Update from NASA Astrobiology Program

Mary Voytek
Astrobiology Senior Scientist

PAC
Nov 15, 2021

Research Coordination Networks Update

NExSS
investigate the diversity of exoplanets and to learn how their history, geology, and climate interact to create the conditions for life

NfoLD
investigate life detection research, including biosignature creation and preservation, as well as related technology development

From Early Cells to Multicellularity
investigate the earliest biological processes and the evolution of life on Earth into more complex organisms up to the advent of multicellularity

Prebiotic Chemistry and Early Earth Environments
Investigate chemical processes under the conditions on the Early Earth and the formation of basic proto/biological molecules and pathways, leading to the emergence of systems harboring the potential for life

Ocean Worlds (Habitable Worlds)
investigate the diversity of other worlds in the solar system and to learn how their history, geology, and climate interact to create the conditions for life

Earliest Cells to Multicellularity

Co-Leads
Betül Kaçar
Frank Rosenzweig
Ariel Anbar
Mary Droser

HQ Liason(s)
Becky MCauley Rench
Mary Voytek

Astrobiology Research Network- Review Implementation

Internal review after 3 years

- HQ Program Officers review and offer corrective measure or guidelines if necessary
  - 2018 NExSS
  - 2022 NFoLD
  - 2023 NOW and PCE3

External review every 5 years, much like a senior review.

- 2022 NExSS

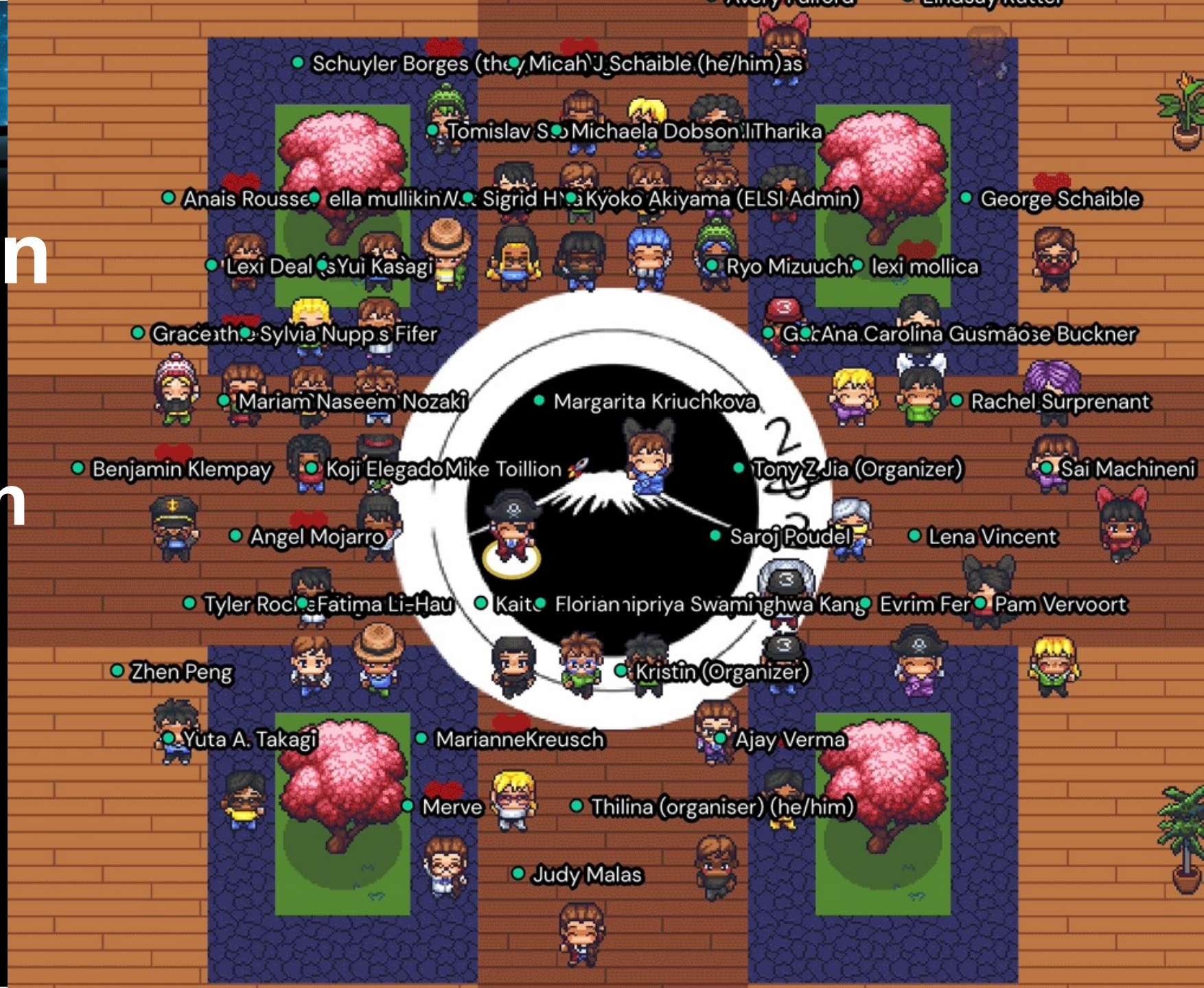
Measures of Success of RCN

- **Investigators carry out and propose interdisciplinary research through new collaborations stimulated by RCN interactions**
  - **Should be able to to identify impact on own research, produce list of new research topics, and point to new proposals going into different programs**
- Demonstration of technology transfer between research areas and disciplines
- Produces a plan for utilization of current mission data and spawns ideas for new and exciting missions (if applicable)
- Influences Decadal Surveys for all SMD Divisions
- Enhances international engagement
- Supports development of early AB community

Astrobiology Program NPP Fellows

- Currently 14 active NPP Fellows and two NPMP Fellow
- Solicitations had been suspended due to COVID
- New Management USRA>>> ORAU
- We are accepting applications for the March 1 deadline.

AbGradCon 2021: All-Virtual Gather Town Experience



May 15-20, 2022, in Atlanta, Georgia

Next year’s theme is Origins and Exploration: From Stars to Cells.

Questions?

