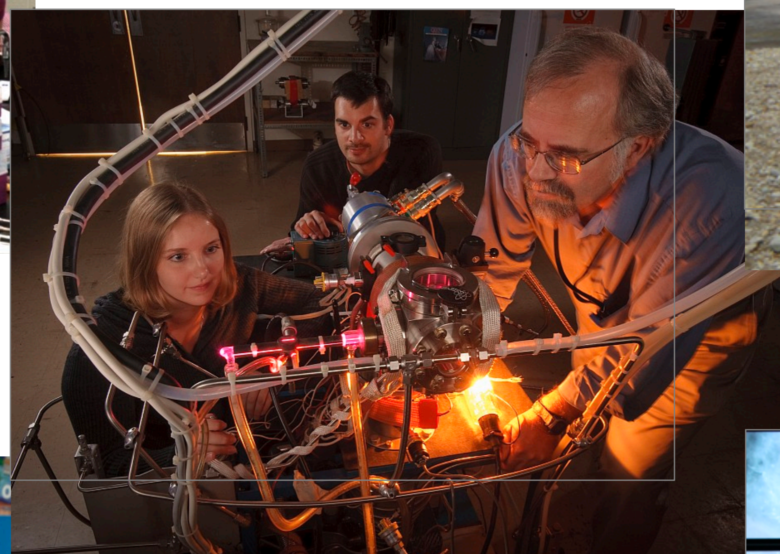
NASA Astrobiology Institute

Dr. Mary Voytek
Senior Scientist for Astrobiology
NAI Program Scientist

NAI Mission Statement

5 Elements

Train the Next Generation of Astrobiologists

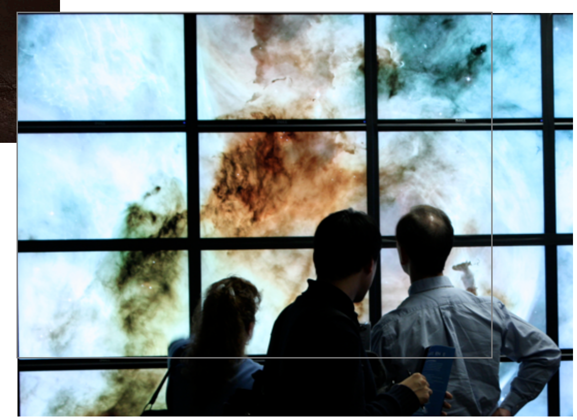


Collaborative, Interdisciplinary Research

Provide Leadership for NASA Space Missions

Education and Outreach

In Transition…



Information Technology for Research

NAI: A Virtual Institute Without Walls

- Competitively-selected science teams, each a consortium (currently 12 teams)
- ~600 members at ~100 participating institutions
  - ~320 “senior” scientists
  - ~280 postdocs and students
  - ~20 members of the US National Academy of Sciences
- Managed/integrated by a central office at NASA Ames Research Center

CAN 6 TEAMS

- Massachusetts Institute of Technology
- University of Illinois at Urbana-Champaign
- University of Southern California
- University of Wisconsin
- VPL at University of Washington
- **ROTATING OFF THIS YEAR**

CAN 7 TEAMS

- NASA Goddard Space Flight Center
- NASA Ames Research Center
- NASA Jet Propulsion Laboratory
- SETI Institute
- University of Colorado in Boulder
- University of California, Riverside
- University of Montana in Missoula

NAI CAN 6 & 7 Teams

Solicitation Number: NNH17ZDA003C

CAN Release Date: February 27, 2017

Preproposal Conference - March 10, 2017

Step-1 Proposal Due: April 12, 2017

Step-2 Proposals Due: July 6, 2017

Review Fall 2017

Selections

New starts 2018 calendar year

Dr. Mary Voytek, Senior Scientist for
Astrobiology/ NAI Program Scientist
Science Mission Directorate NASA Headquarters
300 E Street SW
Washington, DC 20546
Phone: (202) 358-1577
E-mail: mary.voytek-1@nasa.gov

CAN 6: University of Washington

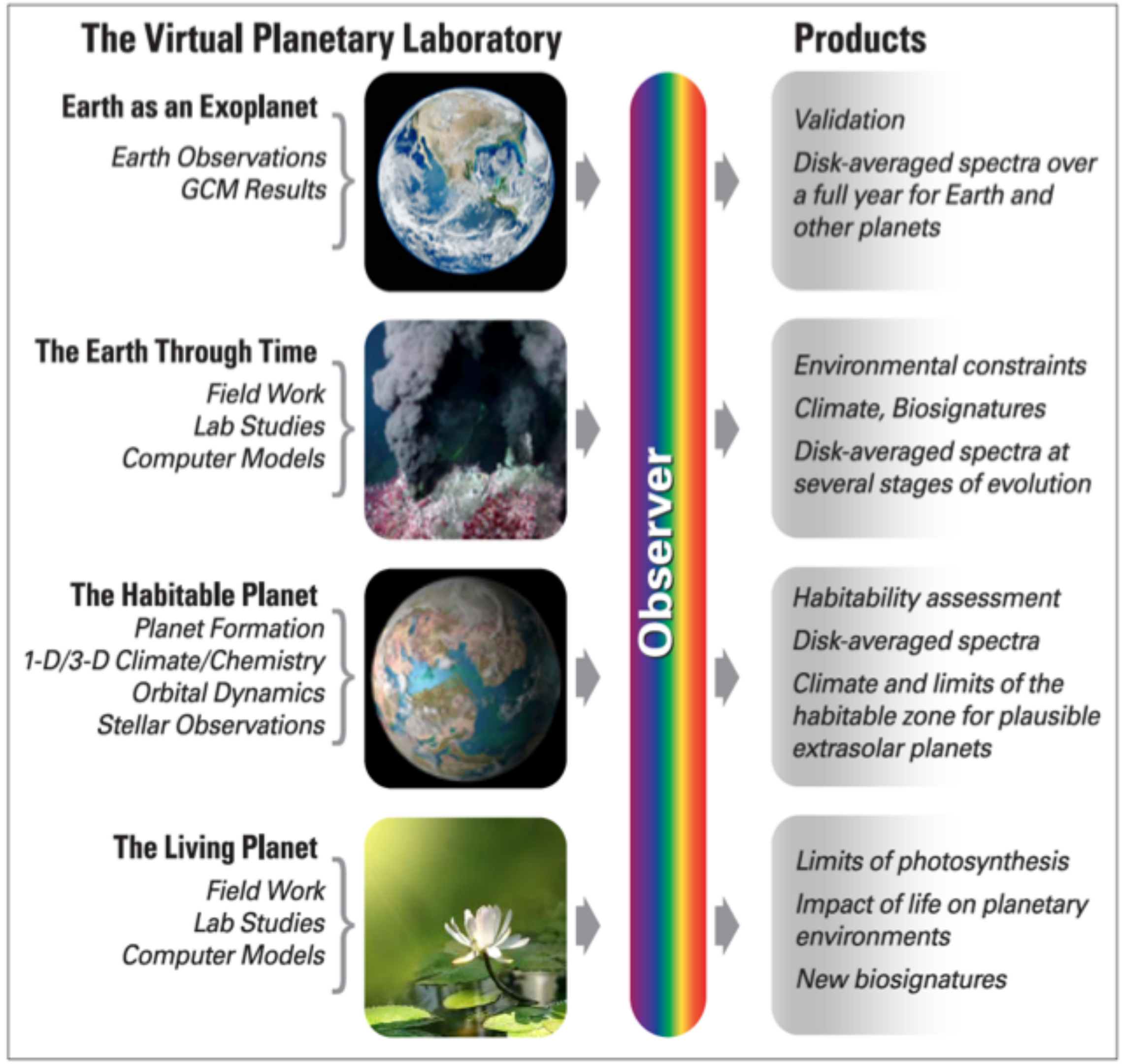
The Virtual Planetary Laboratory

PI is Victoria Meadows

. . to develop, refine and combine 1-D and 3-D climate, photochemical, radiative transfer, atmospheric escape, planetary interior, biogeochemical, biological productivity, vegetation, orbital evolution and planet formation models and,

. . as input to these models, to obtain laboratory, field and observational data from the stellar, planetary and biological sciences, and

. . use these results to recognize habitable worlds and to discriminate between the spectra of planets with and without life, by understanding the signatures of life in the context of their planetary environment



