NASA Astrobiology Institute

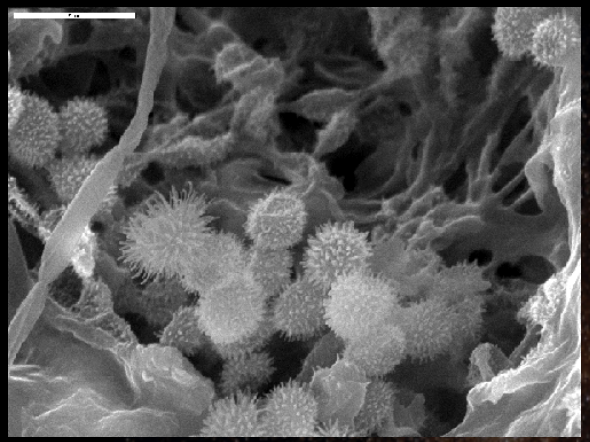
Penelope J. Boston
NASA Astrobiology Institute
NASA Ames Research Center, Moffett Field, CA 94035

2017

Astrobiology

3 fundamental questions

How does life begin & evolve?



Does life exist elsewhere in the universe?

What is the future of life on Earth & beyond?

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Sulfuric acid (pH=0), H_2S, CO, & other poisonous gases

Cueva de Villa Luz, Tabasco, Mexico

-3°C, poisonous SO_2 & other gases

Fumarolic Ice Caves, Mt. Rainier, WA

40-60°C, 100% Rh

Naica Caves, Chihuahua, Mexico

World's largest cave decoration, 18.5km & going

Snowy River, Ft. Stanton Cave, NM, Image, BLM

NASA Astrobiology Institute

LIFE IN THE UNIVERSE

Solar System and Beyond:
Our Journey of Discovery

Exoplanet Biosignatures

Icy Worlds: Habitability and Life Detection

Mars: *NASA's Journey to Mars*
Habitability of Early Mars

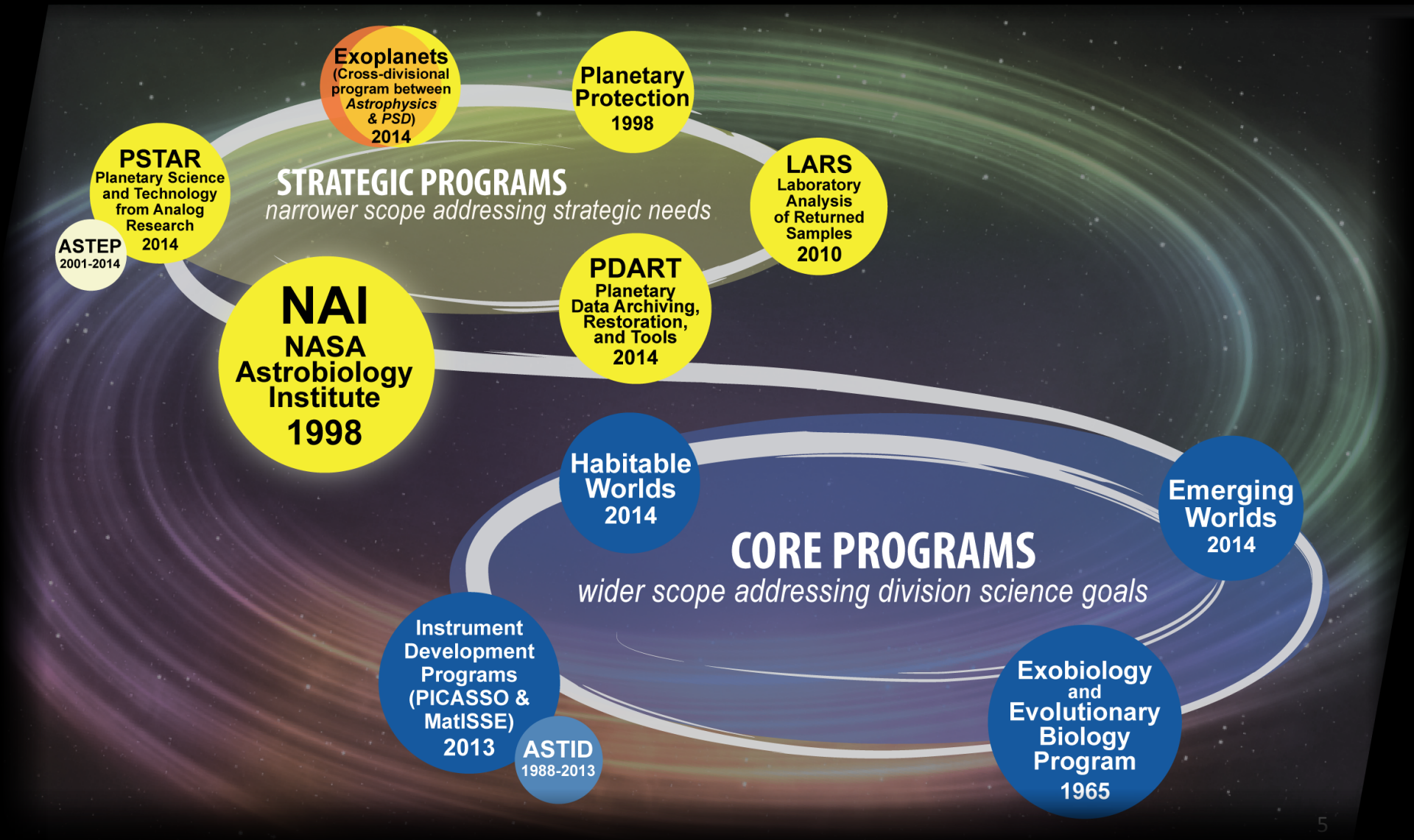
Technology: *Technology Drives Exploration*
Global Partnerships Employing Collaborative Technologies

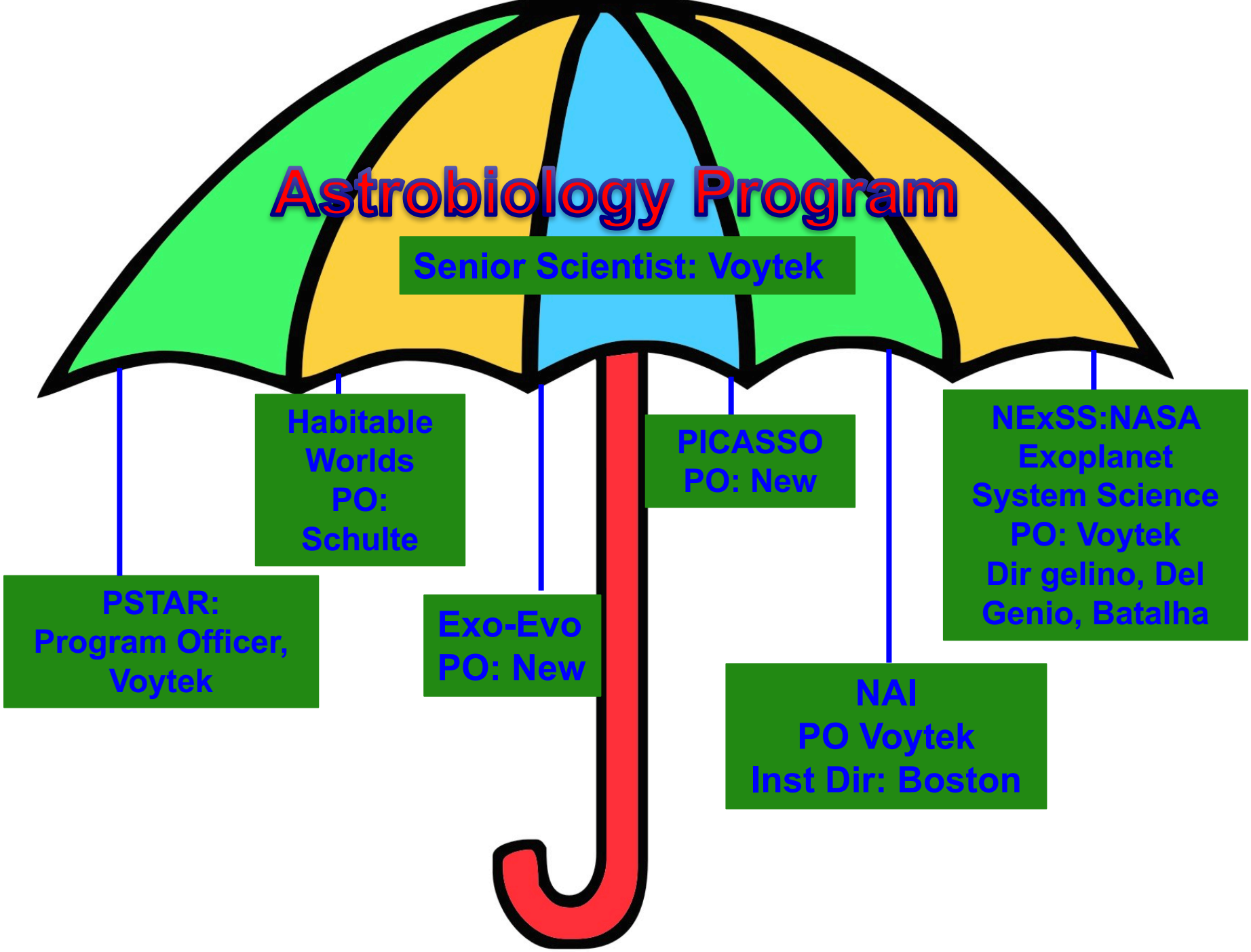
Origin and Nature of Life, Co-evolution with Planet Earth