BIOSIGNATURE STANDARDS OF EVIDENCE WORKSHOP

Victoria Meadows (UW/NExSS-VPL) and Heather Graham (NASA/GSFC)

Science Organizing Committee:

Giada Arney (GSFC)
Dina Bower (GSFC)
Bradley Burcar (Georgetown U.)
Thomas Fauchez (GSFC)
Yuka Fujii (NAOJ-Japan)
Lee Grenfell (DLR-Germany)
Sonny Harman (Ames)
Sarah Johnson (Georgetown U.)
Josh Krissansen-Totton(UCSC)
Graham Lau (BMSIS)
Melody Lindsay (Bigelow)
Grace Ni (UMD)
Stephanie Olson (Purdue)
Niki Parenteau (Ames)
Heike Rauer (DLR-Germany)
Britney Schmidt (Cornell)
Eddie Schwieterman (UC-Riverside)
Lauren Seyler (Stockton U.)
Amy Smith (Bard College)
Andrew Steele (CIW)
Sara Walker (ASU)
Mike Wong (UW)

Asia/Pacific Satellite Chairs

Yuka Fujii (NAOJ), Harrison Smith(ELSI), Hajime Yano (JAXA)

European Satellite Chairs

Lee Grenfell (DLR), Heike Rauer (DLR), Karen Olsson-Francis (OU)

sdecoret

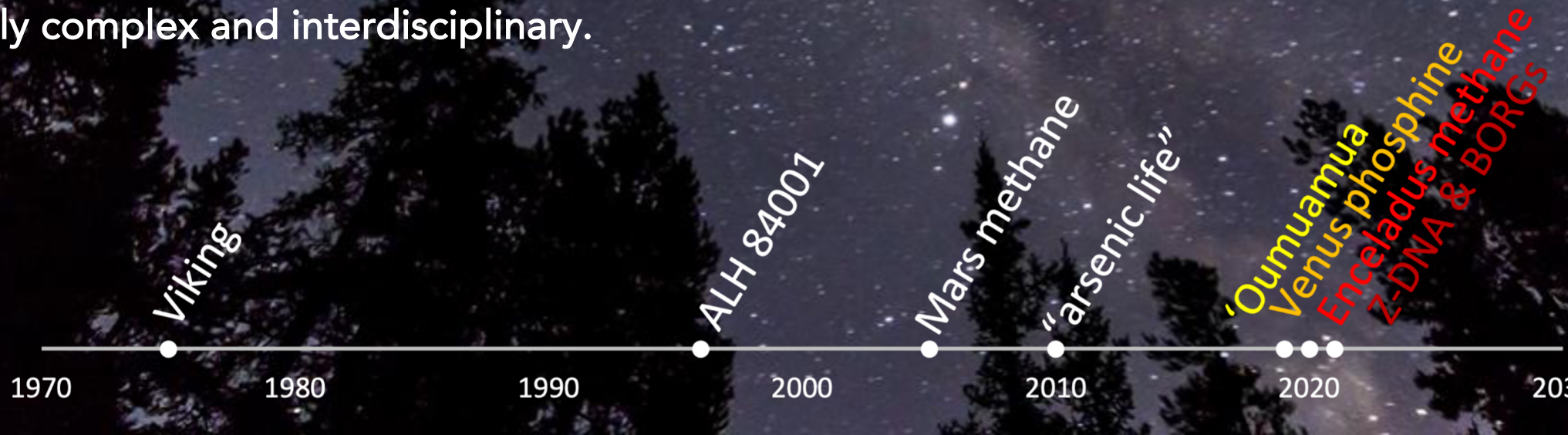
The need for biosignature standards of evidence

The detection of extraterrestrial life, in our Solar System and beyond will likely be neither instantaneous, nor unambiguous---and is a high stakes scientific achievement with high public interest.

Extraterrestrial life detection is now an explicit goal for planetary science and astronomy research and missions.

There needs to be an effective way to convey the multi-step, continuum process that is life detection, which may span missions and multiple measurement techniques (Green et al., 2021)

With increasing claims of possible life detection, it is timely to discuss as a community the *best process* for vetting and supporting discoveries, and how to report and convey information on a topic that is inherently complex and interdisciplinary.



Workshop Goals

Develop a generalized, progressive framework for robust biosignature assessment that:

- is applicable to a range of detection methods
- is efficient for the community to implement
- frames the search for life as a continuum of objectives
- Helps convey what is and isn't known, what needs to be known

Discuss and document community best practices for clearly communicating results and their significance to our colleagues and the public.

The Biosignatures SoE workshop

Held a "flipped format" fully-virtual workshop on July 19-22, 2021

- background material was provided for viewing in advance
- 29 suggested reading papers and 10 ~20-30 minute plenary videos
- The workshop was then 3 five hour days devoted to community discussion and writing
- Encouraged co-writing sessions on Day 3 to kickstart the whitepaper writing process

To support international input, we ran the workshop spanning three time zones

- US Main and satellite sessions (3 days each) during business hours in Asia/Pacific, Europe
- Information was transferred between the three sessions each day.

To make significant progress in 13.5 hrs of discussion, the co-Leads and SOC developed a strawman Framework for Biosignature Assessment for the community to react to and modify.

Workshop Demographics

Workshop Attendees

125 discussion participants (95 US, 15 Asia/Pac, 15 Euro)

215 asynchronous participants (40 of those signed up for Slack).

19% SOC

16% Invited

65% Community Applicants

Discussion participant disciplines:

