astrobiology program development & research

- **Cohesive Strategy for Ocean Worlds Exploration**
  (Decadal Survey Recommendation)
  - Supporting new Ocean Worlds Working Group w/ OPAG & SBAG
  * Delighted to welcome Michael Bland & Cynthia Phillips as new co-leads ☺

- **Facilitated Team Building & proposal development for major ROSES calls:**
  - Preparatory Science Investigations for Europa (PSIE-PSD)
  - Interdisciplinary Research in Earth Sciences (IRES-ESD)
  - Interdisciplinary Consortia for Astrobiology Research (ICAR-Astrobiology)

- **Joint Research Coordination Network-wide discussions**
  - Future directions of astrobiology at pan-SMD level

Future Leaders of Ocean Worlds (FLOW)

https://oceanworlds.space/flow/

- FLOW Leadership (attend NOW St. Comm meetings)
  - Laura Rodriguez (LPI); Alta Howells (NASA Ames), Mariam Naseem (UMD& BMSIS)
- Activities
  - FLOW-NOW Co-lead monthly check-ins
  - FLOW Monthly Meetings sharing opportunities for early career scientists
  - Participated in collaborative Coffee Hour with NOW Steering Committee
  - Polling FLOW membership to stimulate engagement
- Future Activities
  - Taking lead on Inclusion, Diversity, Equity and Access committee
  - To play a role in the NOW Retreat topical module design and leadership
  - Early career participation in the NOW retreat (~45%)
  - Mentoring Best-Practices Discussion Fall 2023 (Early Career Activity)

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Network members – publish high impact research

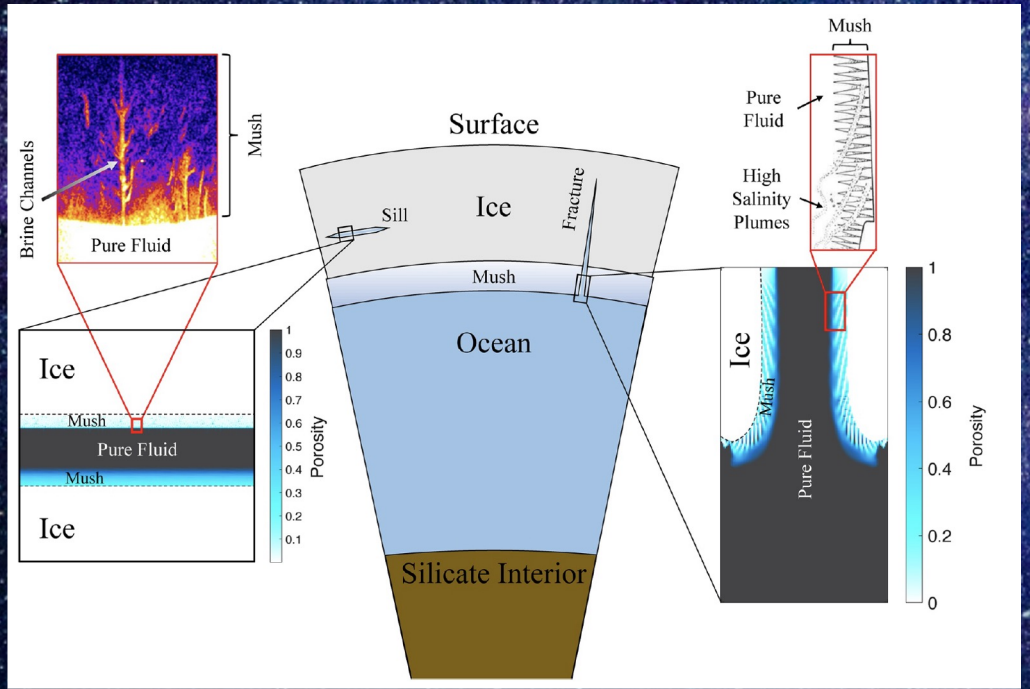
- May 2023 Newsletter highlighted 9 recent peer-reviewed articles

Geophysics:

- *Freezing impacts on ice composition*
- *Interiors of large Uranian moons*
- *Heat exchange and vapor flow in ice fractures on Enceladus*
- *Cryogenic liquid rain on Titan*
- *Icy satellite radar properties*
- *Atmospheric seismic-acoustic coupling to detect Venus quakes*

Habitability & geochemistry

- *Biodiversity in serpentinization-hosted ecosystems*
- *Phosphate availability on ocean worlds*
- *Hyperhydrated sodium chloride hydrates, stable at icy moon conditions*



Buffo et al. 2023. Fig. 1. Hydrological features and multiphase interfaces in planetary ice shells.