NAI: the Community

Astrobiology

Planetary Science Division (PSD), Research & Analysis Program



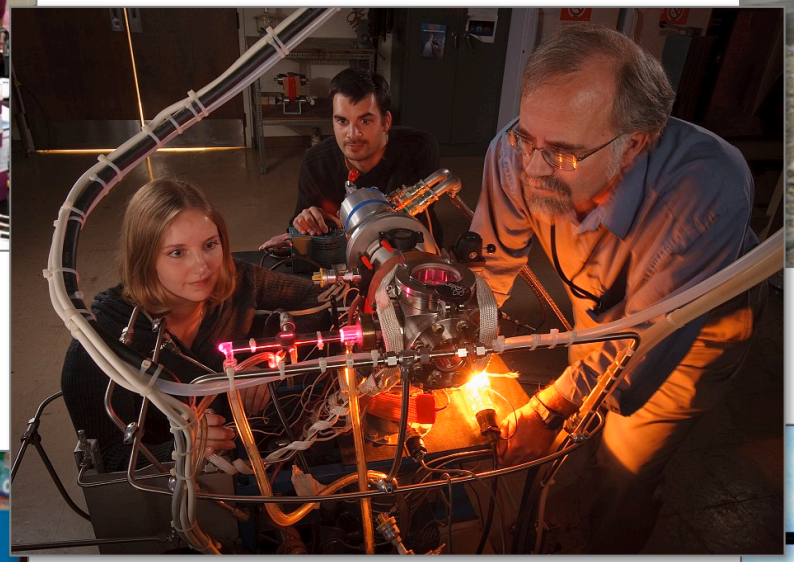

Astrobiology Program
Senior Scientist: Voytek
PSTAR:
Program Officer,
Voytek
Habitable
Worlds
PO:
Schulte
Exo-Evo
PO: New
PICASSO
PO: New
NAI
PO Voytek
Inst Dir: Boston
NExSS:NASA
Exoplanet
System Science
PO: Voytek
Dir gelino, Del
Genio, Batalha

Microbial Ecology
Physical Science
Molecular Biophysics
Infrared Astronomy
Materials Science
Marine Chemistry
Earth Science
Geomicrobiology
Geophysical Sciences
Computational Science & Engineering
Environmental Fluid Mechanics
Planetary Dynamics
Solid State Physics
Molecular Biophysics
Soil Science
Evolution
Earth Science
Soil Chemistry
Geography
Genetics
Applied Mathematics
Inorganic Chemistry
Cellular Biology
Geology
Meteorology
Physics
Remote Sensing
Anthropology
Isotope Geochemistry
Philosophy
Oceanography
Paleontology
Astronomy
Astrophysics
Bioinformatics
Biotechnology
Marine Biogeochemistry
Volcanology
Geochemistry
Zoology
COLLABORATION
Astrochemistry
Ecology
Theoretical Astrophysics
Planetary Sciences
Mineralogy
Astrobiology
Chemistry
Life Sciences
Biology
Marine Biology
Genetics
Paleobiology
Microbiology
Theoretical Physics
Molecular Biology
Biometeorology
Planetary Science
Virology
Philosophy
Artificial Intelligence
Organic Chemistry
Astrogeophysics
Experimental petrology

NAI Mission Statement

5 Elements

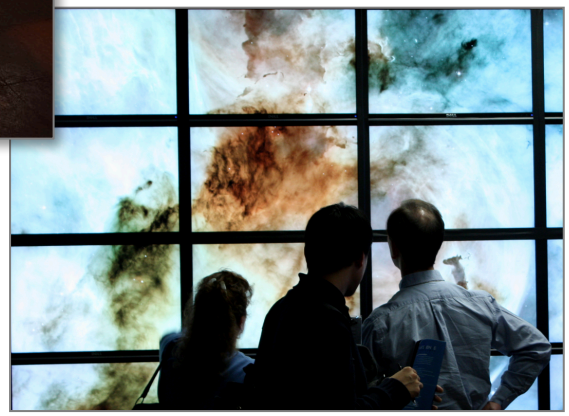
Train the Next Generation of Astrobiologists



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

NASA Astrobiology Institute Cooperative Agreement Notice Cycle 8 Released

Solicitation Number: NNH17ZDA003C

CAN Release Date: February 27, 2017

Preproposal Conference - March 10, 2017

11 AM Pacific Time (2 PM Eastern Time)

Opportunity to better understand the intent, scope, and selection criteria of this CAN.