CAN 6: University of Illinois

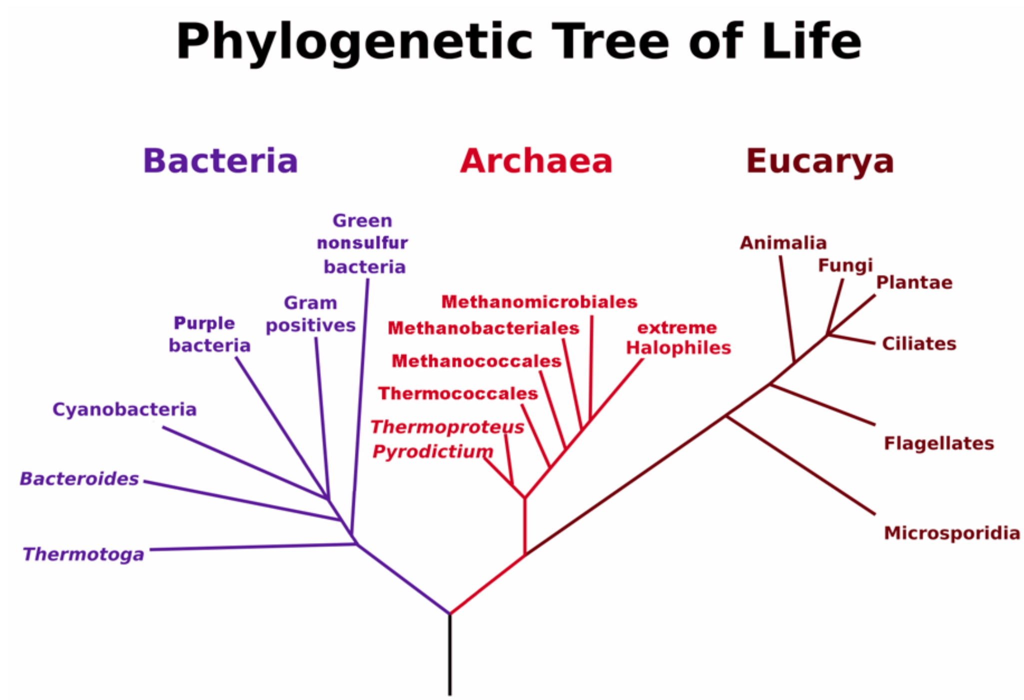
Towards Universal Biology: Constraints from Early and Continuing Evolutionary Dynamics of Life on Earth

PI is Nigel Goldenfield

- Study the general physical principles underlying the emergence of life – a mathematical basis for the emergence of evolvable dynamical processes

- Investigate Life before the Last Universal Common Ancestor (LUCA) – the “progenote”, a hypothetical communal state of gene sharing that preceded cellular life, using detailed and sophisticated analyses of core translational machinery

- Examine how environmental conditions affect the speed with which evolutionary adaptation takes place, i.e., how the ability to evolve itself evolves



- Understand the emergence of cellular machinery following the progenote state – focusing on mining Archaeal genomes, searching for the ancestors at the root of the Eukarya-Archaeal branching and determining how genomes became more stable over evolutionary time

CAN 6: University of Wisconsin

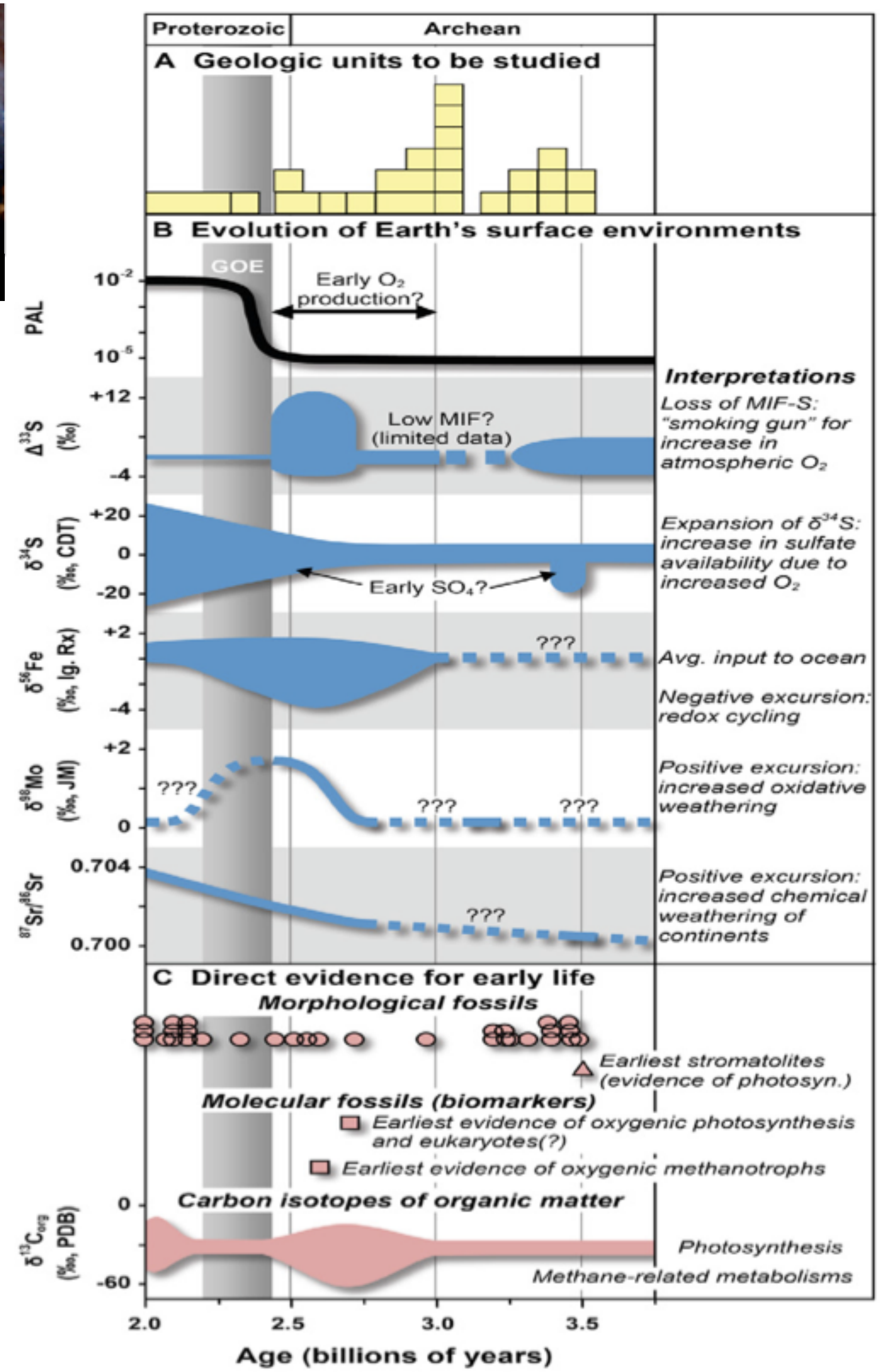
Habitability, Life Detection, and the Signatures of Life on the Terrestrial Planets

PI is Clark Johnson

. . to develop, using Mars analog environments, new approaches for the detection of biomolecules, and increase our knowledge of biomolecule-rock substrate interactions

. . to develop a mechanistic understanding of the proxies that have been used to interpret ancient rocks and ancient microbial ecology – and to develop new proxies focusing on three mineral groups: clays, Fe-Si oxides, and carbonates

. . to use the ancient rock record on Earth, largely using isotopic tracers, to understand the co-evolution of the environment and a diverse range of microbial metabolisms – providing an essential interpretive context for studies of ancient rocks on Mars