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Network members organize the *Quarterly Lecture Series*

@ oceanworlds.space & YouTube

Session	Episodes	Invited Speakers
S01: Life on Ocean Worlds	E01: Introduction to Cryospheres: The Ocean Worlds and Earth	Jill Mikucki & Cynthia Phillips
	E02: Life on the seafloors and in the oceans	Julie Huber & Kevin Hand
	E03: Life in the ice and ice-ocean interface	Kevin Arrigo & Mike Malaska
	E04: Life on the surface and in atmospheres	Juan Lora & David Smith
S02: Motivations for Ocean Worlds Exploration	E01: Signatures of Life: Detection and Characterization	Marc Neveu & Richard Quinn
	E02: Geophysics and habitability	James Roberts & Angela Marusiak
	E03: Geochemical exploration of Ocean Worlds and links to habitability	Chris Glein & Abel Mendez
	E04: Sensing the Environment	Charity Lander & Ved Chirayath
S03: Exploring Ocean Worlds through Analogs	E01: Field studies	Alexis Templeton & Craig Lee
	E02: Lab studies	Xinting Yu & Paul Johnson
	E03: Numerical Simulations	Dimitris Menemenlis & Krista Soderlund
	E04: Combined approaches to clathrates	Angela Marusiak-Schools & Elodie Gloesener

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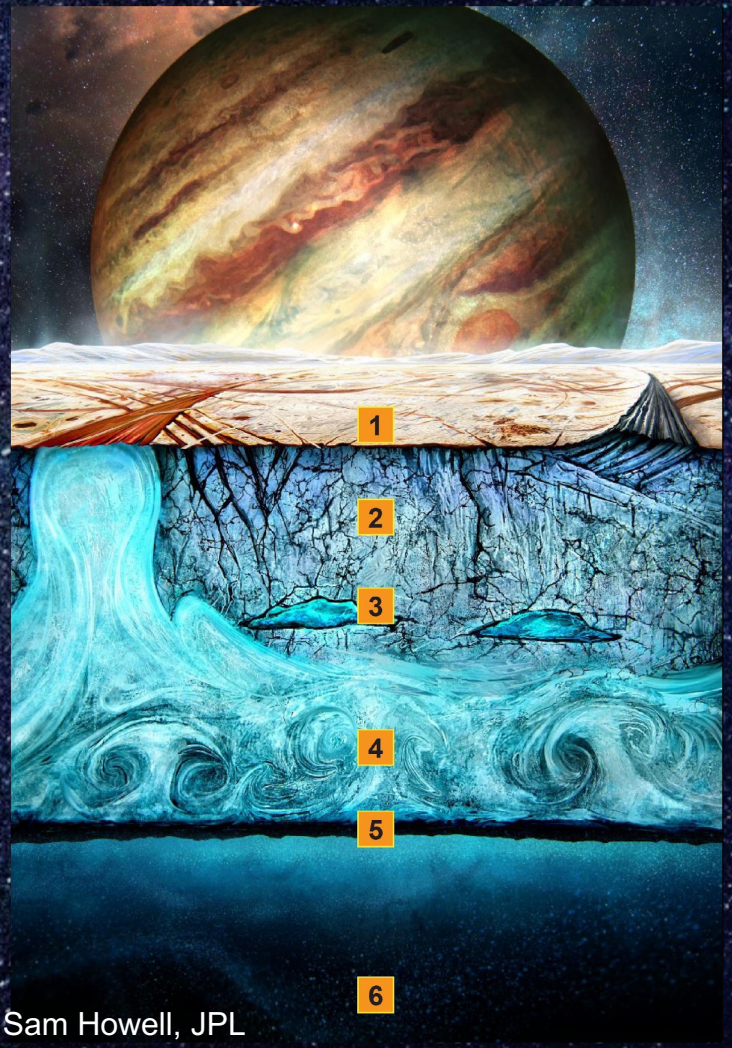
Network members – identify high priority needs of the community



Graphic: Sam Howell, JPL

- Many distinct potentially habitable ocean world environments that signs of life may exist (#s1-6).
- Future missions will require robust ocean access technology (landed ops and drilling) and instrumentation.
- Realistic testing facilities and infrastructure are needed to ensure ocean world science investigations are successful.
- Currently NASA does not have a mechanism to provide routine access to any of these environments.