Step-1 Proposal Due: April 12, 2017

Step-2 Proposals Due: July 6, 2017

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

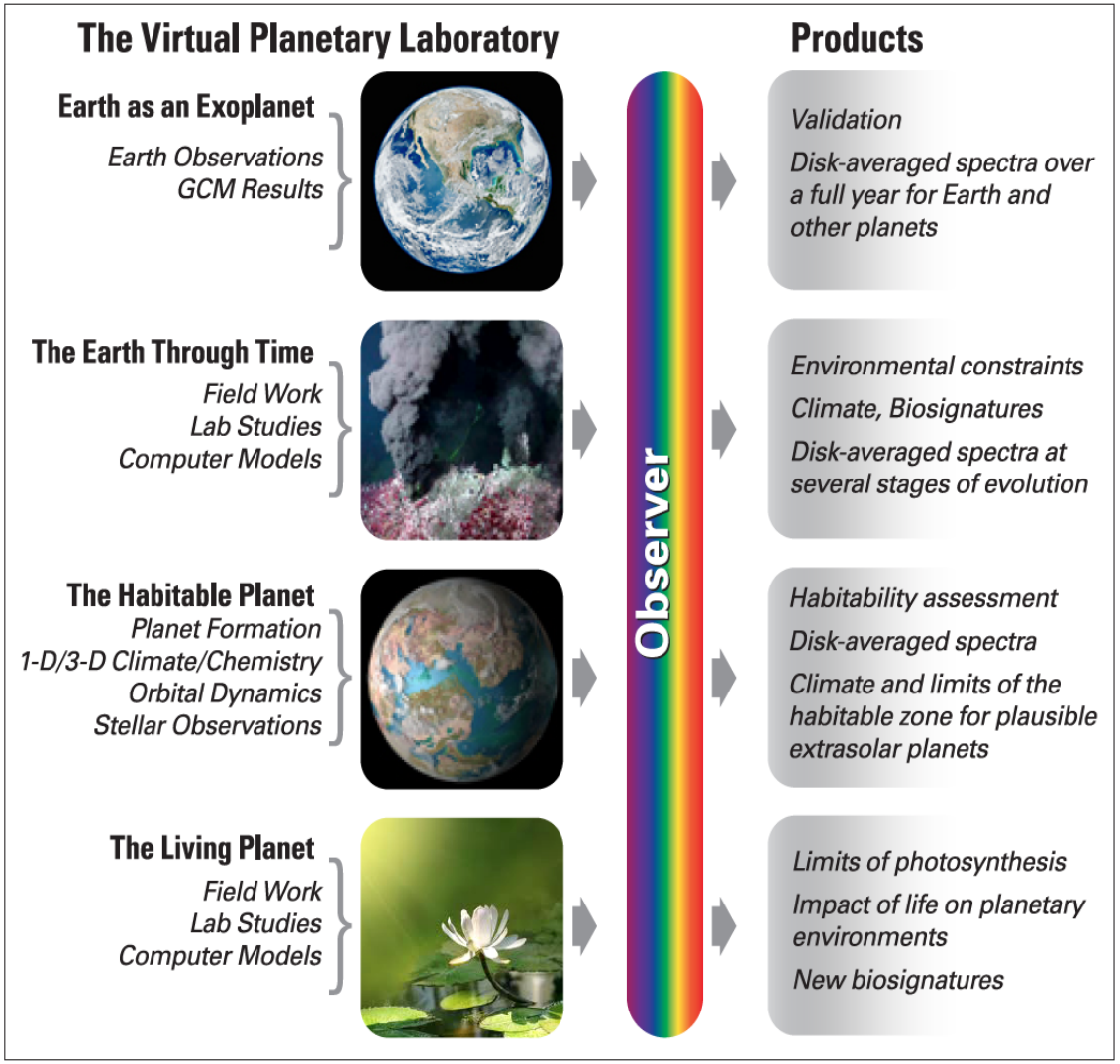
The Virtual Planetary Laboratory

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

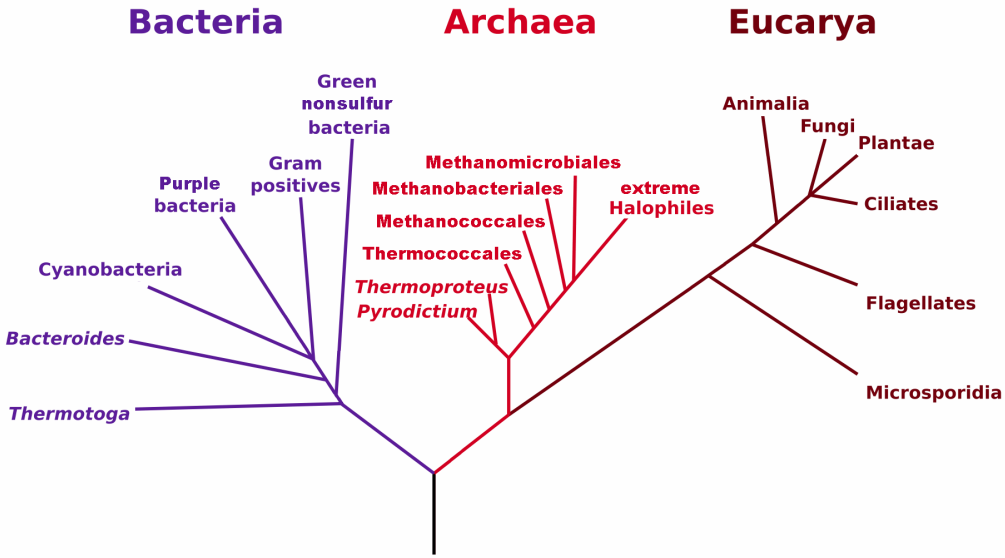
PI is Nigel Goldenfield

- 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

Phylogenetic Tree of Life



- 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

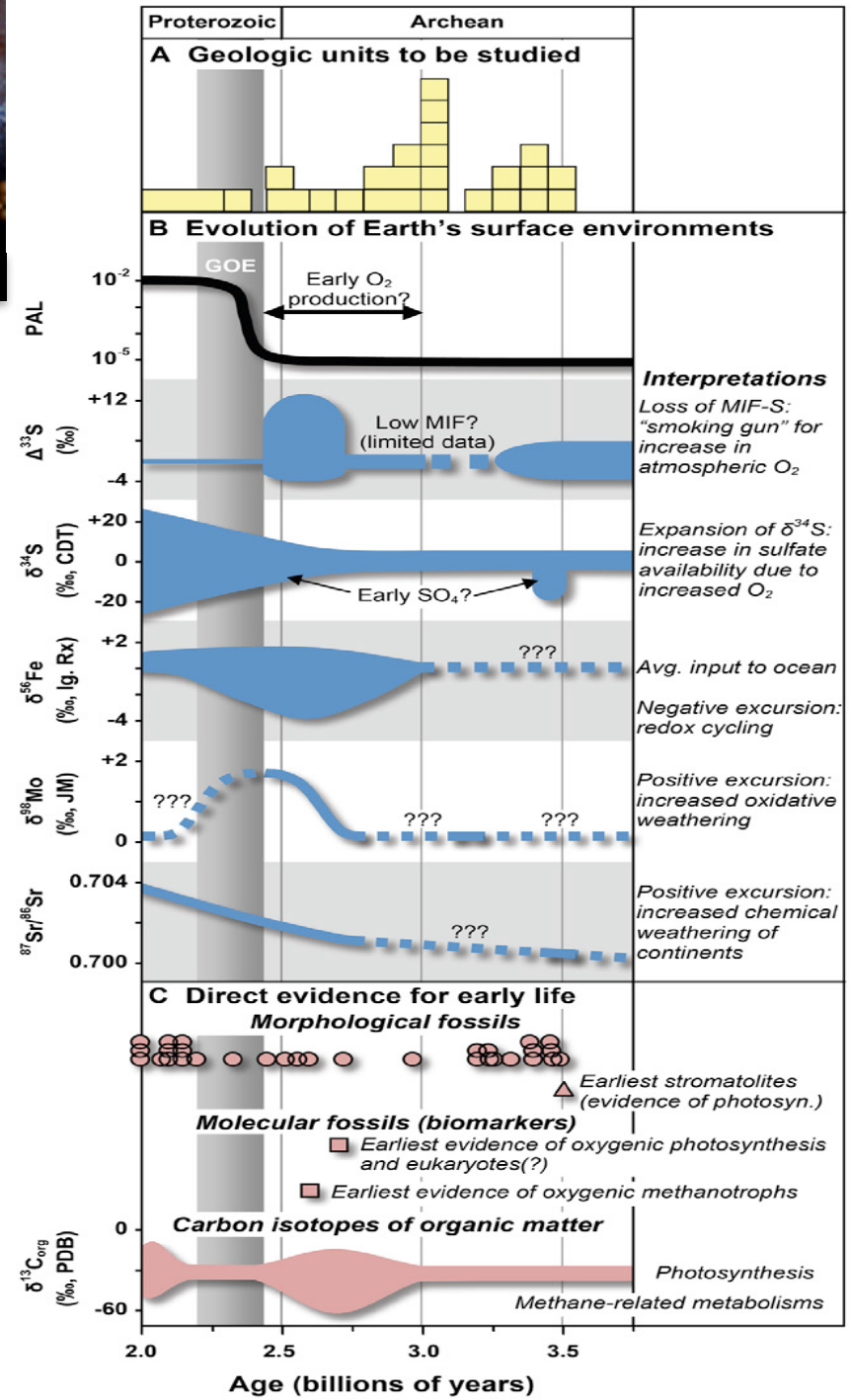
Habitability, Life Detection, and the Signatures of Life on the Terrestrial Planets

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

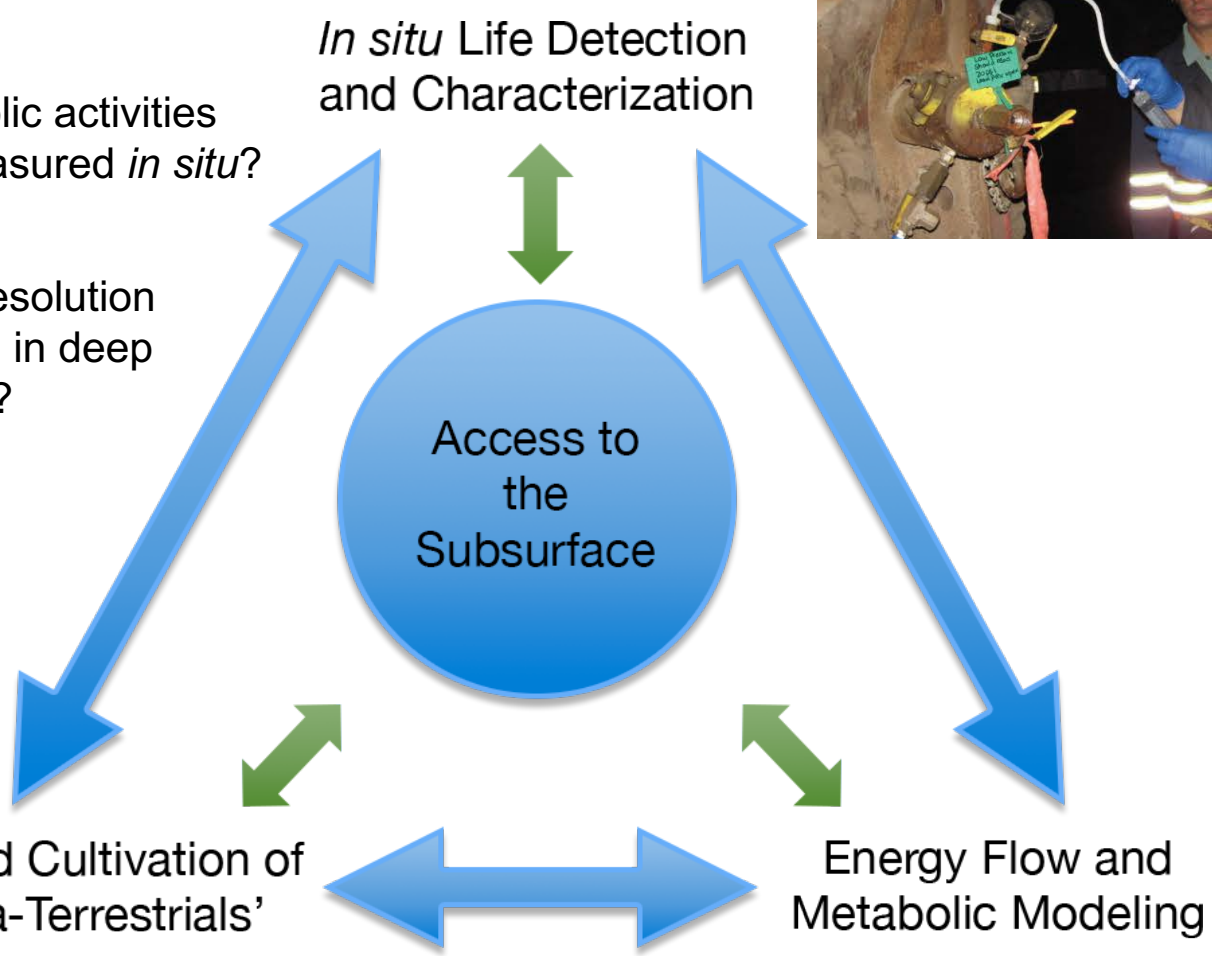


CAN 6: University of Southern California

Life Underground

PI is Jan Amend

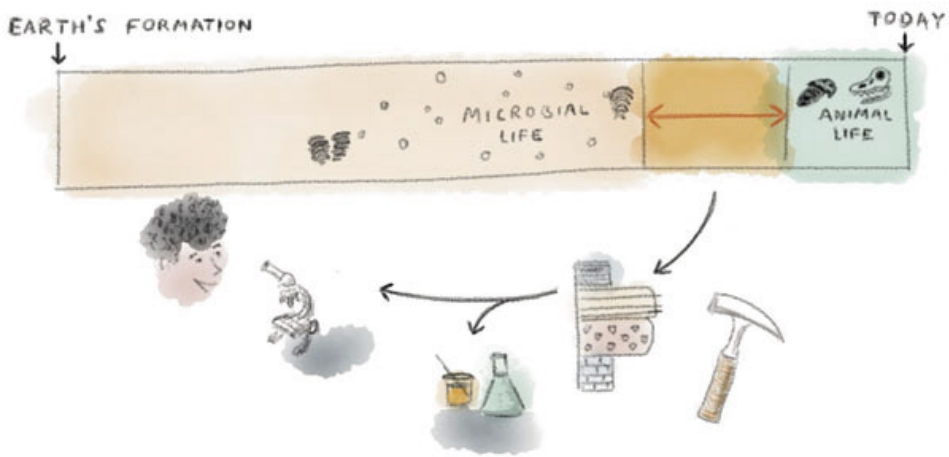
- What spectral/optical signals indicate the presence of biomass?
- What kind of metabolic activities can be detected/measured *in situ*?
- What is the limit of resolution of biomass detection in deep subsurface samples?
- Can one distinguish living from dead biomass *in situ*?