25% exoplanet/observers

57% solar system/planetary science

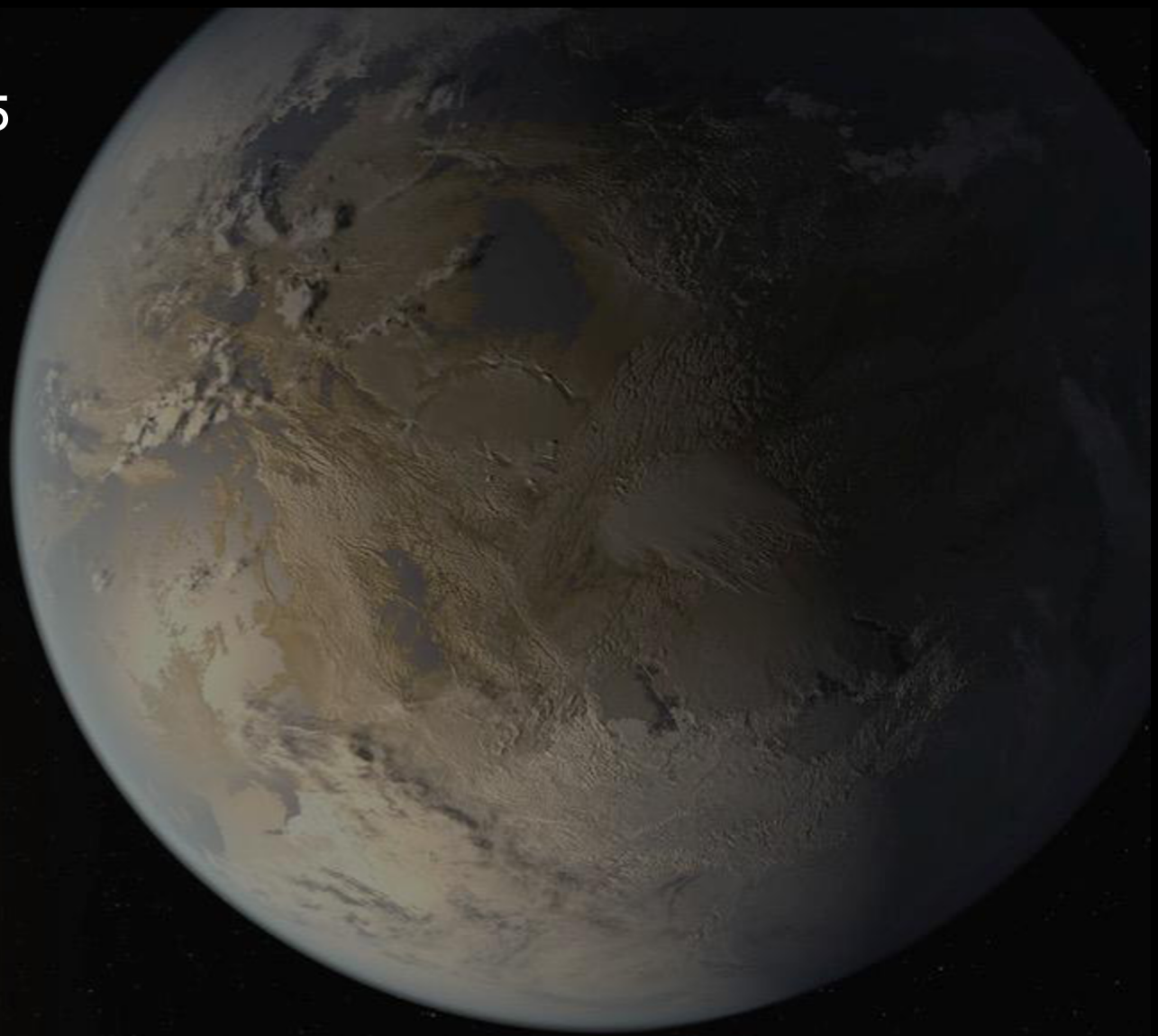
18% early earth/paleobiology

Participant demographics:

50% pre-tenure/50% post-tenure

10% grad students, 20% post-doc, 20% early career, 20% mid-career, 30% senior.

Apparent gender parity



Summary of Workshop By Day

Day 1: We examined and tested a draft framework for biosignature assessment and worked towards developing a generalized assessment framework that can meet the needs of a diversity of biosignature searches (125 discussion participants)

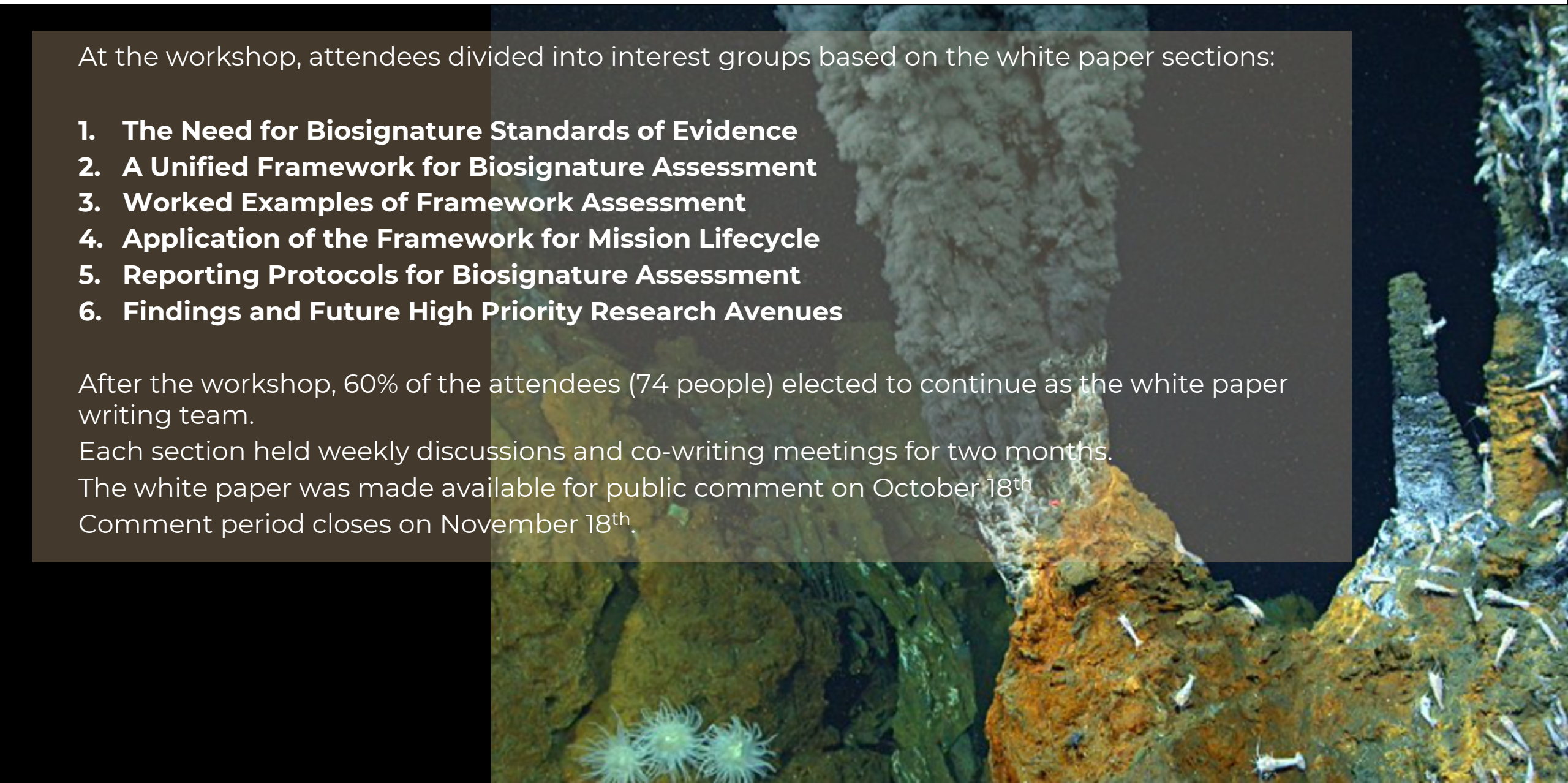
Day 2: We worked through any issues in the consensus assessment framework identified in discussions the day before, and broke up into groups to start working on drafting sections of the workshop white paper (121 discussion participants)

Day 3: The US group engaged in co-writing sessions on the workshop white paper.

Day 4: We discussed reporting protocols for biosignature detection, including applications of the assessment framework. We identified challenges and disincentives to an ideal process and developed a series of findings on best practices for reporting biosignature detection (96 discussion participants)

Continued engagement was high (84% over 4 days in US group, 90% over 3 days in satellites)

White Paper Writing Activities



At the workshop, attendees divided into interest groups based on the white paper sections:

1. **The Need for Biosignature Standards of Evidence**
2. **A Unified Framework for Biosignature Assessment**
3. **Worked Examples of Framework Assessment**
4. **Application of the Framework for Mission Lifecycle**
5. **Reporting Protocols for Biosignature Assessment**
6. **Findings and Future High Priority Research Avenues**

After the workshop, 60% of the attendees (74 people) elected to continue as the white paper writing team.

Each section held weekly discussions and co-writing meetings for two months.

The white paper was made available for public comment on October 18th

Comment period closes on November 18th.

The Biosignature Assessment Framework

Question 1: Have you detected an authentic signal?

Question 2: Have you adequately identified the signal?

Question 3: Are there abiotic sources for your detection?

Question 4: Is it likely that life would produce this expression in this environment?

Question 5: Are there independent lines of evidence to support a biological (or non-biological) explanation?