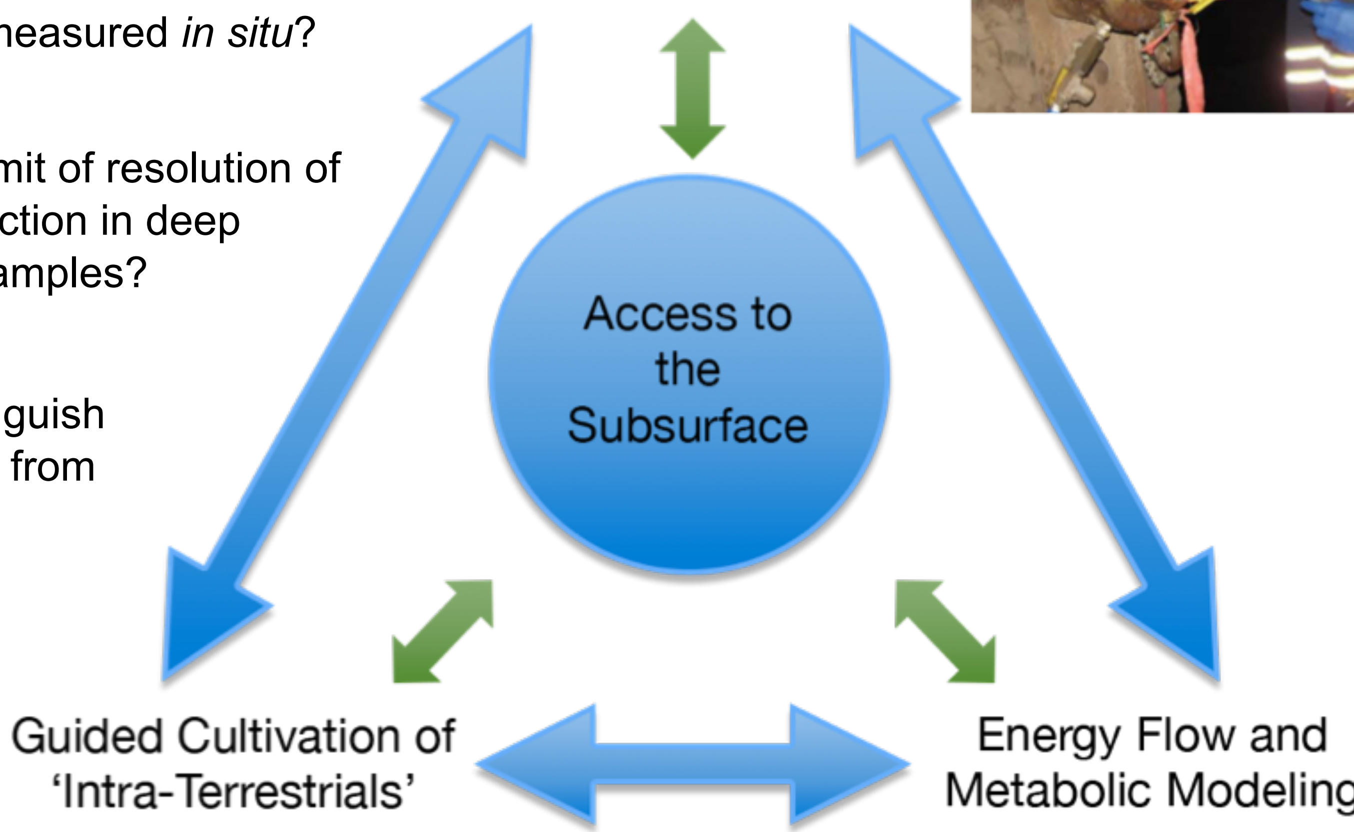


CAN 6: University of Southern California

Life Underground

PI is Jan Amend

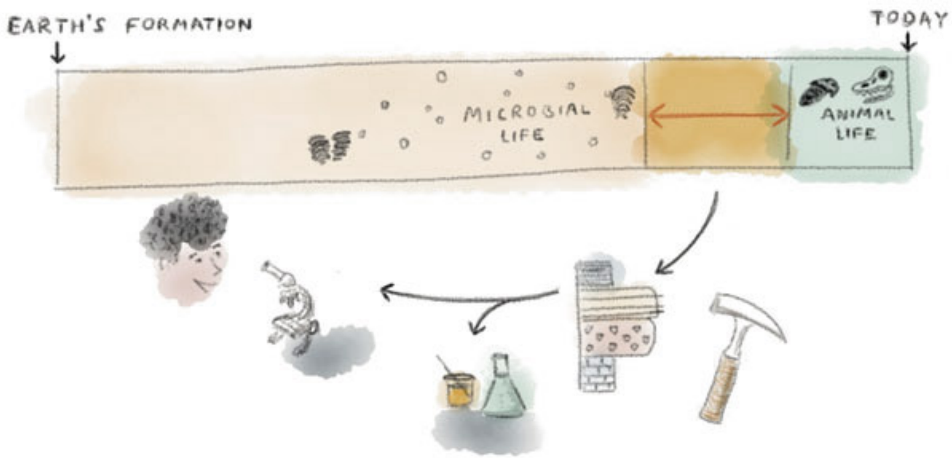
- What spectral/optical signals indicate the presence of biomass?
- What kind of metabolic activities can be detected/measured *in situ*?
- What is the limit of resolution of biomass detection in deep subsurface samples?
- Can one distinguish living biomass from dead *in situ*?



CAN 6: Massachusetts Institute of Technology

Foundations of Complex Life: Evolution, Preservation and Detection on Earth and Beyond

PI is Roger Summons



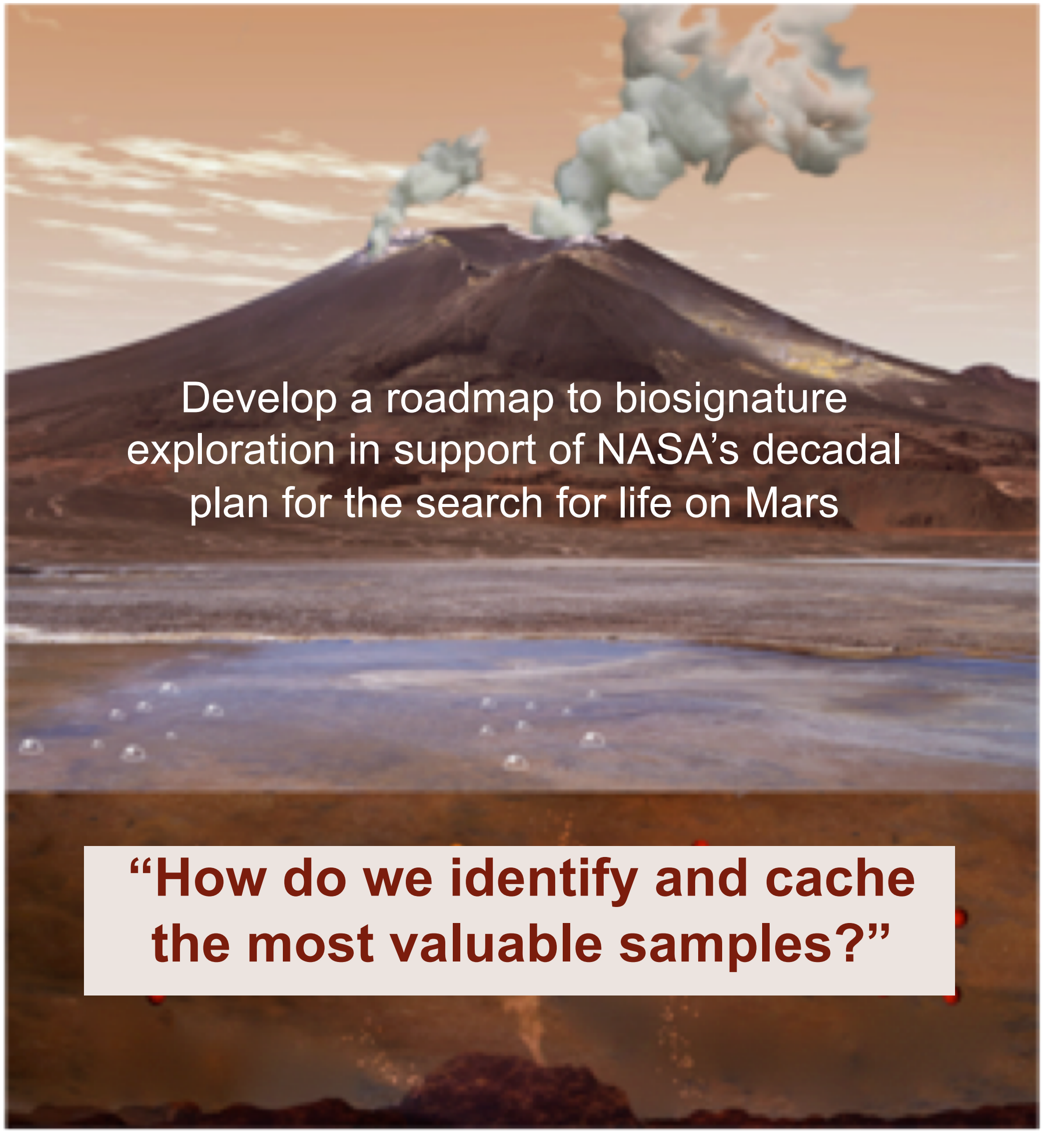
Questions to be addressed include:

- What is the relationship between genomic and morphological complexity?
- What caused large Neoproterozoic (1000-542 million years ago) perturbations of the carbon cycle, and how do they relate to the emergence of biological complexity?
- What principles and mechanisms determine the preservation of organic matter and fossils, through time and in relation to ocean-atmosphere chemistry?
- What taphonomic insights drawn from these studies apply elsewhere, particularly Gale Crater on Mars?