CAN 6: Massachusetts Institute of Technology

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

PI is Roger Summons



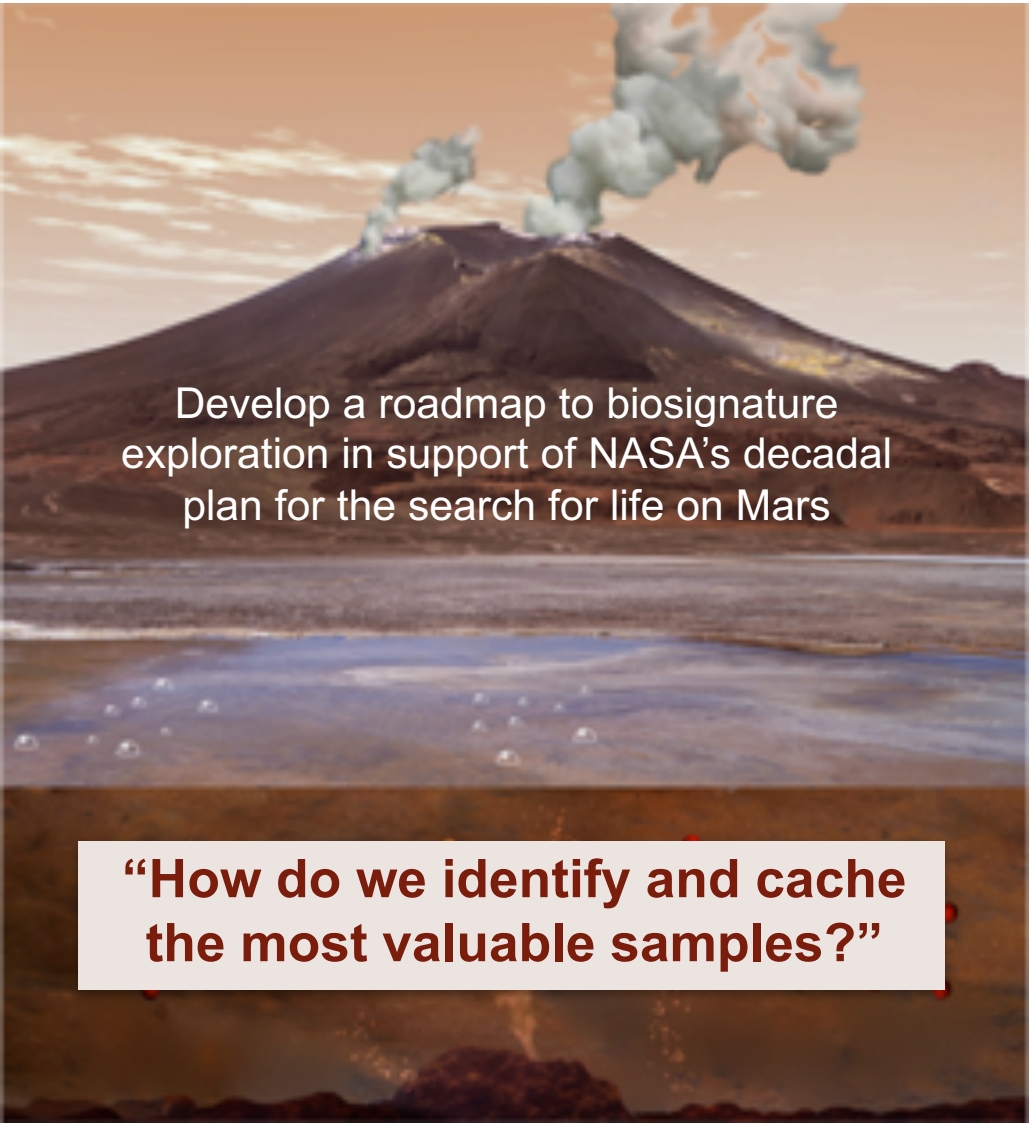
Questions to be addressed include:

- 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

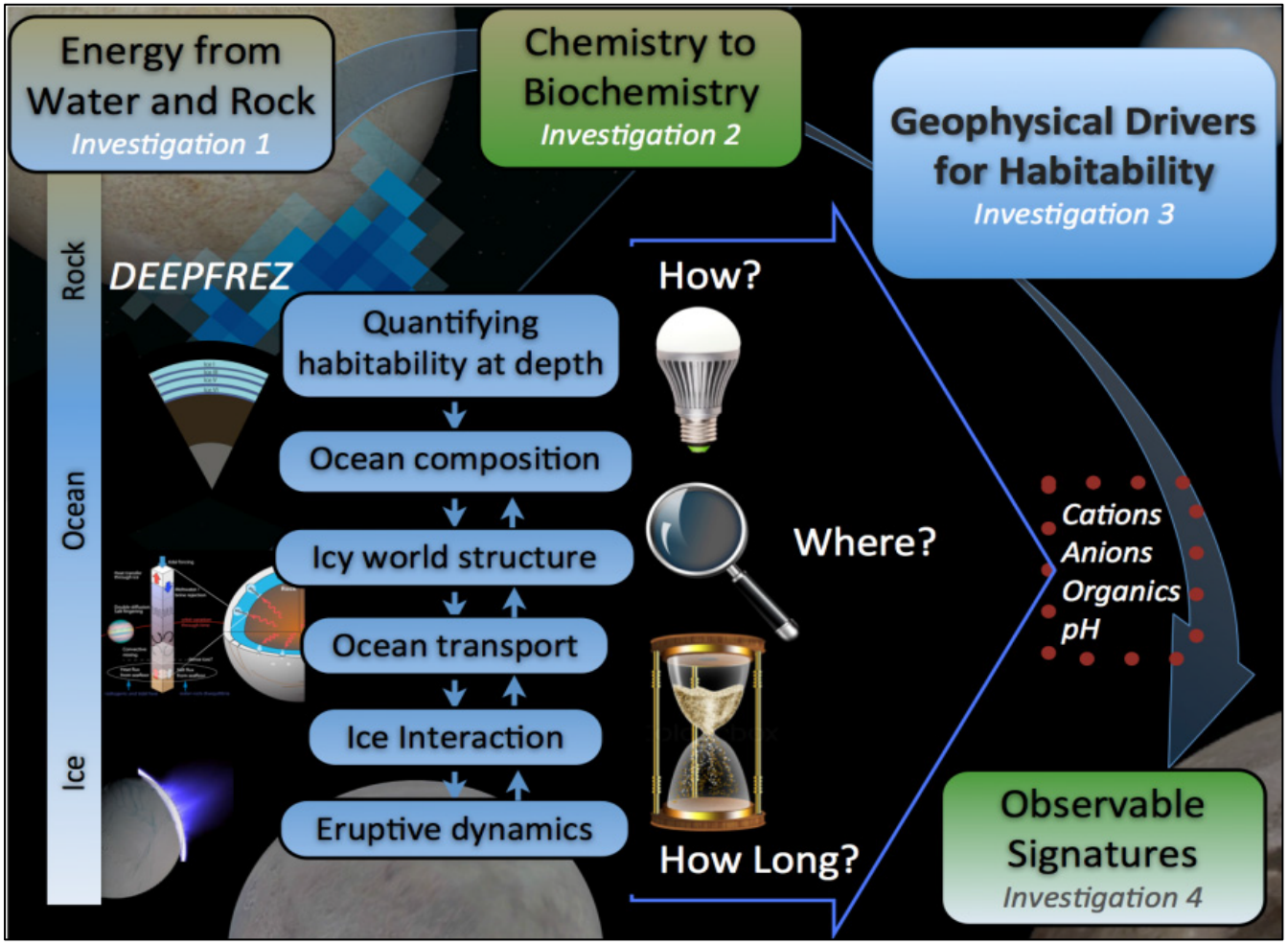
Adaptive Detection of Biosignatures: Applying Data Fusion, Novelty Detection, and Autonomous Detection of Biogenicity

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?



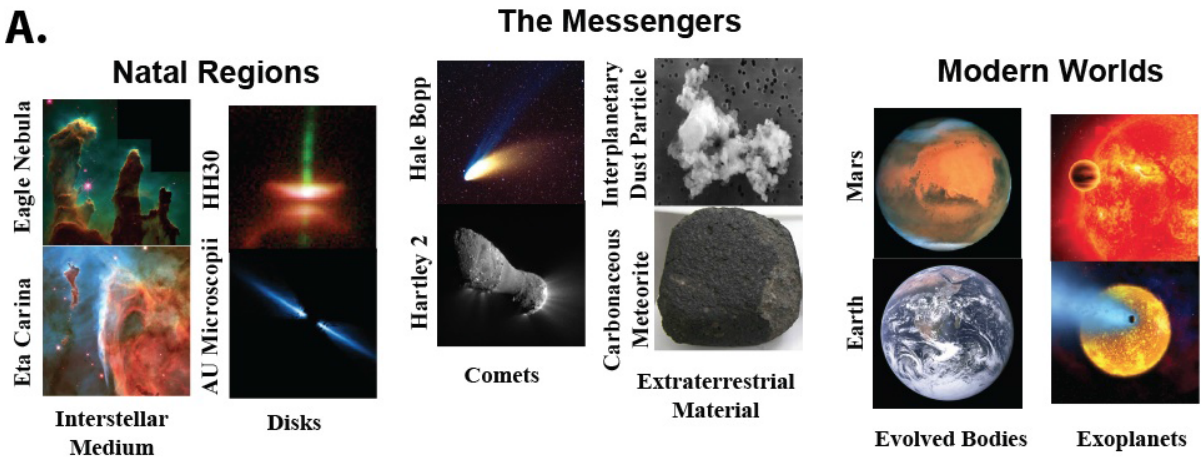
CAN 7: NASA Goddard Space Flight Center

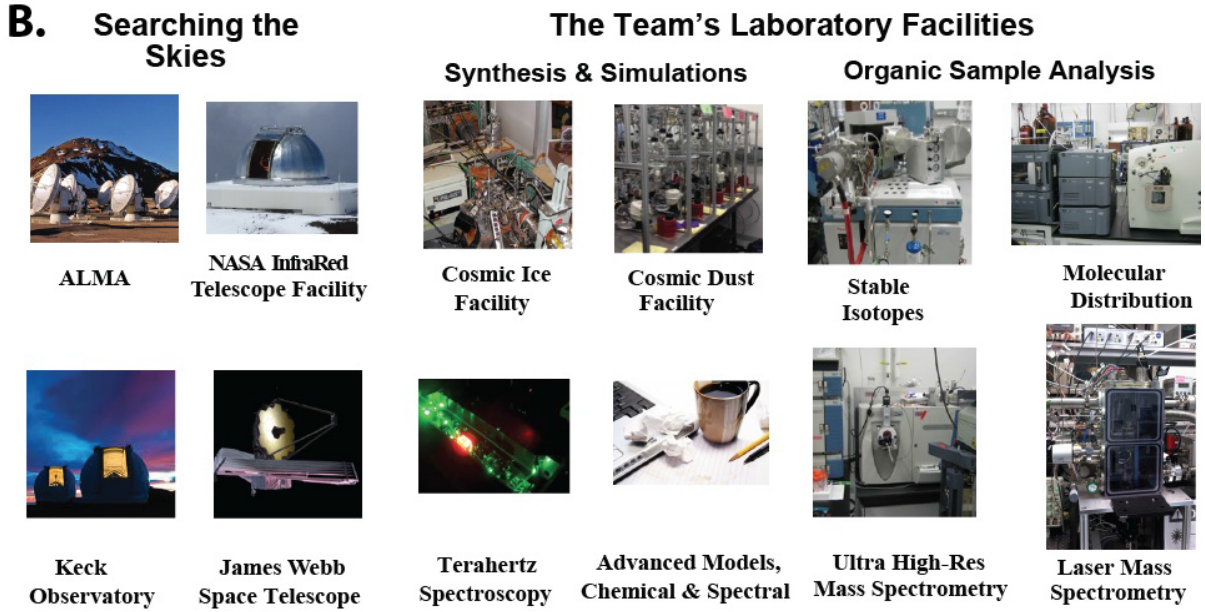
Origin and Evolution of Organics and Water in Planetary Systems

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.