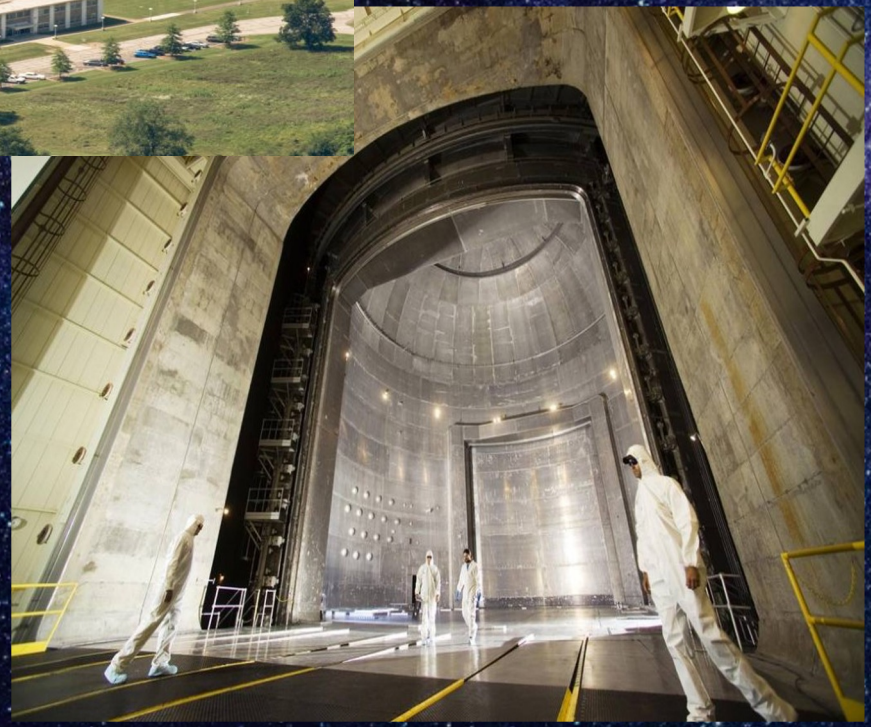
- Discussed: NOW Steering committee discussions (June 2022 face-to-face and May 2023)
- Priorities were identified to mature concepts for both laboratory and field-based opportunities

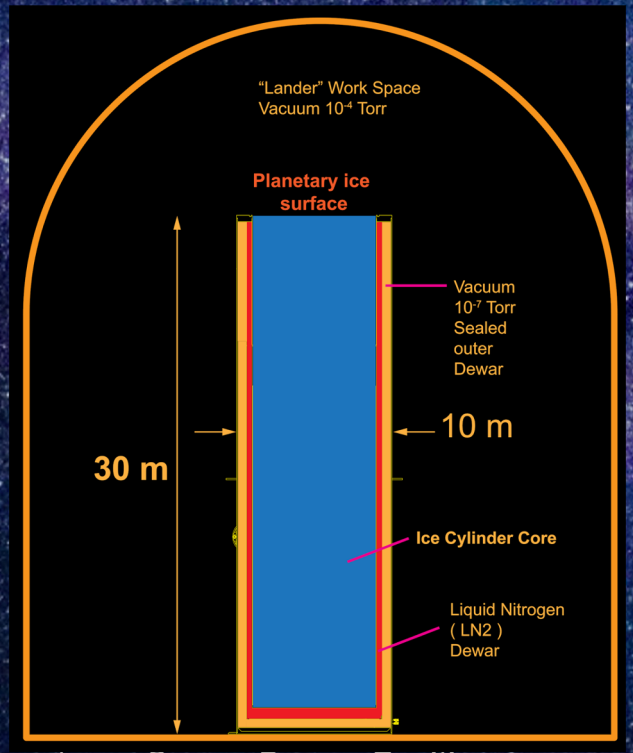
Space Environments Complex (formerly Plum Brook Station)
NASA Glenn Research Center

Potential for a National Ocean Worlds Cryo-Vac-Ice Test Facility??

Simulate Ocean World surface ice conditions (vacuum and cryo-temperature)

- Test drilling technologies
- Test new instruments, and electronics etc.