CAN 7: The SETI Institute

Changing Planetary Environments & the Fingerprints of Life

PI is Nathalie Cabrol



The Signatures of Habitability: Mars Ancient Mineral Record and Terrestrial Aerial Imagery

Taphonomic Windows & Biosignature Preservation: Earth Analogs

Environmental Control on the Survival & Preservation Potential of Organic Molecules

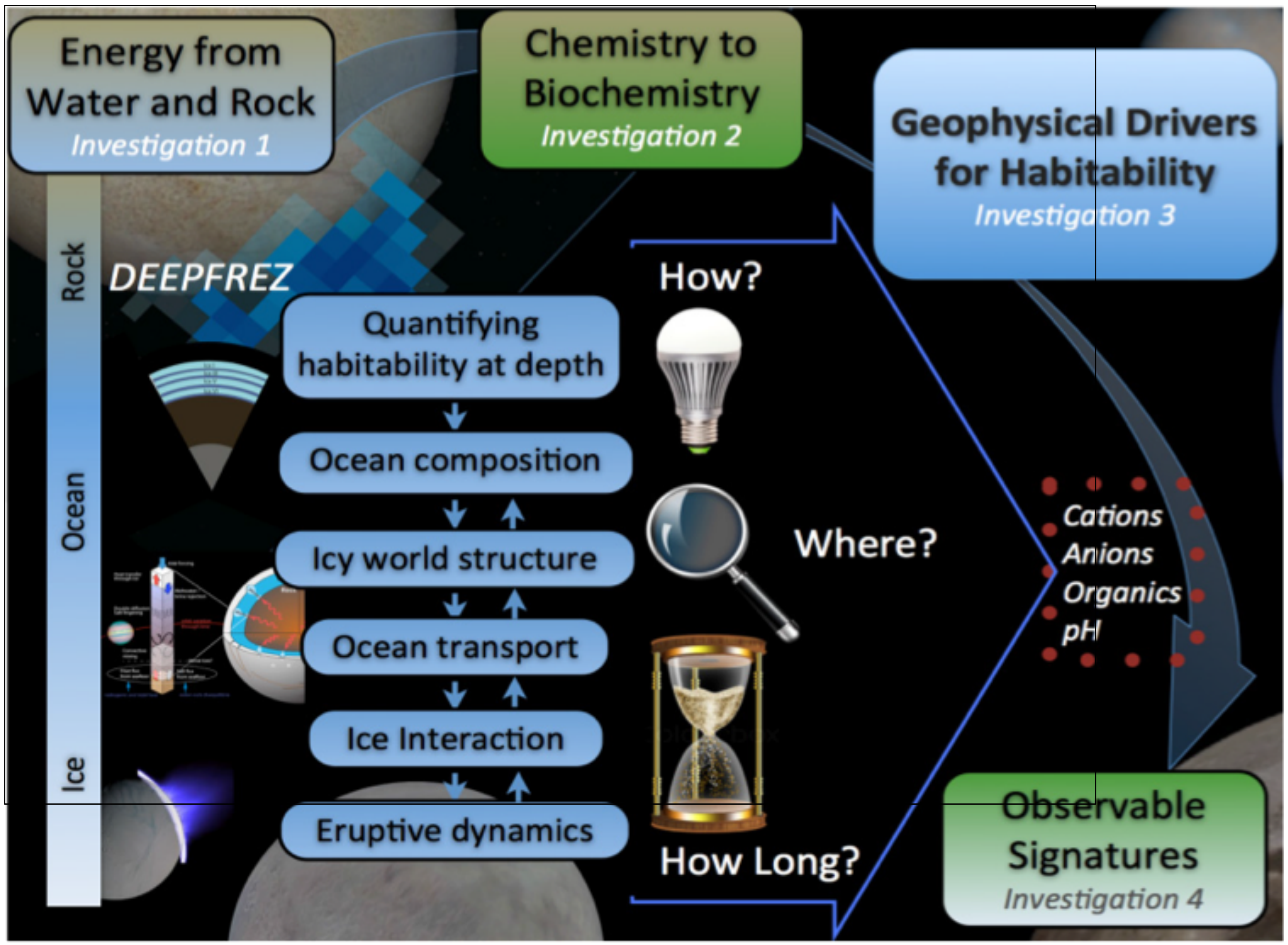
Adaptive Detection of Biosignatures: Applying Data Fusion, Novelty Detection, and Autonomous Detection of Biogenicity

CAN 7: Jet Propulsion Laboratory

Icy Worlds: Astrobiology at the Rock-Water Interface and Beyond

PI is Isik Kanik

How can geochemical disequilibria drive the emergence of metabolism and ultimately generate observable signatures on icy worlds?



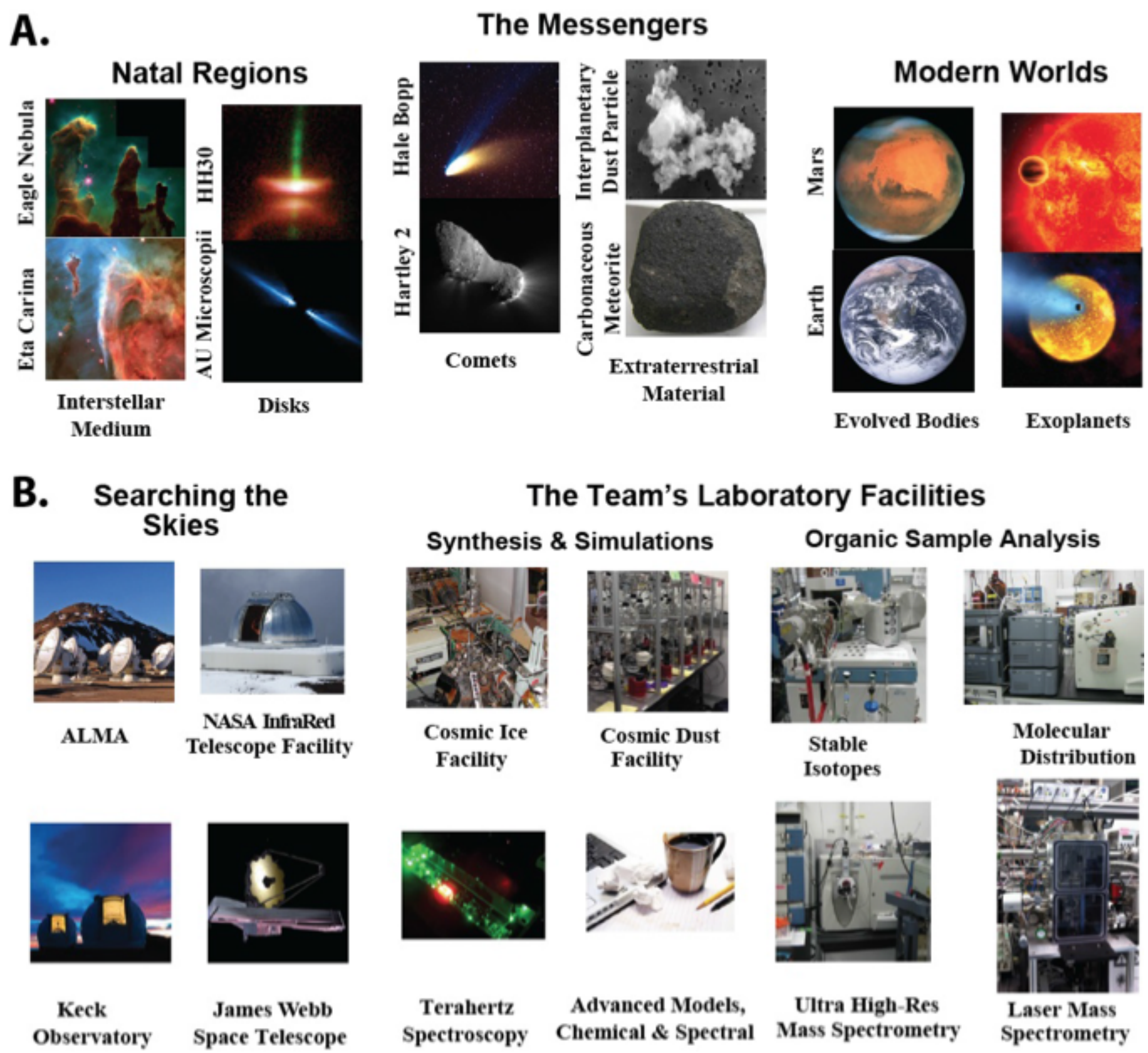
CAN 7: NASA Goddard Space Flight Center

Origin and Evolution of Organics and Water in Planetary Systems

PI is Mike Mumma

Did delivery of exogenous organics and water enable the emergence and evolution of life? Why is Earth wet and alive?