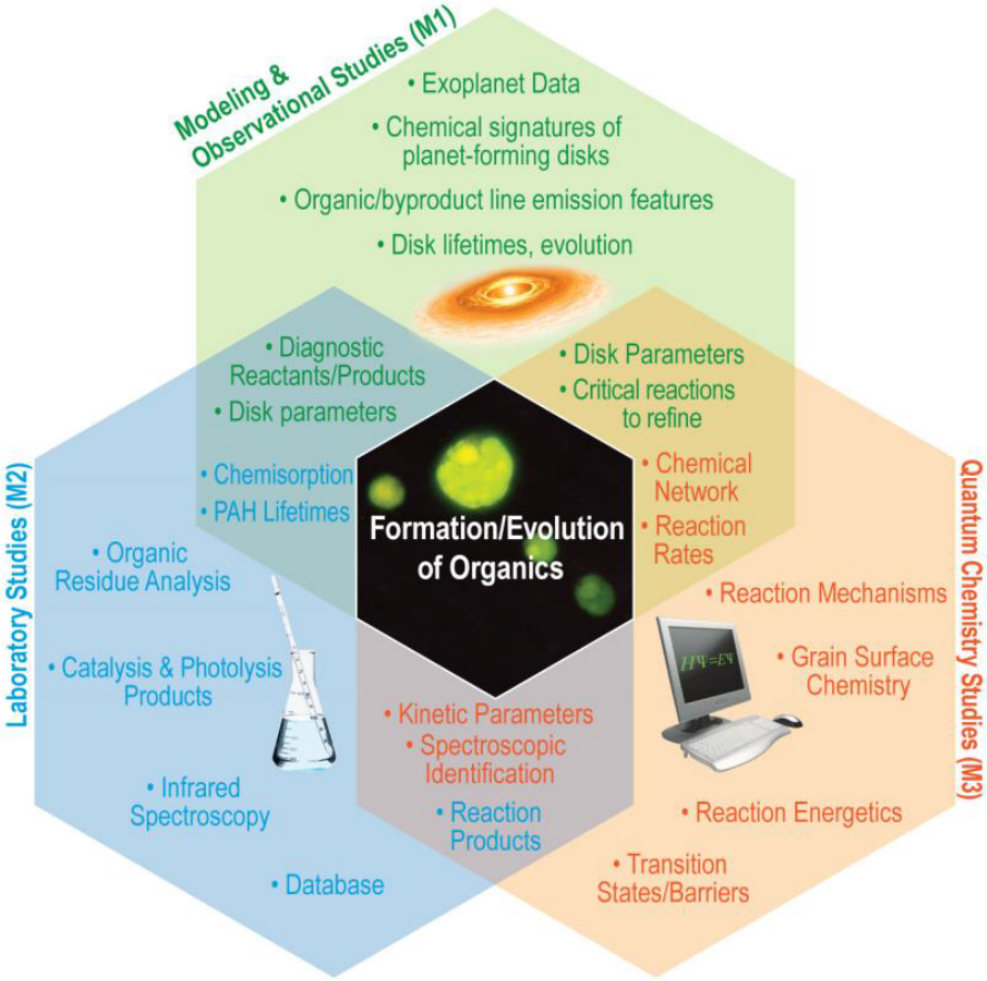




CAN 7: NASA Ames Research Center

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

PI is Scott Sandford



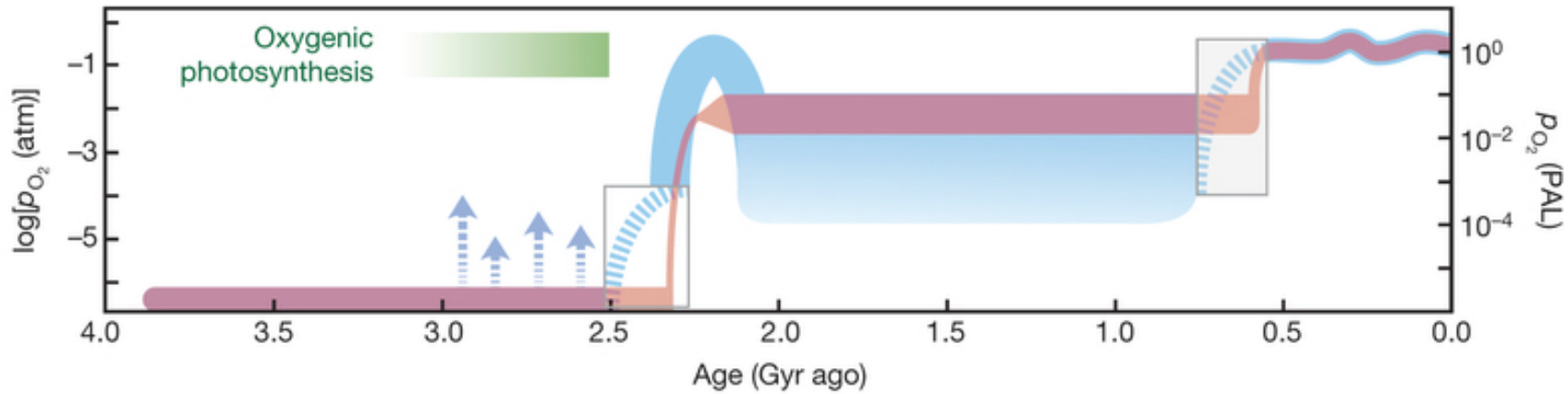
. . . to understand the chemical processes at every stage in the evolution of organic chemical complexity, from quiescent regions of dense molecular clouds, through all stages of cloud collapse, protostellar disk, and planet formation, and ultimately to the materials that rain down on planets - and to 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?



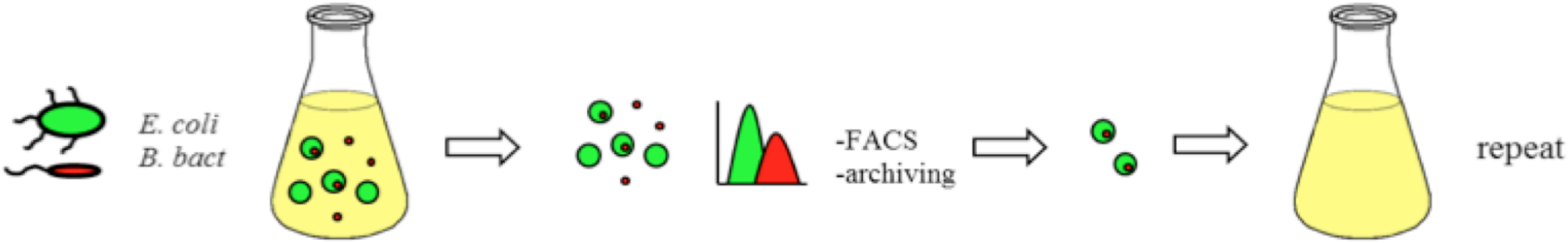
Alternative Earth 1	Resolve when oxygenic photosynthesis first left traces in Earth's atmosphere and whether (and, if so, why) there was a lag between oxygen's first biological production and its persistent accumulation.
Alternative Earth 2	Determine whether Earth's surface underwent a unidirectional 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?

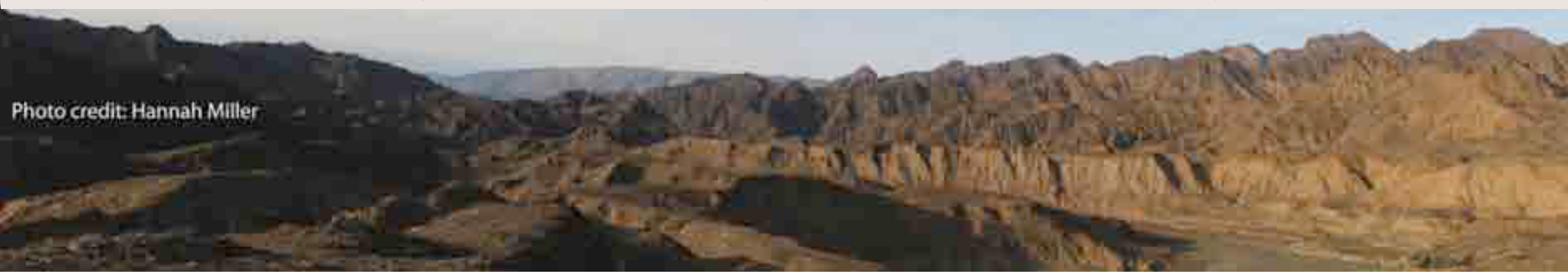
A unifying theme underlying these questions is: how do cooperative vs. competitive interactions play out in driving major transitions that occur when independently replicating entities combine into a larger, more complex whole?

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.