Ultimately need assessment of standards of *confidence/certainty* for each step (future workshop)

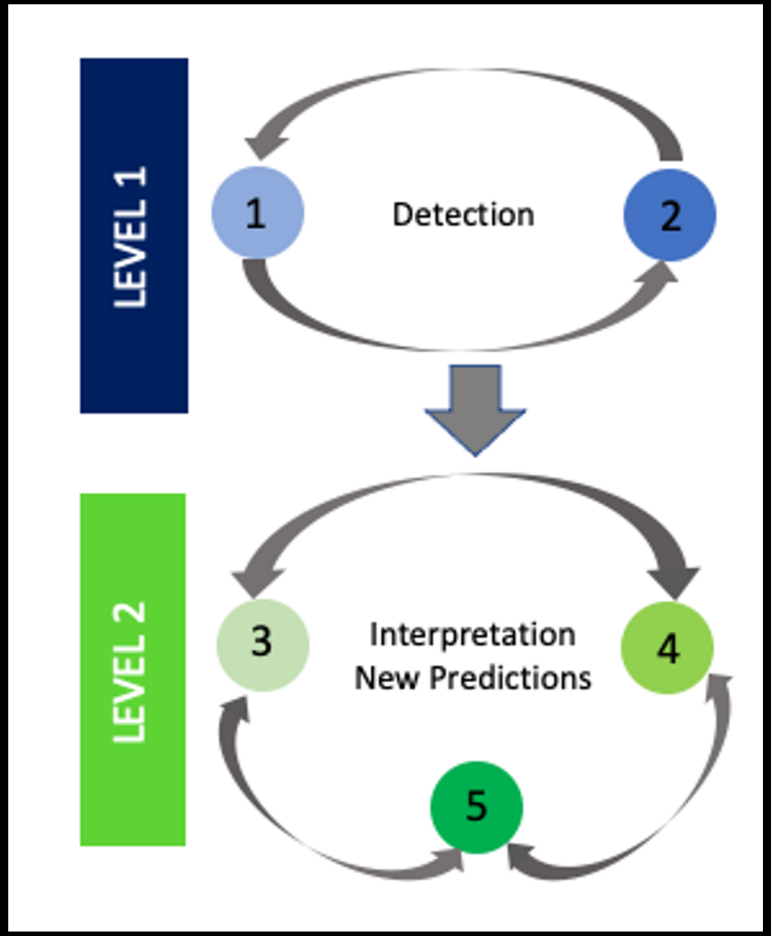
A workshop goal was assessing and *challenging* the framework with a range of examples.

Towards a Generalized Framework

Five scientific questions that guide assessing a biosignature claim can be arranged as two levels

Questions 1 & 2 (Level 1): Biosignature Detection
Questions 3-5 (Level 2): Biosignature Context & Assessment

- Emphasizes that Framework is iterative within levels
- Measurements and models can simultaneously address questions within a level
- A high level of confidence in candidate detection and identification is encouraged before moving to Level 2
- While Level 1 activities could be focused within a discipline, Level 2 requires a significant community effort to assess whether a biological source is a likely explanation



- "Energy" between Level 1 & 2 is high (**need to decide on threshold**)"

- As we move down the framework we are going from strongly disciplinary to interdisciplinary and require more and more expertise

- *Remote sensing* and *in situ* measurements should be on the same scale, even if they have very different confidences

Biosignature Detection

Q1. Have you detected an authentic signal?

Do you have a real, statistically significant signal? Have you ruled out artifacts from the measurement, pre-processing or analysis process that might mimic a signal?

- Is your measurement recognized to be of high statistical significance compared to standards for detection in your field?
- Are instrumental artifacts accounted for?
- Is the result repeatable/reproducible or verified by other groups or supporting measurements?

Q2. Have you adequately identified the signal?

Have you adequately ruled out other potential sources for this signal? Have you ruled out contamination in the environment, or other real phenomena that could produce a similar signal?

- Have you confirmed identification with a standard/line list to identify possible co-elution/blended lines?
- Is contamination accounted for, including outgassing, poor contamination control, possible spectral contamination?
- Were multiple bands of the same molecule detected, or different methods used to confirm identification?

Biosignature Assessment

Q3. Are there abiotic sources for your detection?

Is it likely that there is a current or past environmental process, other than life, that could be producing this signal? Have you ruled out potential false positives for the biosignature?

- Do you understand the environmental context?
- Have you ruled out plausible false positives? (geochemical sources, photochemistry, etc)

Q4. Is it likely that life would produce this expression in this environment?

Given what we know about the likely environment that an organism is operating in, or would have operated in, does it make physical and chemical sense that life would produce this potential biosignature?

- Does it make sense energetically and thermodynamically?
- Is it plausible that life would have overcome all of the barriers in this environment?
- Are the flux/abundance and survival/preservation of biosignature quantities in the environment plausible

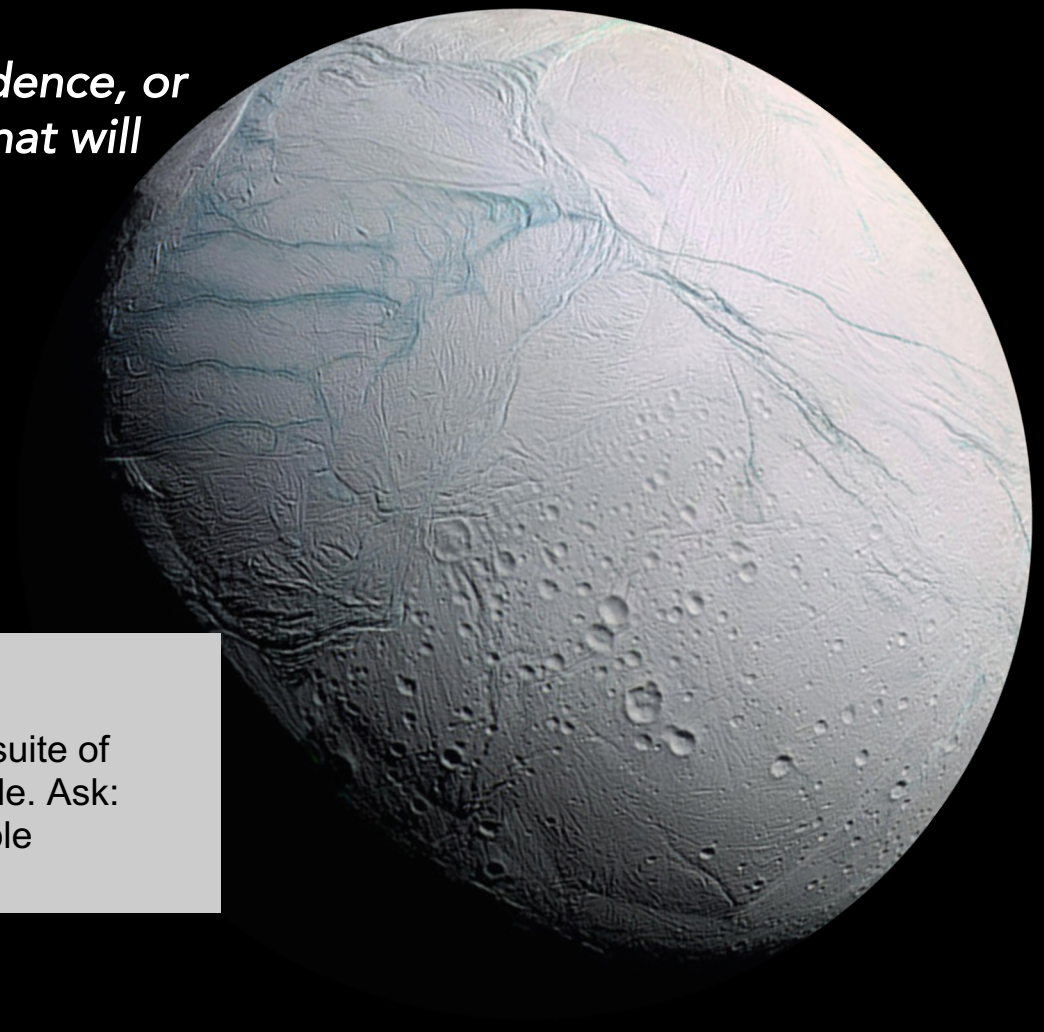
Context is Everything

Further Testing the Life and Abiotic Hypotheses

Q5. Are there independent lines of evidence to support a biological (or non-biological) explanation?