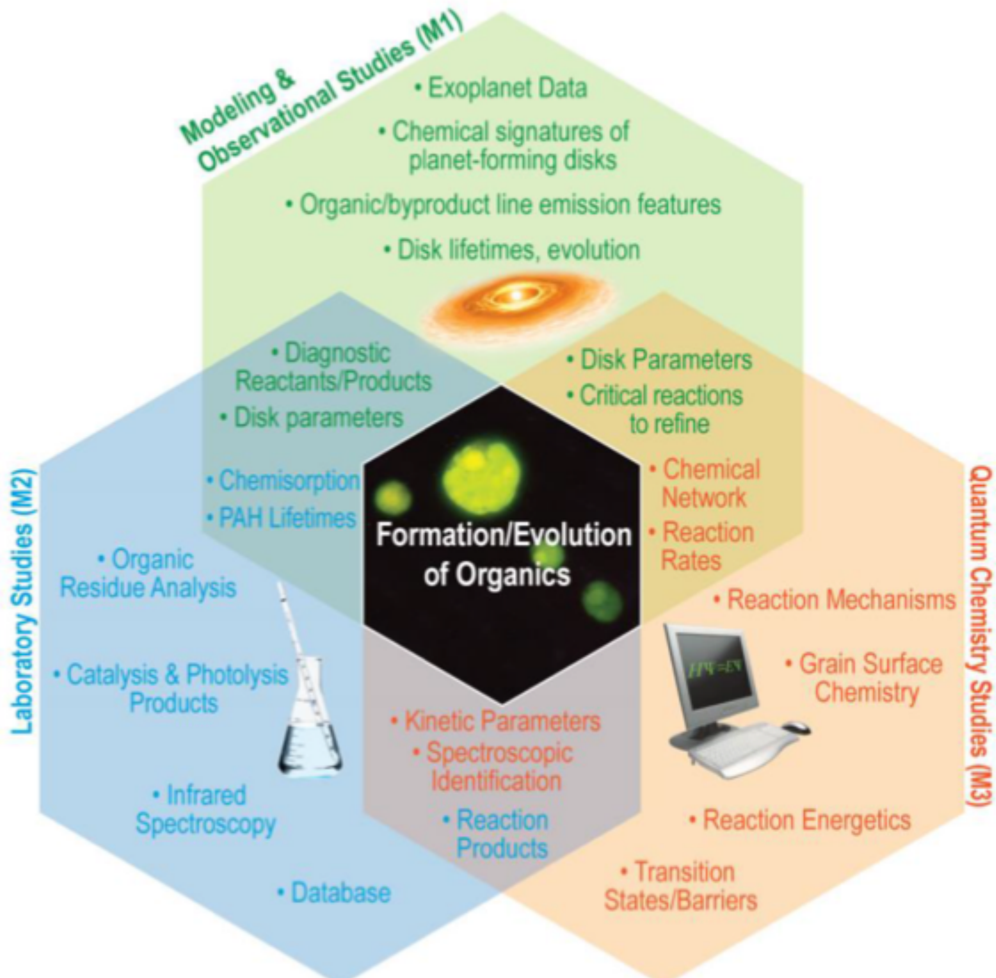
- What material was delivered?
- How was prebiotic matter synthesized and processed?
- What dynamical mechanisms delivered these primitive bodies?
- Can we find evidence for habitability elsewhere in the present day Solar System?
- Develop instrument protocols for future *in situ* investigations.



CAN 7: NASA Ames Research Center

The Evolution of Prebiotic Chemical Complexity and the Organic Inventory of Protoplanetary Disks and Primordial Planets

PI is Scott Sandford



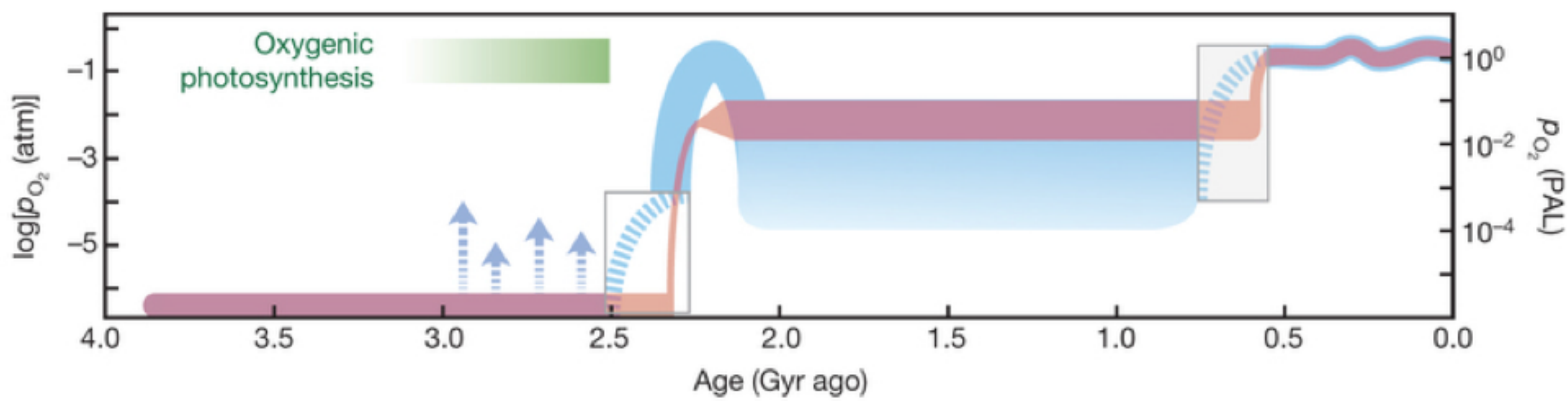
. . . to understand the chemical processes at every stage in the evolution of organic chemical complexity, from quiescent regions of dense molecular clouds, through all stages of cloud collapse, protostellar disk, and planet formation, and ultimately to the materials that rain down on planets - and to understand how these depend on environmental parameters like the ambient radiation field and the abundance of H2O.

CAN 7: University of California, Riverside

Alternative Earths: Explaining Persistent Inhabitation on a Dynamic Early Earth

PI is Timothy Lyons

How has Earth remained persistently inhabited through most of its dynamic history, and how do those varying states of inhabitation manifest in the atmosphere?



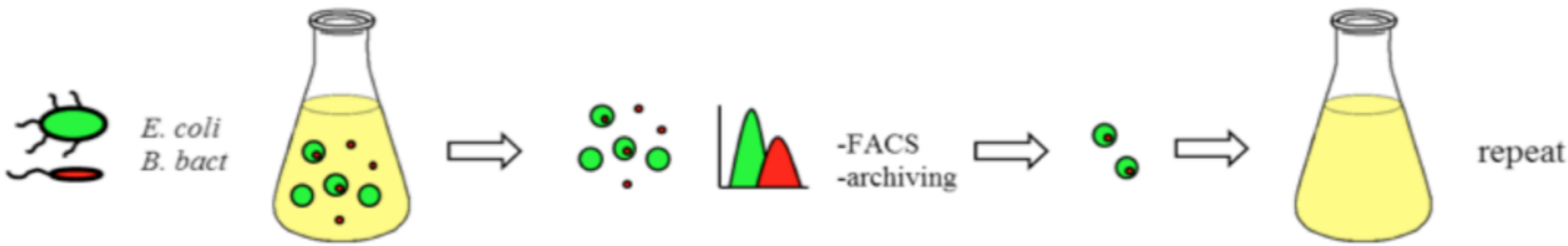
Alternative Earth 1	Resolve when oxygenic photosynthesis first left traces in Earth's atmosphere and whether (and, if so, why) there was a lag between oxygen's first biological production and its persistent accumulation.
Alternative Earth 2	Determine whether Earth's surface underwent a unidirectional oxygen rise—as typically envisioned—or whether (and why) this early history was characterized by a series of rises and falls.
Alternative Earth 3	Determine whether surface oxygen concentrations maintained sufficiently low levels, for perhaps a billion years of Earth's history, to play a direct role in when animals first hit the scene and diversified.