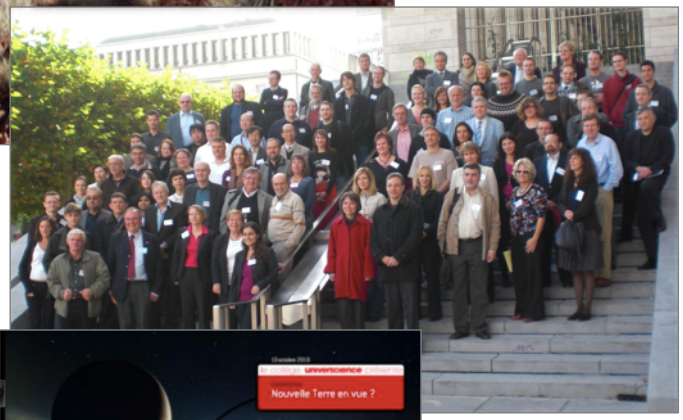
International Partners

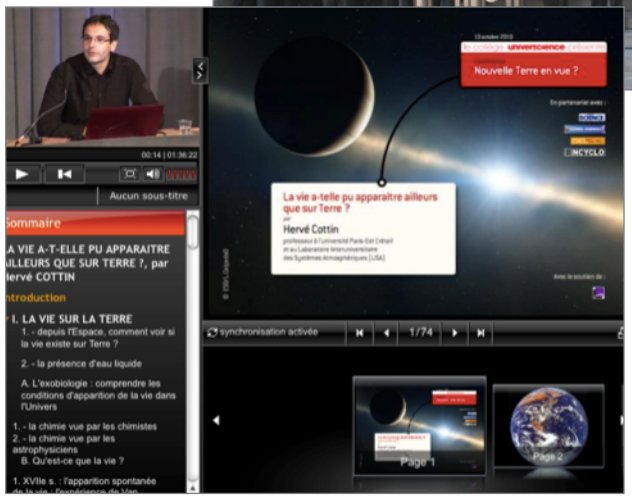
ASSOCIATE PARTNERS:

- Australian Centre for Astrobiology
- Centro de Astrobiología (Spain)

AFFILIATE PARTNERS

- Astrobiology Society of Britain
- Canadian Astrobiology Network
- European Exo/Astrobiology Network Association (EANA)
- Helmholtz Alliance: Planetary Evolution and Life (Germany)
- Instituto de Astrobiología Colombia
- Nordic Network of Astrobiology
- Russian Astrobiology Center
- Société Française d'Exobiologie
- Sociedad Mexicana de Astrobiologia
- UK Centre for Astrobiology
- USP Research Unit in Astrobiology (NAP-Astrobio) (San Paolo)





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- 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 Programs

- Minority Institution Research Support Program (*for faculty*)
- Postdoctoral Fellowship Program *(for postdoctoral scholars)*
- 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
- Education and Public Outreach in Transition…..

Training the next generation

Resources:

The Astrobiology Primer v2.0

Astrobiology Career Path Suggestions, https://astrobiology.nasa.gov/career-path-suggestions/

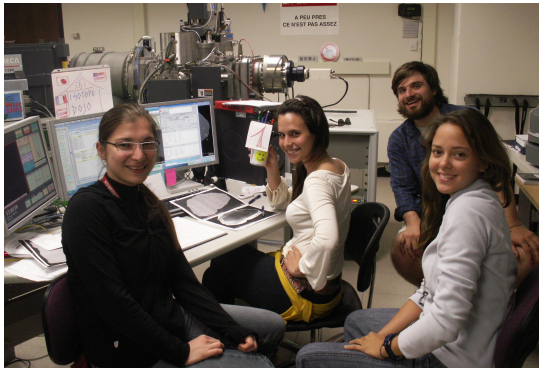
Astrobiology Summer Schools/Courses:

Santander, Geobiology Course, MBL Microbial Diversity Course

Student Support to Conferences:

AbSciCon, April 2017, Phoenix

AbGradCon, June 2017, abgradcon.com



Funding Opportunities:

NASA Postdoctoral Program

Astrobiology Early Career Collaboration Awards

Lewis and Clark Fund for Field Research

SAGANET, http://saganet.org

Science outreach

”Talk to an Astrobiologist” Series

Astrobiology Book Club

Minority Institution Research Support Program (MIRS)

- Started in 2002 to increase the number of:
  1) faculty from Minority Serving Institutions (MSIs) actively and competitively engaged in astrobiology research and related pursuits,
  2) students from underrepresented groups pursuing careers in astrobiology
- Supports MSI faculty [summer] sabbaticals in the laboratories of NASA Astrobiology Program investigators and follow-up funding for student stipends, materials, travel, etc.
- Sabbatical opportunities for MI faculty with Astrobiology researchers
- 37 MIRS Fellows since 2003
- Collectively, these NAI-MIRS fellows have:
  - published more than 55 research papers and abstracts in astrobiology, with the majority containing student authors
  - directly impacted ~70 students each (on average) with either new research or curriculum

NAI and AB Program
NASA Postdoctoral Program

101 NPPs since 2000

Where are they now…

- 49 Faculty
- 5 hired by NASA
- 10 were NPP Advisors
- 13 are on NAI teams
- 4 have been Exo/ASTEP/ ASTID PIs
- 18 have research or university positions
- 1 Policy Fellow and 1 Journal Manager

2000

Virginia Edgecomb, MBL
Eric Gaucher, Scripps*
Marc Kramer, NASA Ames
Mark Messerli, MBL
Yanan Shen, Harvard U.
David Warmflash, NASA JSC

2001

Charles Boyce, Harvard U.
Ruth Ley, U. of CO
Sara-Eva Martinez-Alonso, U. of CO
Michelle Minitti, ASU
Alexander Panlov, U. of CO
Henry Scott, CIW

2002

Seth Bordenstein, MBL
Geoffrey Garrison, U. of WA
Susannah Porter, UCLA
Tracy Norris, NASA Ames
Michael Smoliar, CIW
Christopher Staples, ASU

2003

Corien Bakermans, Michigan SU
Matthew Hurtgen, Harvard
Daniel Lessner, PSU
Peter Sazani, Harvard
Giovanna Tinetti, JPL

2004

Jamie Elsila, NASA Ames*
Aline Gendrin, MBL
Jinling Huang, MBL
Julie Huber, MBL*
Evgenya Shkolnik, UHI*
Brandy Toner, MBL
Margaret Turnbull, CIW*

2005

Elise Furlan, UCLA
Shannon Hisna, Michigan S.U.
Sean Raymond, U. of CO*
Matthew Schrenk, CIW*
Feng Tian, PSU*
Melissa Trainer, U. of CO

2006

Oleg Abramov, U. of CO
Jennifer Biddle, MBL/U Delaware*
Curtis Cooper, U. AZ
Matt Pasek, U. AZ

2007

Julien Foriel, U. Wash (UA)
Daiki Horikawa, NASA Ames
Steven Mielke, GISS

2008

Dina Bower, UW
Mark Claire, Penn State

2009

Nancy Akerman, MBL/CIW
Eric Boyd, NAI/Montana State U*
William Brazelton, ECU/CIW
Gregory Fournier, MIT
Neal Gupta, MIT/CIW*
James Henderson Cleaves, CIW
Brant Jones, U Hawaii
Styliani (Stella) Kafka, CIW
Jennifer Kyle, OSU/NASA Ames
Siobhan (Sasha) Wilson, Indiana U
Felisa Wolfe-Simon, LBNL/NASA Ames

2010

Jennifer Glass, Cal Tech*
Sara Imari Walker, ASU

2011

Betul Kacar, G Tech
Arsev Aydinoglu, NAI/UTenn
Svetlana Berdyugina, UHI
Aaron Engelhart, Harvard
Aaron Goldman, GIT/Princeton
Matthew Herron, UMT
Jordan Okie, Exo ASU
Melissa Rice, Cal Tech
Paula Welander, MIT

2012

Jose Aponte, NASA GSFC
Tammy Campbell, Exo/Scripps
Natascha Riedinger, ASU
Erik Sperling, MIT
Laurie Barge, Icy Worlds
Trinity Hamilton, PSU
James Morris, UIUC
Corinne Myers, MIT
Dorian Parker, U Hawaii

2013

Rika Anderson, UIUC
Maya Gomes, MIT
Neha Kamat, Exo/Harvard
Margie Kinnersley, Exo/U Montana
Jonathan Toner, VPL

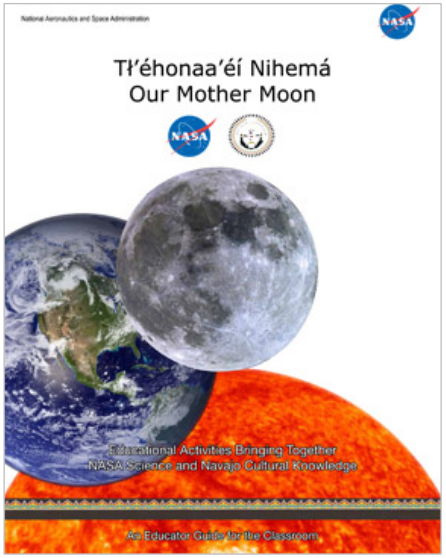
2014

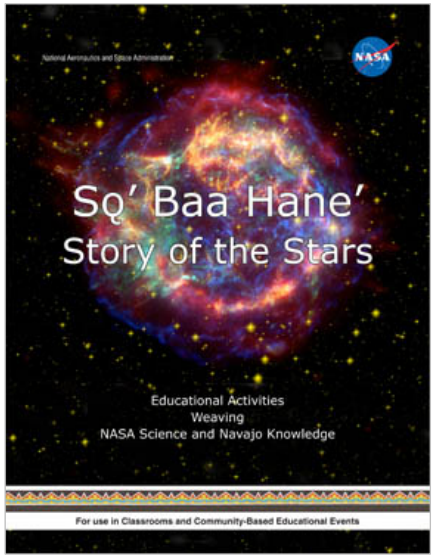
Bradley Burcar, Georgia Tech
Geoffrey Gilleaudeau, ASU
Luke McKay, Montana State
Alan Rooney, Harvard/MIT
Leigh Anne Riedman, Harvard/MIT
Tim Efthymiou, Scripps
Benjamin Charnay, VPL
Eva Stueekan, VPL
Elizabeth Wilbanks, USC