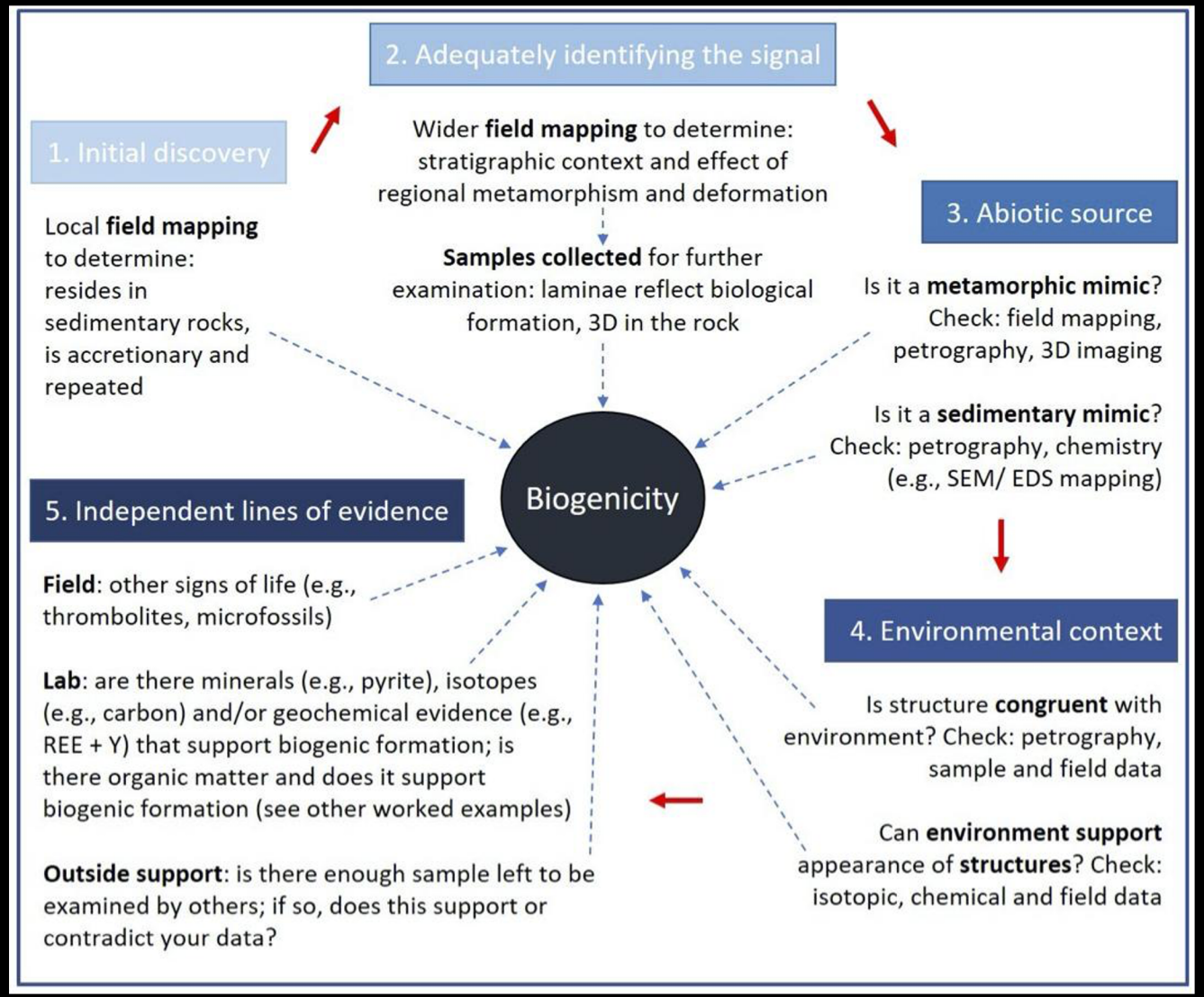
Are there other measurements that provide additional evidence, or allow you to predict and execute follow-on experiments, that will help discriminate between the life or non-life hypotheses?

- False positives further ruled out?
- Predicted biological behavior/impact confirmed?

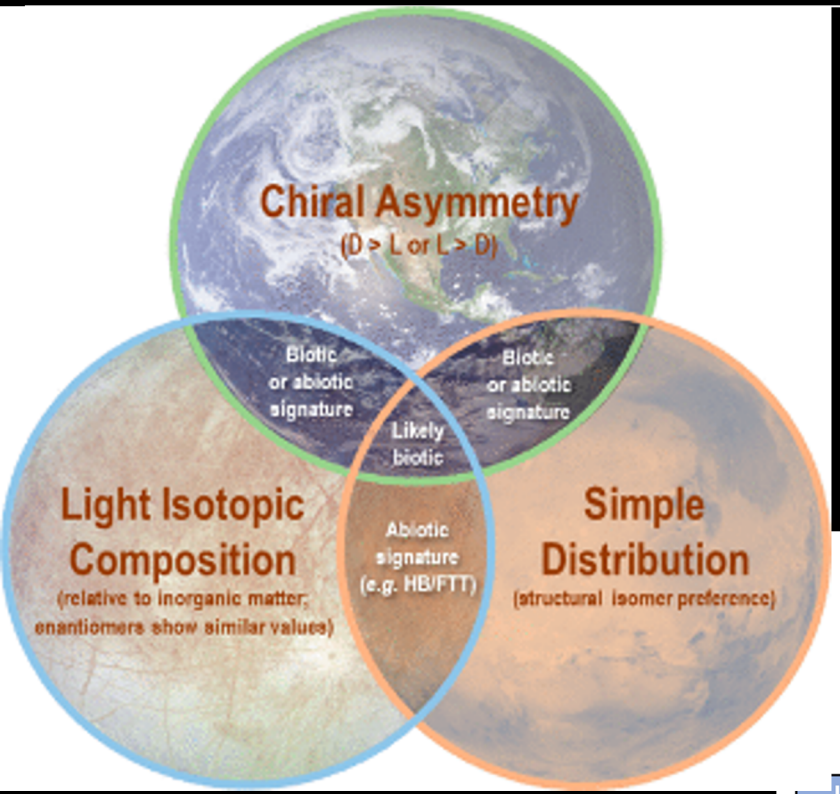


●No single detection of a compound will increase the level of confidence –
<u>Need: Multiple lines of evidence</u>
Confidence level may be increased by identifying not just a single compound, but a suite of compounds that are self-consistent with the geologic history/thermal history of sample. Ask: What else has been detected in the same sample?; is it a complex mixture or a simple distribution...is this expected or not?