CAN 7: University of Montana (Georgia Tech)

RELIVING THE PAST: Experimental Evolution of Major Transitions in the History of Life

PI is Frank Rosenzweig

What forces bring about major transitions in the evolution of biocomplexity?



Organized around five questions related to major transitions in the history of Life:

How do enzymes and metabolic networks evolve?
How did the eukaryotic cell come to be?
How do symbioses arise?
How does multicellularity evolve? and
How do pleiotropy, epistasis and mutation rate constrain the evolution of novel traits?

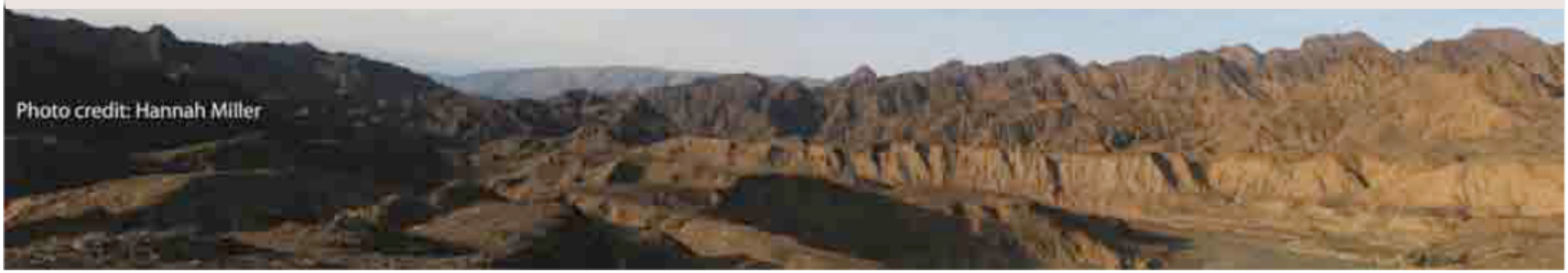
A unifying theme underlying these questions is: how do cooperative vs. competitive interactions play out in driving major transitions that occur when independently replicating entities combine into a larger, more complex whole?

CAN 7: University of Colorado

Rock-Powered Life: Revealing Mechanisms of Energy Flow from the Lithosphere to the Biosphere

PI is Alexis Templeton

How do the mechanisms of low temperature water/rock reactions control the distribution, activity, and biochemistry of life in rock-hosted systems?



- Defining the pathways that control how energy is released from ultramafic rocks as they react with low-temperature fluids,
- Identifying and interpreting the process rates and ecology in systems undergoing water/rock reactions,
- Quantifying the geochemical and mineralogical progression of water/rock reactions in the presence and absence of biology,
- Characterizing microbial communities within rock-hosted ecosystems and evaluating their metabolic activities,
- Developing and testing predictive models of biological habitability during water/rock interaction.

International Partners

ASSOCIATE PARTNERS:

- ✪ Centro de Astrobiología (CAB)
- ✪ Australian Centre for Astrobiology (ACA)

AFFILIATE PARTNERS:

- ✪ Astrobiology Society of Britain (ASB)
- ✪ Canadian Astrobiology Network (CAN)
- European Exo/Astrobiology Network Association (EANA)
- Helmholtz Alliance: Planetary Evolution and Life
- ✪ Instituto de Astrobiología Colombia (IAC)
- ✪ Nordic Network of Astrobiology
- ✪ Russian Astrobiology Center (RAC)
- ✪ Société Française d'Exobiologie (SFE)
- ✪ Sociedad Mexicana de Astrobiologia (SOMA)
- ✪ UK Centre for Astrobiology (UKCA)
- ✪ USP Research Unit in Astrobiology

Other NAI Efforts

- The Lewis and Clark Fund for Exploration and Field Research in Astrobiology *(for graduate students & postdocs)*
- Early Career Collaboration Award *(for graduate students & postdocs)*
- Meeting and Workshop Support, Workshops Without Walls
- *Education and Public Outreach in Transition…..*

NASA/Library of Congress
Blumberg Astrobiology Chair

Lucianne Walkowicz

Oct. 2017 – Sept. 2018

An astronomer based at the Adler Planetarium, Walkowicz intends to work on a project entitled “Fear of a Green Planet: Inclusive Systems of Thought for Human Exploration of Mars.” Her project will create an inclusive framework for human exploration of Mars—a vision that encompasses both cutting-edge research on Mars as a place of essential astrobiological significance and weaves in lessons from the diverse histories of exploration on Earth. In addition to studying stellar magnetic activity and the effect on planetary suitability for extraterrestrial life at Adler Planetarium, Walkowicz is a TED senior fellow and artist.

The Nexus for Exoplanet System Science

Research Coordination Network

A Cross-division Initiative

https://nexss.info

Objectives

- To further our joint strategic objective to explore exoplanets as potential habitable and inhabited worlds outside our solar system.
  - Exoplanet research cuts across divisions in SMD including Planetary Science (PSD), Heliophysics (HPD), Earth Science (ESD) and Astrophysics (APD)
- To leverage existing Programs in SMD to advance the field of Exoplanet Research, specifically research in comparative planetology, biosignature and habitat detection, and planet characterization.
- Establish a mechanism to break down the barriers between, divisions, disciplines and stove piped research activities.

What is a Coordination Network?

- A virtual structure to support groups of investigators to communicate and coordinate their research, training and educational activities across disciplinary, organizational, divisional, and geographic boundaries.

What Research Coordination Networks have accomplished?

- Provided opportunities to share information and ideas, foster new collaborations, including international partnerships, and address interdisciplinary topics.
- Provided innovative ideas for implementing novel networking strategies, collaborative technologies.
- Supported the development of community standards for data and meta-data.
- Supported the means by which investigators can
  - coordinate ongoing or planned research activities,
  - and in other ways advance science and education through communication and sharing of ideas.

Implementation

Astrophysics
- Exoplanet Detection
- Star Characterization
- Existing Mission Data Analysis
- JWST

PSD Astrobiology
- Comparative Planetology
- Planetary atmospheres
- Exoplanet Detection
- Biosignatures
- Habitability

Earth Sciences

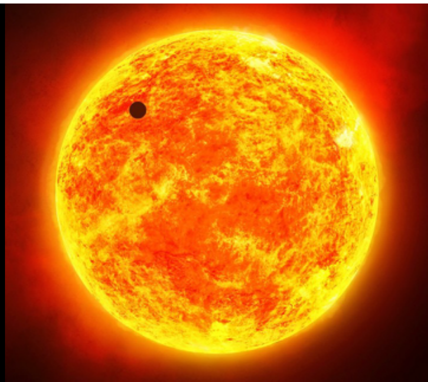
PSD Exoplanet Research Program (XRP)
- Exoplanet characterization
- Protoplanetary Disks
- Planet Formation
- Comparative Planetology

Heliophysics Detection of planetary magnetospheres
- Stellar winds

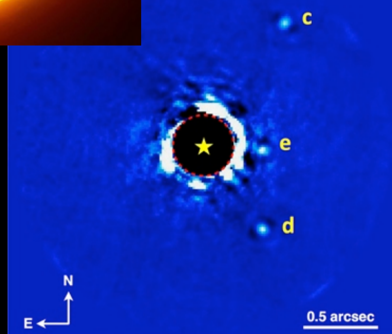
Measure of Success

- Investigators carry out and propose interdisciplinary research through new collaborations
- Produces a plan for utilization of current space telescopes
- Spawns ideas for new and exciting missions
- Identifies new targeted technologies needed not yet reported elsewhere
- Influences Decadals for both PSD and APD
- Enhances International engagement

The NExSS Teams



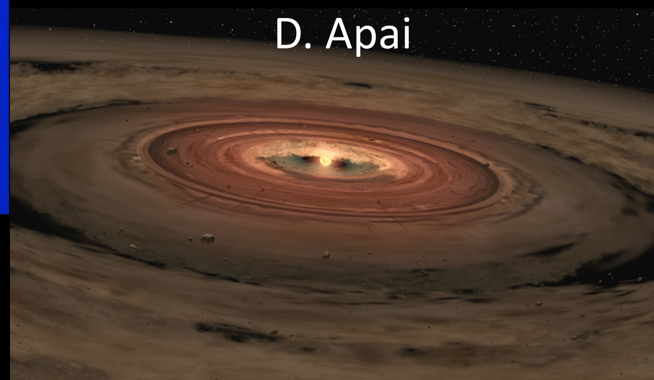
D. Fischer
E. Ford
J. Wright
D. Deming
A. Jensen
J. Graham