Bold = NPP advisor
* = Current NAI Team member Faculty Hired by NASA

NASA and the Navajo Nation

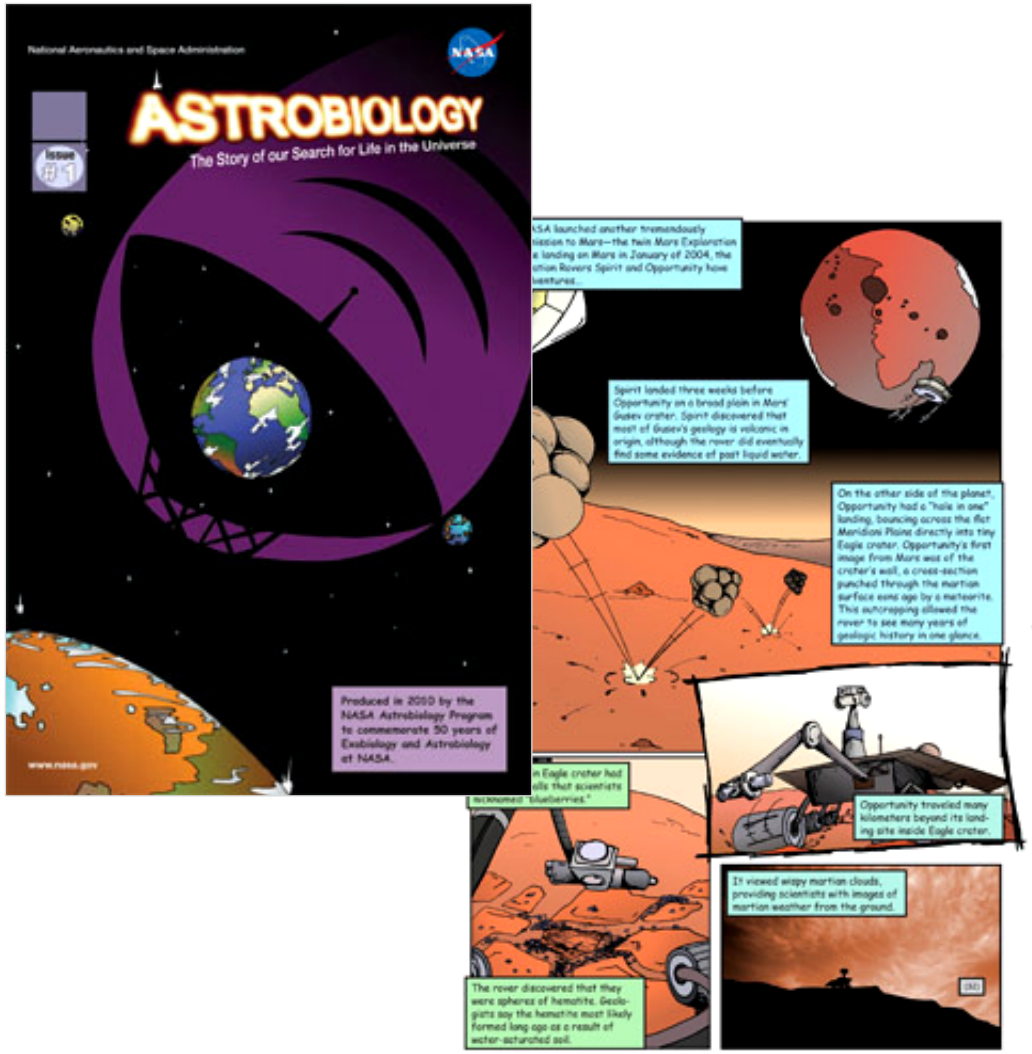
- Began in 2005 with a question: are you interested in partnering with NASA on educational programs?
- Co-developed two educator guides and hosted a summer camp
- “Dual-learning” environment enables scientific and cultural knowledge to co-exist without one dominating the other





Innovative Products:
Astrobiology Graphic Novels

- Astrobiology Program leadership at NASA HQ collaborating with an artist to produce a series of graphic novels.
- Issue #1 covers the history of Astrobiology
- Issue #2 covers the history of Mars Exploration
- Issue #3 covers Astrobiology's relationship to Solar System exploration missions
- Issue #4 covers field sites where astrobiologists are studying extreme environments



FameLab USA

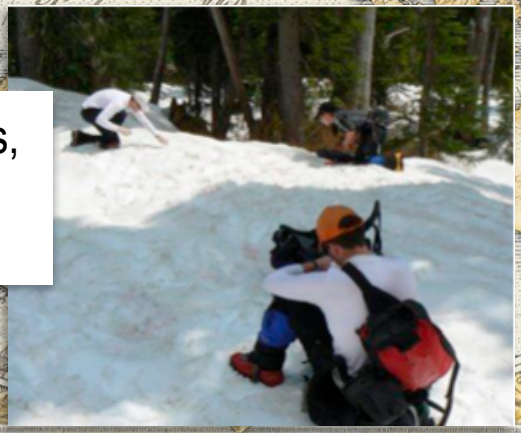
- Encourages career scientists to develop the skills to deliver engaging scientific presentations to a public audience
- FameLab started in UK in 2005. NASA partnered with the British Council in 2012 to run FameLab in the US.
  - Competitions held at AGU, LPSC, Society of American Archaeology, Nat Geo, Stony Brook U, Washington U, Denver Museum of Nature and Science, YouTube (online)
- US finals on April 2014 in DC at National Geographic had 11 career scientists competing to advance to international finals

The Lewis & Clark Fund for Exploration and Field Research in Astrobiology

2006 - Today

Partnership between American Philosophical Society and NAI

Provides small grants (up to $5K) to graduate students, postdocs, and early career scientists for astrobiology field research around the world



Integrating Research Themes of the NAI

Serpentinizing Systems
(Univ. of Colorado, USC, SETI Inst., JPL, U.C.-Riverside, Univ. of Montana, Univ. of Wisconsin, Univ. of Illinois)

Habitable Planetary States, the Evolution of Microbial Life, and their Astronomical Biosignatures
(U.C.-Riverside, Univ. of Montana, Univ. of Washington, Univ. of Wisconsin, MIT, SETI Inst., JPL, Univ. of Colorado, USC)

Planetary Inventory of Organics and Water, and the Origin of Life
(GSFC, U.C.-Riverside, MIT, Univ. of Illinois, NASA Ames)

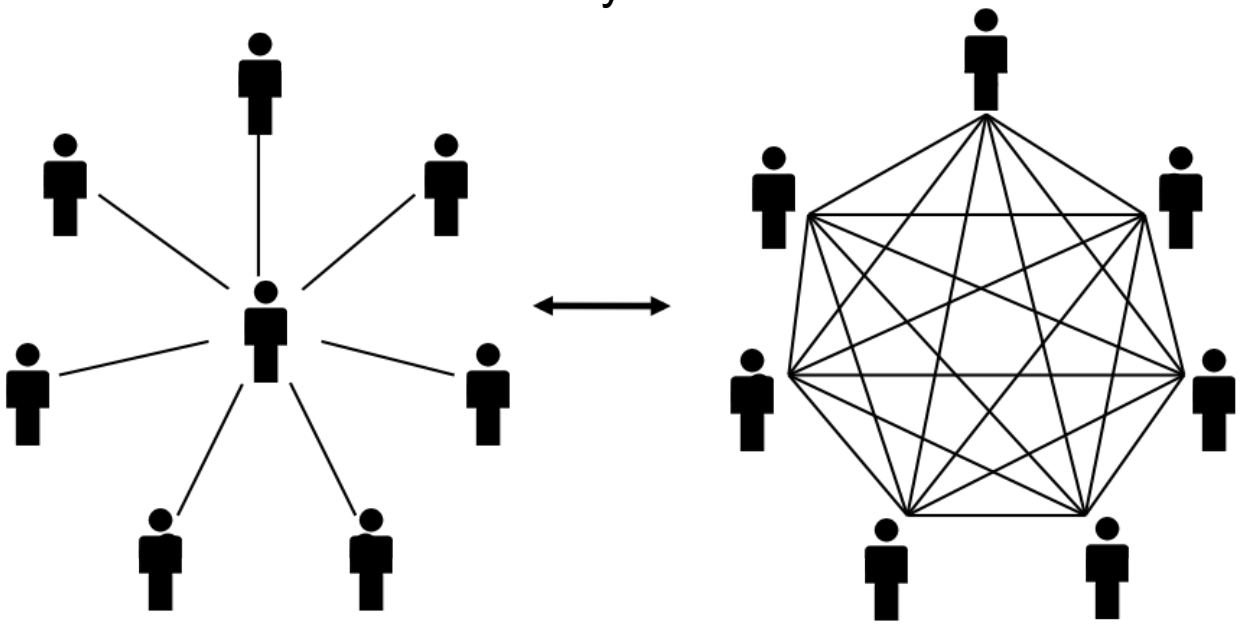
Environmental Change and Biosignatures
(SETI Inst., Univ. of Wisconsin, Univ. of Colorado, USC, U.C.-Riverside, MIT, others)

GeoBioCell Applications
(Univ. of Illinois, Univ. of Montana, USC, Univ. of Wisconsin, JPL, Univ. of Colorado, U.C.-Riverside, GSFC)

Evolution of Complex Life
(Univ. of Montana, MIT, SETI Inst., U.C.-Riverside, USC, Univ. of Colorado)

Collaborative Technologies for Astrobiology: Information Technology Working Group (ITWG)

- Composed of IT enthusiasts from each team
- Meets virtually once a month
- Share lessons learned and knowledge
- Test hardware, software and integration
- POCs for virtual events
- Provides local training, support, expertise and **feedback** within the system
- Build organizational structures within NAI to promote an optimal interaction between centralization and autonomy