Worked Examples: Stromatolites/Early Earth

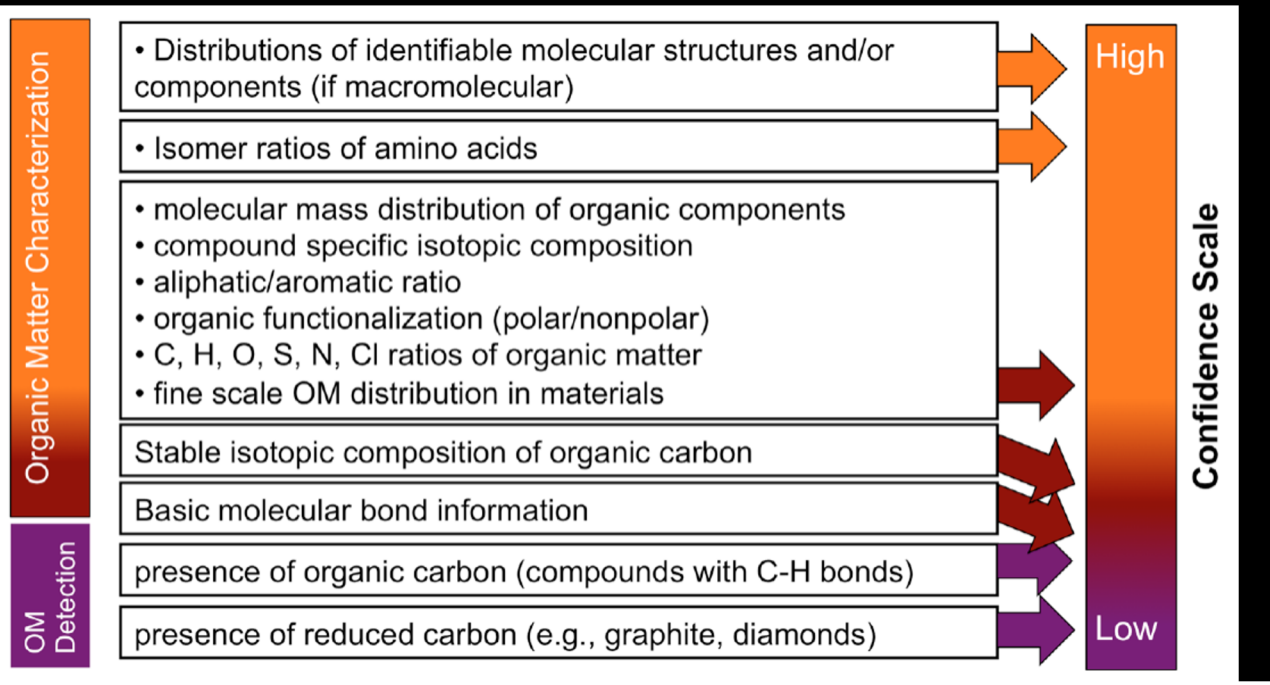


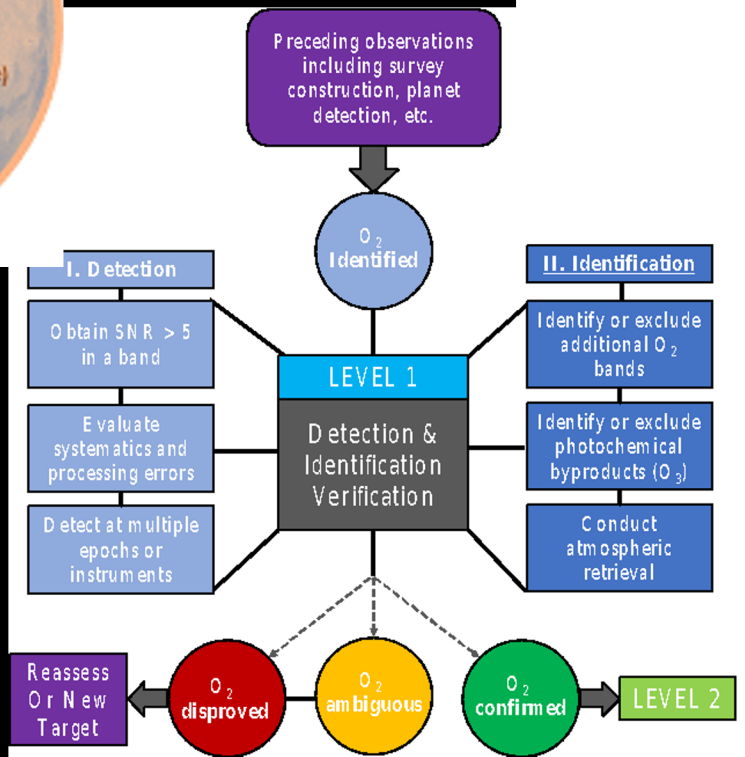
Other Worked Examples



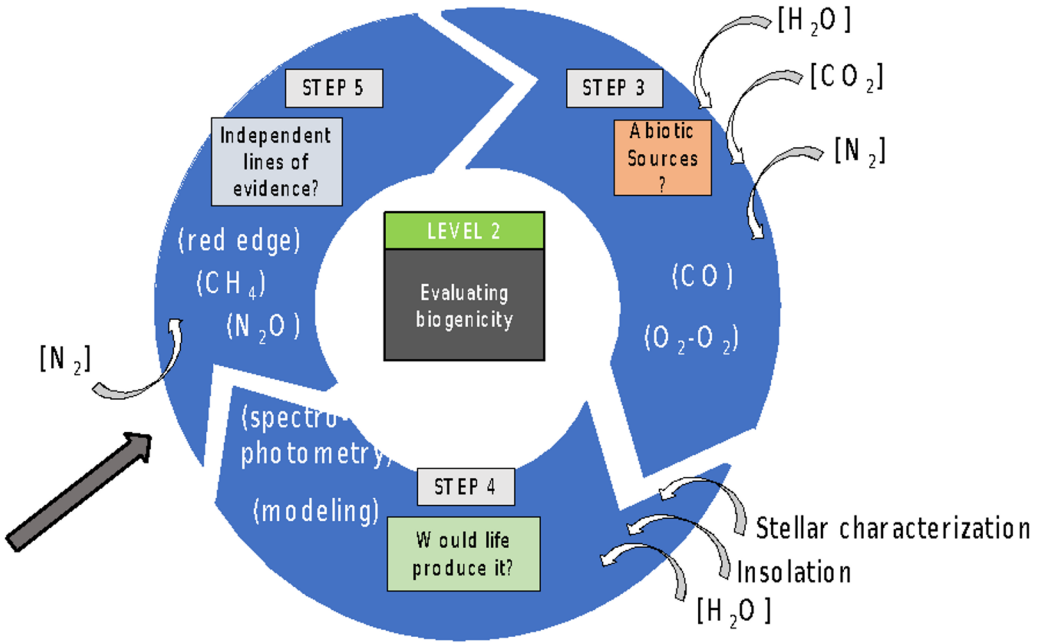
In situ agnostic biosignatures: chirality + isotopic composition

In situ detection of Kerogens





Remote-sensing detection of O_2 on exoplanets



Towards a Biosignature Reporting Protocol

Participants focused on actions the scientific community can adopt, recognizing that a wider discussion requires input from stakeholders in the publication and communication fields

- Participants discussed mechanisms that could improve collaboration by funding and organizing pre-publication claim verification science activities.
  - “Rapid response” funding pools to support verification
  - Collaboration coordination and data sharing supported through international networks, professional societies, or a new Astrobiology Society
  - Concurrent publication of discovery and verification papers; stepwise reporting of results; published reviews

- New publication models that encourage interdisciplinary, incremental results, or even negative data. Prevent miscommunication in the literature by increased partnering with journals and editors to support specialized subject matter experts for peer review.