Space environments complex (SEC) Vacuum Chamber - Space Power Facility - Worlds' largest vacuum chamber

Stone Aerospace © 2022

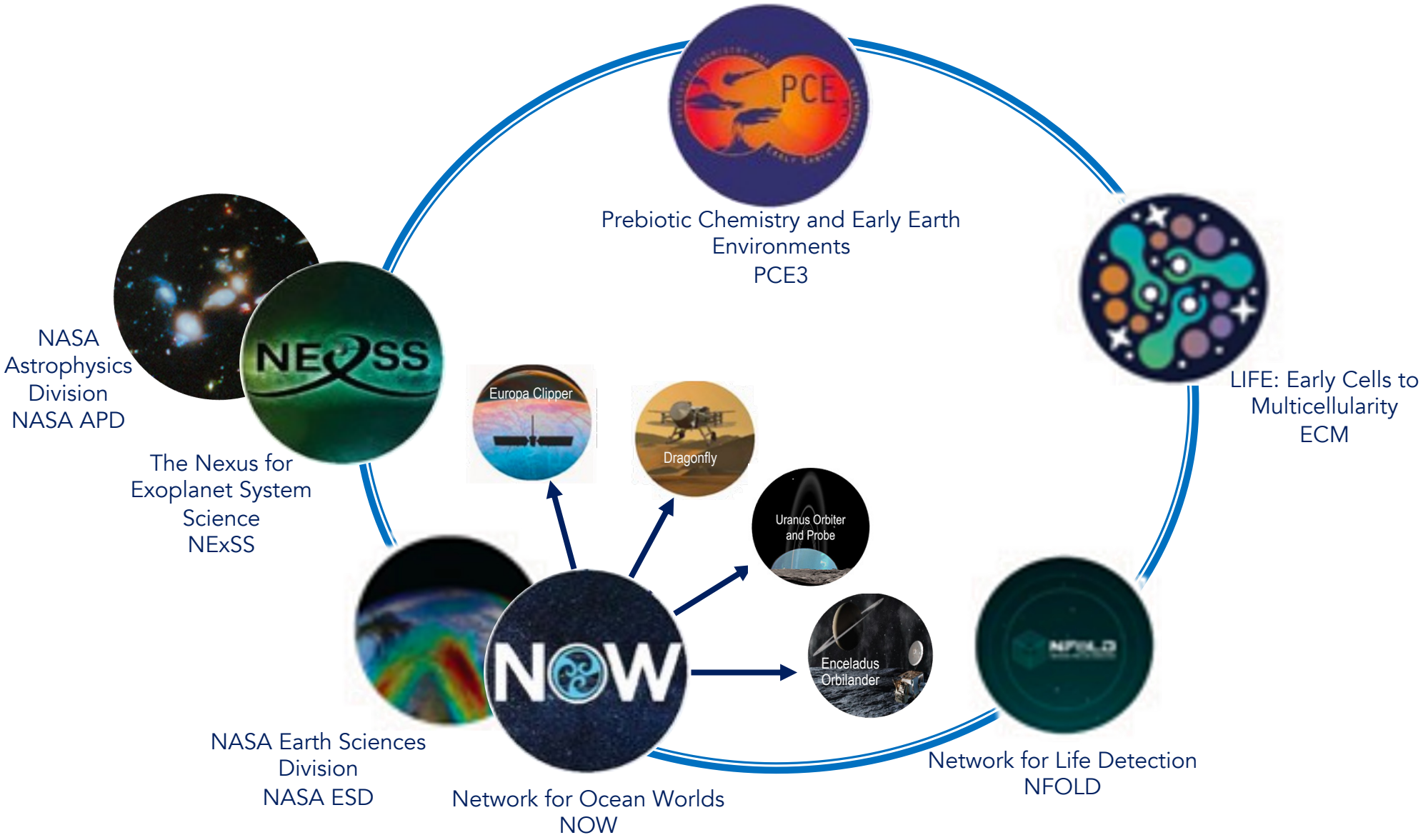
Forthcoming Activities & News (2023)

- Establishing an Ocean Worlds Access Action Group
  National Testing Capability for Ocean Worlds Technology
  - Highest Priority community-wide need for OW Astrobiology
  - Community workshop to follow

- 1st Annual NOW Retreat: *Exploring the science and technology of ocean worlds across the solar system* (August 2023) (Steering Committee & FLOW)
  - Building bridges among ocean & planetary science & technology
  - Identify synergies in technology development that are mission-related
  - Wrigley Marine Science Center, Catalina Island (inc. at-sea field experience)

- Workshops: Uranus Orbiter Probe Workshop Participation, Pasadena, July 2023
  Ocean Worlds Special Session at AGU Ocean Sciences Meeting (New Orleans LA, Feb. 2024)
  Ocean Worlds Theme at Astrobiology Science Conference (Providence RI, May 2024)

NOW– feeds directly into current and future NASA Mission Science



RCNs are value-added for NASA Missions