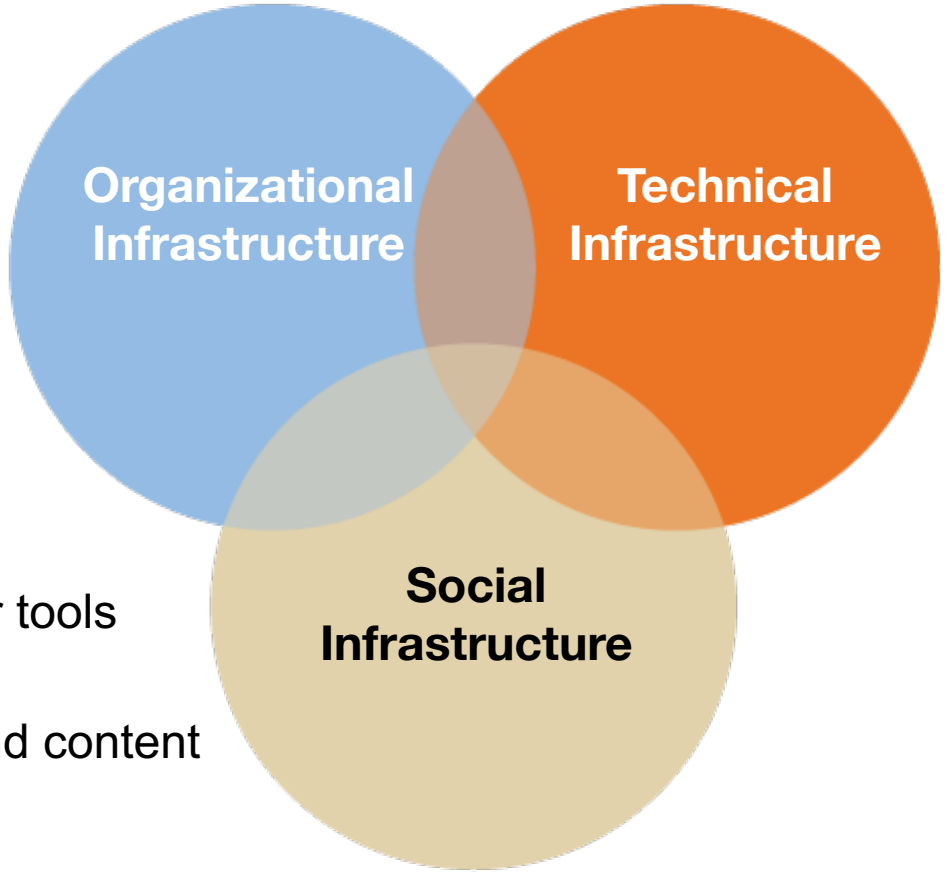


Information Technology Working Group (ITWG)

APPROACH

- Provide a suite of tools
- Standards based when possible
- Cross platform and mobile support
- Integrate multiple technologies for better solutions
- Transparent, reliable technologies
- Heuristic evaluations (usability)
  - **Reduction in help calls**
- Simple training and documentation
- We live in our community, we use our tools
  - Allows for iterative improvements
  - Deep understanding of culture and content
  - Flexibility
- **Empower the end-users**

COLLABORATIVE INFRASTRUCTURE



NAI Virtual Collaboration

- Multipoint Video/Telephone Connections
  - Integrates up to 30 HD video connections and 60 phone lines
- Real-time meeting applications
  - Integrates video, audio and supports high resolution screen sharing, chats, polls, and interactive features.
- Integrated web technologies
  - Newsletters
  - Directories and reports
  - Online communities

Combine to run…

- Seminars
- Workshops
- Large scale meetings
- Small group meetings
- Collaborative document writing
- Training
- Remote courses
- Journal clubs
- Public talks

Technology is not enough, *the human element is crucial*

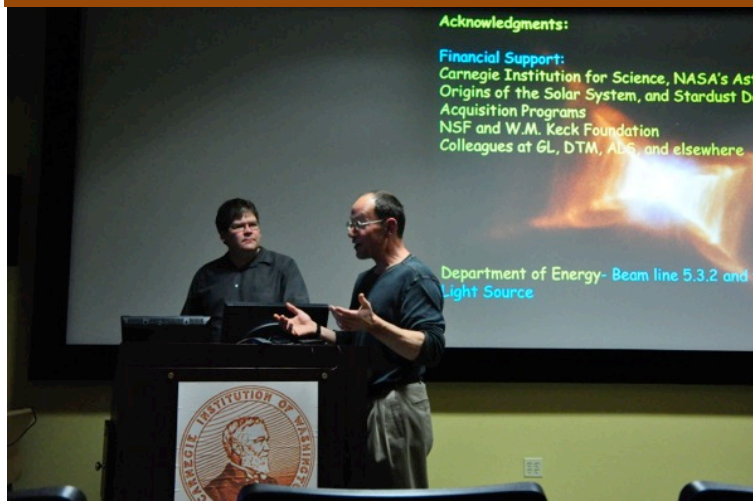
NAI: Workshop Without Walls

12+ Virtual Workshops

ARC showing 6 videocon sites

University of Hawaii

Carnegie Institution of Washington



Rensselaer Polytechnic Institute

NAI: Workshop Without Walls
Comments From Participants

"I congratulate you on the format of the conference… it's the format of the future, so you're way ahead."

"… I had to teach during most of the conference… I did wow my 7th graders with a couple of minutes of a live science conference for the fun of it."

"…having workshops like these which are very interactive, and accessible to virtually anyone who is interested encourages collaboration and a push towards new frontiers of knowledge collectively."

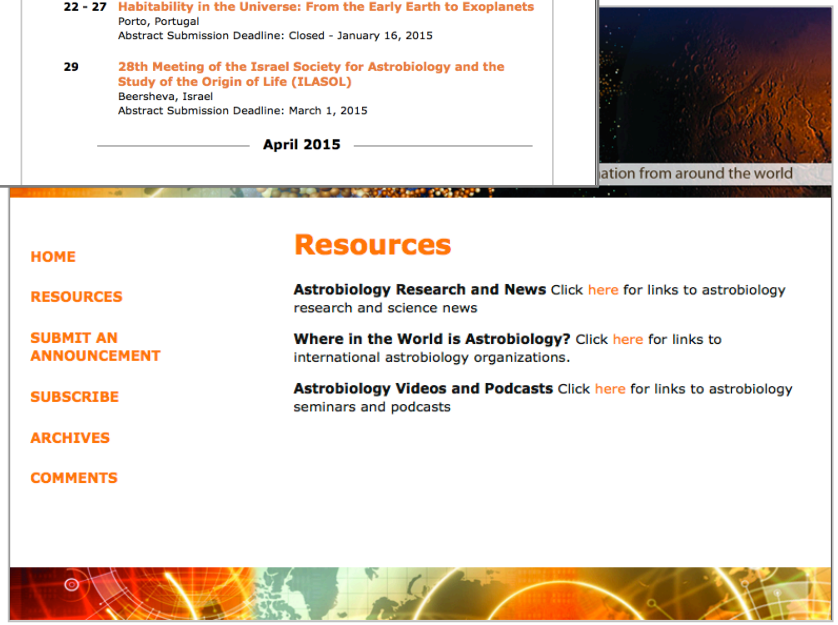
"What I liked most was: No walls! It was great to see so many people participating from around the globe. It was also really wonderful to have access to so many great talks without having to leave my home institution."

"I had a great experience I will remember for the rest of my life."

Workshop became a subject for science bloggers in real time:
http://pandasthumb.org/archives/2010/11/report-on-virtu.html

International Astrobiology Newsletter (IAN)

http://ian.arc.nasa.gov



A quarterly newsletter providing information about astrobiology events and opportunities around the world to the international astrobiology community

- Content provided by the community
- Distribution ~5000 world-wide

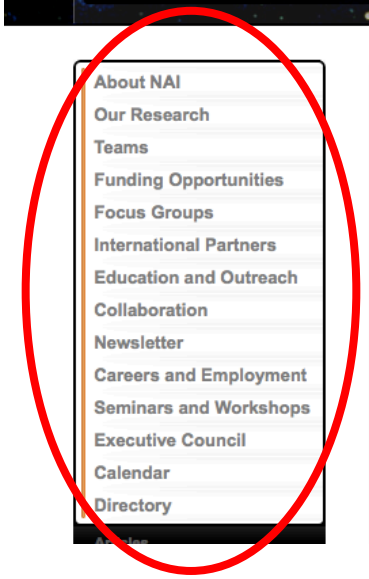
- Topic Headings
  - Conferences, Field Trips, and Workshops
  - Student & Early Career Opportunities
  - Funding Opportunities
  - Other Opportunities
  - Meeting Reports

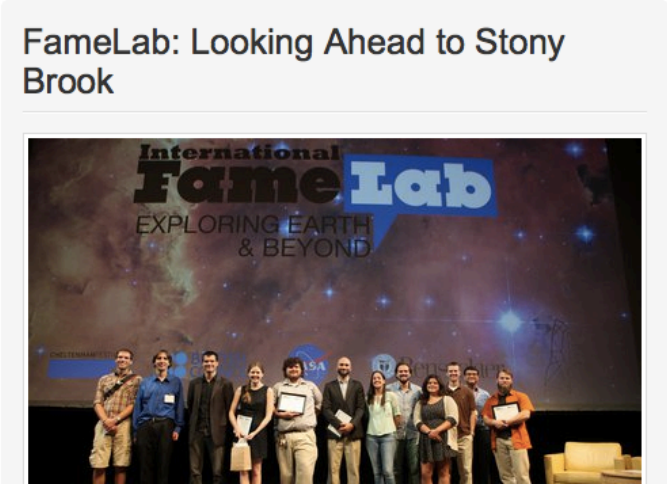
NAI Website

http://astrobiology.nasa.gov/nai

Intended for:

- Science-interested public
- Educators/students
- NAI researchers and the astrobiology science community





NASA/Library of Congress
Blumberg Astrobiology Chair

David Grinspoon
2012 – 2013

Steven Dick
2013 – 2014

Nathaniel Comfort
2015 – 2016

- LOC is the nation's oldest federal cultural institution
  - Serves as research arm of Congress
  - Largest library in the World
- Chair conducts research at the interface of astrobiology and its humanistic aspects, particularly its societal implications

Luis Campos

Oct. 3, 2016 – Sept. 2018

A historian of science, Campos is currently Associate Professor of History at The University of New Mexico. He is the author of “Radium and the Secret of Life” and is co-editor of “Making Mutations: Objects, Practices, Contexts.”

While at the Kluge Center, Campos will use the Library collections to examine the intersection between astrobiology and synthetic biology. Synthetic biology, according to Campos, seeks to engineer novel forms of life. Astrobiology is interested in discovering novel forms of life.

QUESTIONS?