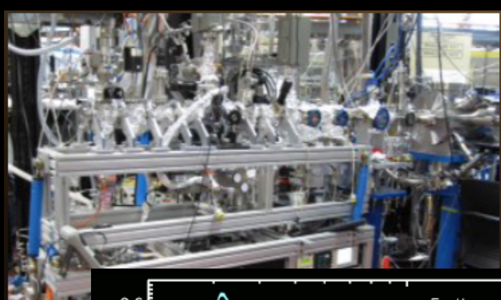


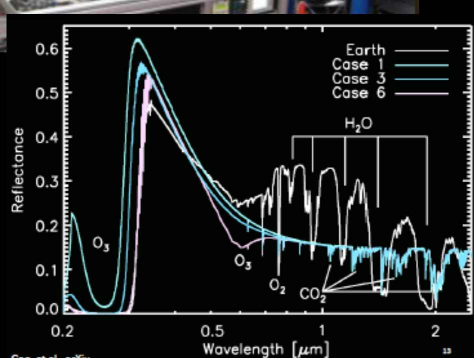
HQ reps:
Mary Voytek (PSD)
Martin Still (APD)
Jeff Newmark (HPD)
Shawn Domagal-Goldman

Co-leads:
Natalie Batalha
Dawn Gelino
Tony Del Genio

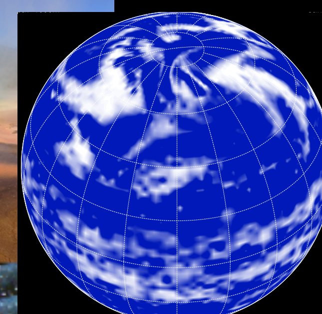
N. Turner
H. Jang-Condell
D. Apai





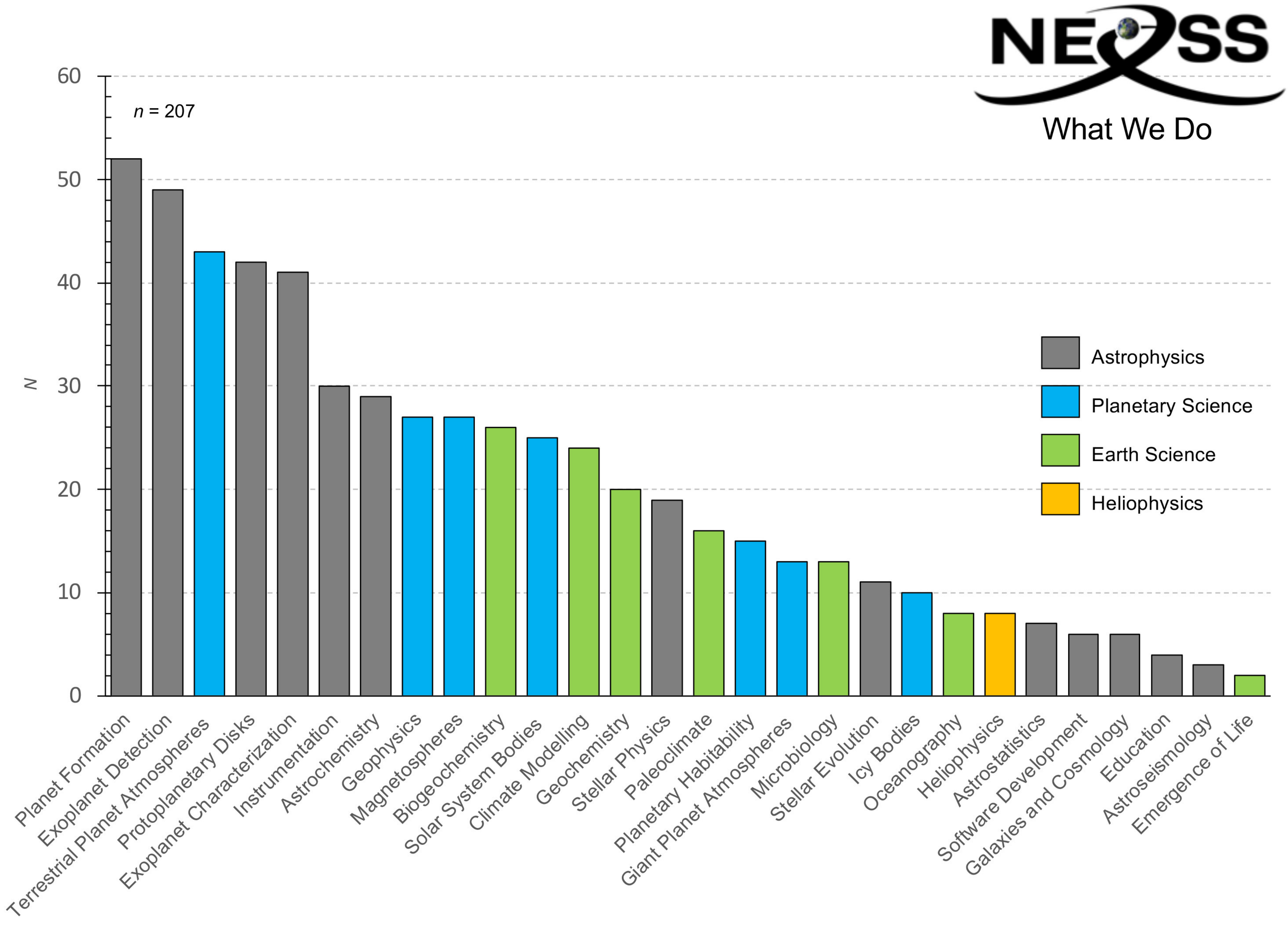


H. Imanaka
J. Fortney



B. Moore
V. Airapetian

W. Henning
S. Desch
V. Meadows
T. Del Genio


What We Do
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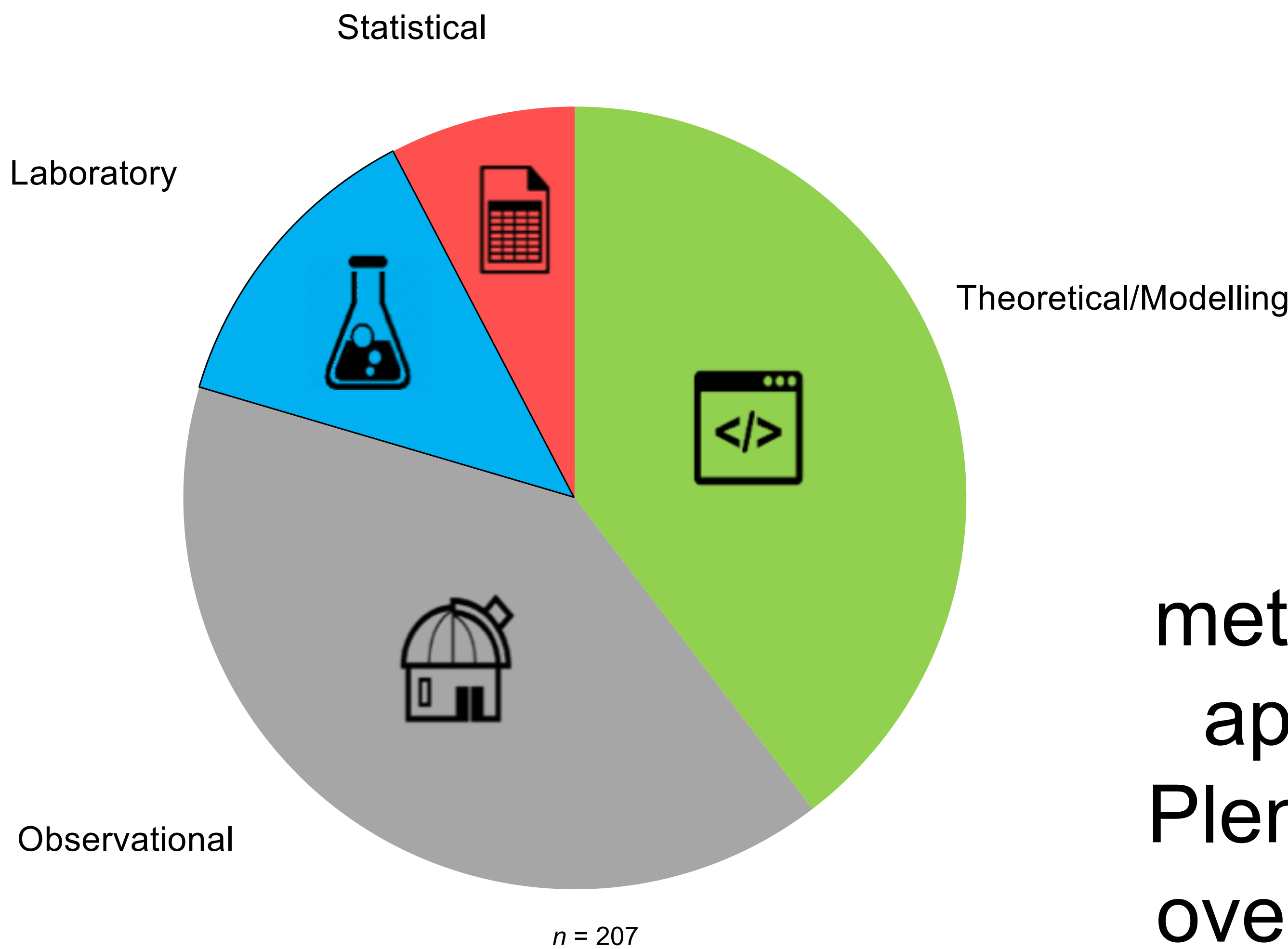
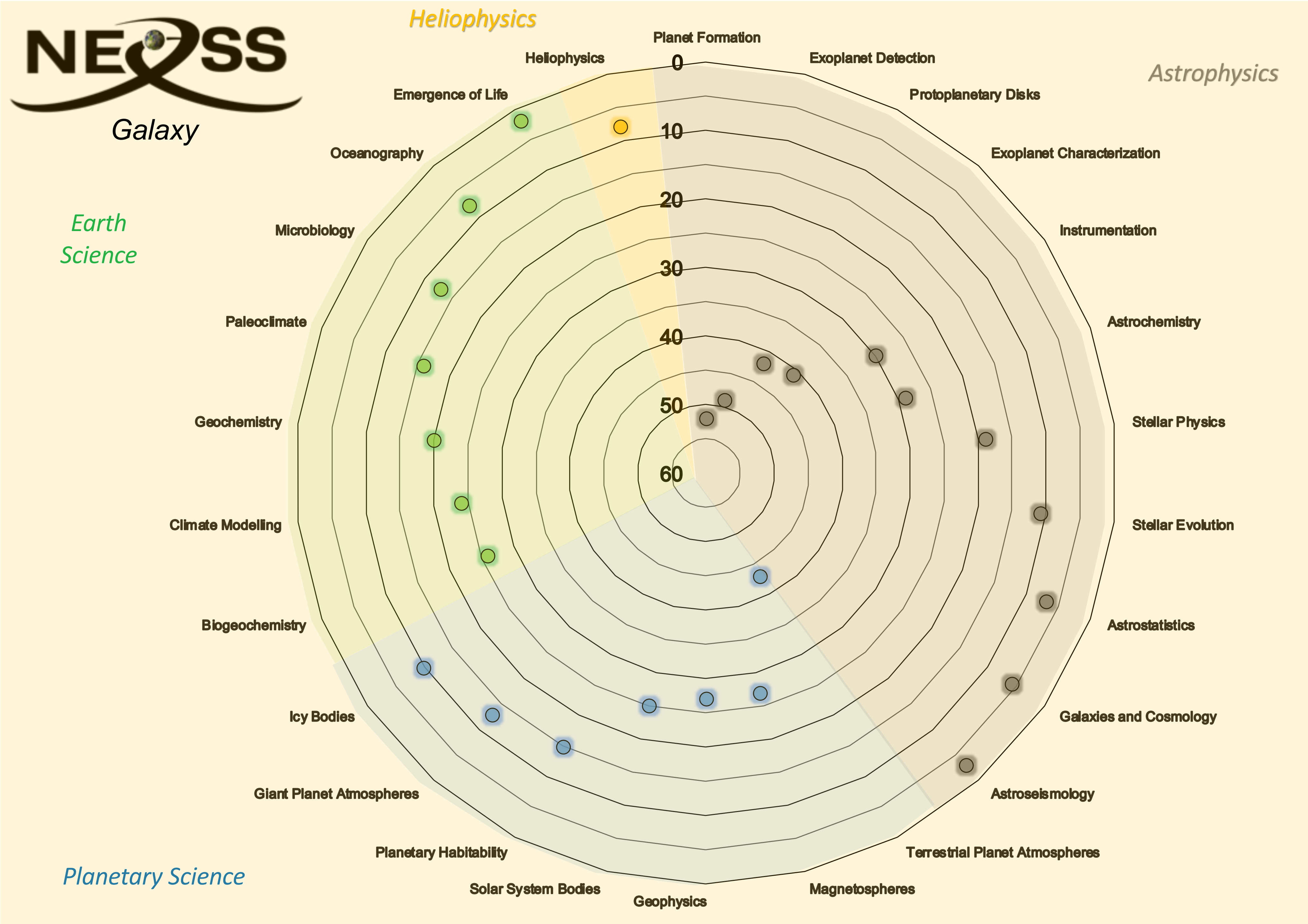
Astrophysics
Planetary Science
Earth Science
Heliophysics
Planet Formation
Exoplanet Detection
Terrestrial Planet Atmospheres
Protoplanetary Disks
Exoplanet Characterization
Instrumentation
Astrochemistry
Geophysics
Magnetospheres
Biogeochemistry
Solar System Bodies
Climate Modelling
Geochemistry
Stellar Physics
Paleoclimate
Planetary Habitability
Giant Planet Atmospheres
Microbiology
Stellar Evolution
Icy Bodies
Oceanography
Heliophysics
Astrostatistics
Software Development
Galaxies and Cosmology
Education
Astroseismology
Emergence of Life

How We Do It



Diverse methodological approaches. Plenty of cross-over, inter- and intra-team.



NExSS
Galaxy
Heliophysics
Astrophysics
Earth Science
Planetary Science
Planet Formation
Exoplanet Detection
Protoplanetary Disks
Exoplanet Characterization
Instrumentation
Astrochemistry
Stellar Physics
Stellar Evolution
Astrostatistics
Galaxies and Cosmology
Astroseismology
Terrestrial Planet Atmospheres
Magnetospheres
Geophysics
Solar System Bodies
Planetary Habitability
Giant Planet Atmospheres
Icy Bodies
Biogeochemistry
Climate Modelling
Geochemistry
Paleoclimate
Microbiology
Oceanography
Emergence of Life
Heliophysics
0
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NExSS Measures of Success

The NExSS leadership is conducting a self-assessment based on NSF evaluation metrics.