- When communicating results with the press and public be sure to include and explain error and uncertainty, as well as what is not *yet* known *and* work yet to do.

Future Work to Develop Framework & Reporting Protocol

Participants identified three high priority areas of future research and community discussion:

- Further development of “worked examples” to generate a more detailed set of criteria that can serve as field-specific guidelines for biosignature assessment

- Collaborative discussions between biosignature scientists and data scientists to develop statistical methodologies that incorporate the step-wise error and uncertainty to build a more quantitative biosignature “confidence” scale and support hypothesis testing

- Further work to incorporate the Framework with community data products and databases, including the Life Detection Knowledge Base, to inform users of the utility of specific life detection measurements in mission concept development

- Focused discussions on developing a reporting protocol that includes publishers, journalists, and science communicators to understand and address obstacles and incentives in those communities that relate to our scientific and communication goals.

Questions?

Backup Slides

Priority Invitees

Elena Amador, JPL
Tim Brooks, PHE
Roger Buick, U. Washington
Sherry Cady, PNNL
Morgan Cable, JPL
Charlie Cockell, U. Edinburgh
Dave des Marais, Ames
Shawn Domagal-Goldman, GSFC
Andrea Jones, GSFC
Chris Kempes, Santa Fe Inst.
Ravi Kopparapu, GSFC
Ralph Lorenz, APL
Cole Mathis, Arizona State
Francis McCubbin, JSC
Aki Roberge, GSFC
Tyler Robinson, NAU
Eva Stueken, U. Edinburgh
Jevin West, U. Washington
Alexandra Witze, correspondent
Marjorie Chan, U. Utah
Loren Williams, Georgia Tech
Yuchiro Ueno, Tokyo Tech

The need for biosignature standards of evidence

Perspective

Call for a framework for reporting evidence for life beyond Earth

https://doi.org/10.1038/s41586-021-03804-9
Received: 8 February 2021
Accepted: 6 July 2021
Published online: 27 October 2021

James Green[1]✉, Tori Hoehler[2], Marc Neveu[3,4], Shawn Domagal-Goldman[5], Daniella Scalice[6] & Mary Voytek[7]

Our generation could realistically be the one to discover evidence of life beyond Earth. With this privileged potential comes responsibility. The magnitude of the question of

- The Green et al. (2021) paper was a call to action
- The community answered that call with the Biosignatures Standards of Evidence Workshop

Pre-meeting Activities

Working with the SOC we:

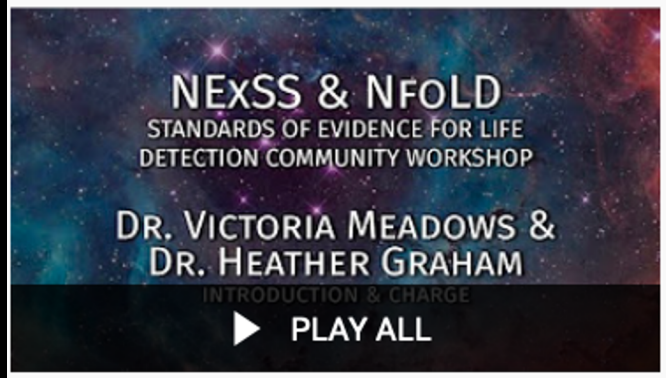
- Invited 20 participants covering early Earth, Solar System, exoplanets, technosignatures, journalism
- Sent out a general call for applicants (NfoLD, NExSS, NOW, PCE3, NASA Astrobiology lists, ExoSS workspace, LPI & PEN Newsletters, SOC were also asked to distribute widely among their networks)
  - We received 355 applications for 80 participant slots
  - We selected 82 discussion participants based on stated contribution and relevance to the workshop topic, along with balance considerations such as career stage, field of specialty and measurement technique
  - The remaining applicants were offered asynchronous participation via YouTube LiveStream and Slack, and with access to the workshop supporting materials.

As a group we also developed:

- A list of 29 suggested reading materials on the topics of remote and in-situ biosignature science and worked example background as well as risk communication and examples of quantitative assessment scales from other fields
- A series of 10 instructional videos that substituted for plenary sessions
  - the state of the field, examples of claims of life detection, relevant information from other fields

On June 28th we held a workshop discussion practice session (for the first breakout) and over 30 people attended.

Pre-meeting Videos



NExSS & NfoLD Standards of Evidence Joint Community Workshop

10 videos • 418 views • Last updated on Aug 19, 2021

Unlisted

NASA Astrobiology

SUBSCRIBE

1. 

NExSS & NfoLD SOE Workshop: Introduction & Charge by Dr. Victoria Meadows & Dr. Heather Graham
NASA Astrobiology
Introduction

2. 

NExSS & NfoLD SOE Community Workshop: In Situ Biosignatures by Dr. David Des Marais
NASA Astrobiology
State of the Field

3. 

NExSS & NfoLD SOE Workshop: Remote Detection of Biosignatures by Dr. Shawn Domagal-Goldman
NASA Astrobiology
State of the Field

4. 

NExSS & NfoLD SOE Workshop: Phosphine on Venus by Dr. Victoria Meadows
NASA Astrobiology
Worked Example

5. 

NExSS & NfoLD SOE Workshop: History of the Viking Biology Experiments by Dr. Richard Quinn
NASA Astrobiology
Worked Example

6. 