1. Investigators carry out and propose interdisciplinary research through new collaborations
–e.g. Exo-Mineralogy- a new "discipline" arose as a result of a workshop between astronomers and solid earth scientists.
–New cross divisional program Hab Worlds. Hab Worlds always had received exoplanet proposals but there an uptick in exoplanet proposals from PIs that had never proposed to Exobiology or the NAI.
–Several proposals from NExSS PIs, CoIs, and collaborators submitted to XRP and TWSC. One grant awarded to two new, collaborating researchers that developed the idea for the proposal at the Upstairs Downstairs Winter school.
Produces a plan for utilization of current space telescopes
– JWST Early Release Science working group lead NExSS. 2 proposals submitted by NExSS PIs and their collaborators won 23% of the allotted ERS time.

NExSS Measures of Success

The NExSS leadership is conducting a self-assessment based on NSF evaluation metrics.

2. Spawns ideas for new and exciting missions
–STDT Leadership and significant participation in Luvoir and HabEx by NExSS.

3. Identifies new targeted technologies needed not yet reported elsewhere
–Laboratory Astro Gap List White Paper Fortney et al. 2016 identified needed studies to increase the list informative wavelengths and enhance our ability to interpret spectra

4. Contributes to decadal review efforts for both PSD and APD
–4 NExSS white papers submitted to NAS-Astrobiology Strategy study and plan to submit 4-5 to the Exoplanet Exploration Study
--NExSS asked to present to the NAS Astrobiology Strategy study committee

5. Enhances International engagement
–Invited lectures; travel awards to international conference;
–46% participation in JWST Early Release Science working group was international researchers
–NExSS Directory developed at the request of International attendees to NExSS workshops