NExSS & NfoLD SOE Workshop: The Controversy & Legacy of ALH 84001 by Dr. Andrew Steele
NASA Astrobiology
Worked Example

Pre-meeting Videos

7

NExSS & NfoLD SOE Workshop: When Do We Get to Drink the Champagne? by Dr. Jill Tarter

NASA Astrobiology

Protocols

8

NExSS & NfoLD SOE Workshop: Statistics, Theory, & Life Detection by Dr. Christopher P. Kempes

NASA Astrobiology

Enrichment Background

9

NExSS & NfoLD SOE Workshop: The Rise of Misinformation In & About Science by Dr. Jevin West

NASA Astrobiology

Enrichment Background

10

NExSS & NfoLD SOE Workshop: Microbiological Safety & Quality Science for Unknown by Dr. Tim Brooks

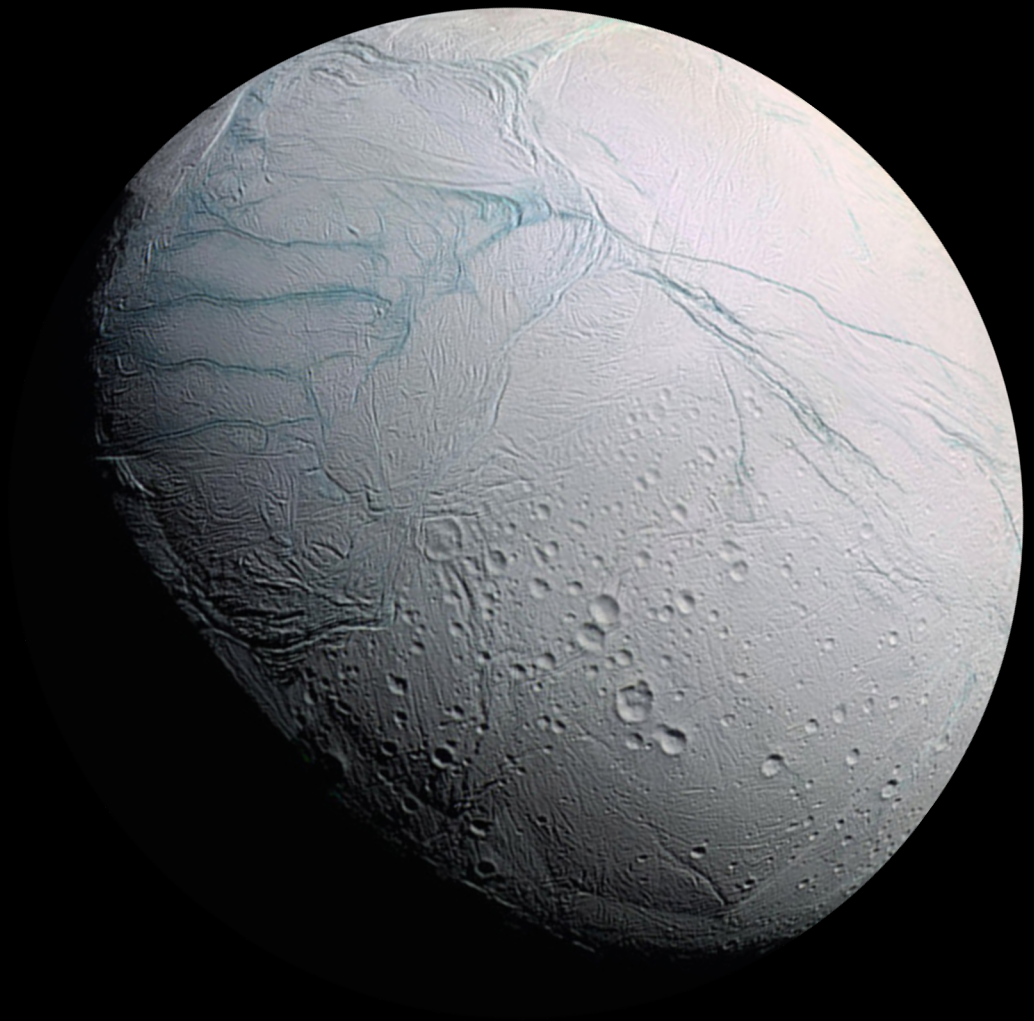
NASA Astrobiology

Enrichment Background

Goal: A Unified Framework for Biosignature Assessment

Develop and describe a universal framework of key scientific evidence needed to progressively increase confidence in life detection, or identify an abiotic process, and that is the most efficient path for the community to take in doing so.

This assessment framework should be sufficiently general that it can be applied to multiple planetary environments, measurement techniques and biosignature targets.



Day 1: The Biosignature Assessment Framework

Goal: critically examine a draft framework for biosignature assessment and work towards developing a generalized assessment framework (White paper sections 1.2 & 1.3)

- **9am Welcome and Discussion of Workshop Charge (Meadows/Graham) (pre-recorded video + discussion also available, given to satellite groups well prior to the workshop start)**
- **10am Breakouts by Measurement/Target**
- *Try to break the Draft Assessment Framework using your favorite biosignature example.*
- *Step 1. Map your biosignature example to the Draft Assessment Framework (45mins)*
- *Step 2. Assess the applicability of the framework and identify key missing aspects of the framework (45 mins)*
- **11:30am Report out to Workshop on findings, suggested changes to assessment scale.**
- **Noon 30 min Break**
- **12:30pm Breakouts in Diverse Groups of multiple measurements/targets**
- *Design an Assessment Framework that meets the needs of multiple targets, instruments, biosignatures. Record changes needed to the protocol and any questions for discussion with the larger group* (1.5 hrs).
- **2pm End for the Day**

Day 2: The Biosignature Assessment Framework

- *Goal: work through any issues identified in the consensus assessment framework and start drafting sections of the workshop white paper. Addressed WP Sections 1.2, 1.3. 1.4*
- 9am Workshop Discussion of assessment protocol/confidence scale outcomes from Day 1, and questions for discussion with the larger group.
- 10am Breakouts for participant-identified questions/issues
  Discuss solutions to the identified problem
- 11:00am Report out to Workshop on findings, questions/issues. Work on a consensus framework.
  Agree on a consensus framework
- Noon 30 minute break
- 12:30pm Discuss outline for white paper (sent to participants prior to meeting) Assign writing groups.
- 1pm Breakouts for writing groups
  Start fleshing out the white paper outline for the section you are responsible for.
  Organize a time on Wednesday for a 2 hr writing session to work on the white paper.
- 2pm End for the Day

Day 3: Writing/Rest/Catchup Day

- ***This third day (US Session Only) provides a break from very long Zoom sessions, and a chance to engage in co-writing sessions on the workshop white paper***

Day 4 US (Day 3 Apac/Euro): Reporting Protocol Development, Wrap Up

Goal: Discuss reporting protocols for biosignature detection, including applications of the assessment framework. Identify challenges to an ideal process, and develop findings on best practices for reporting biosignature detection (WP Sections 1.4, 1.5, 1.6)

9am Check-in on writing progress, discussion of any issues.
10am Charge for discussion on reporting protocol (using the scale developed previously)
How would we use this framework?

10:30am Breakout groups to discuss reporting protocol.
Step 1: Discuss attributes of an ideal reporting protocol (scientific and communication) and identify existing structures and incentives that support or work against those attributes (45 mins)
Step 2: What changes to the incentive structure would be needed to support the ideal reporting protocol?
Noon 30 minute break
12:30pm Discussion of reporting protocol in plenary
1:30pm Wrap up discussion and final writing assignments and plans.
2pm END

Breakout Discussion Questions

Questions guided participants in addressing material needed for the white paper.

Same Measurement/Target Groups : *Try to break the Draft Assessment Framework using your favorite biosignature example.*

- *Step 1. Map your biosignature example to the Draft Assessment Framework*
- *Step 2. Assess the applicability of the framework and identify key missing aspects of the framework*

Diverse Groups of multiple measurements/targets: *Design an Assessment Framework that meets the needs of multiple targets, instruments, biosignatures. Record changes needed to the protocol*

Problem-solving groups for participant-identified questions/issues:

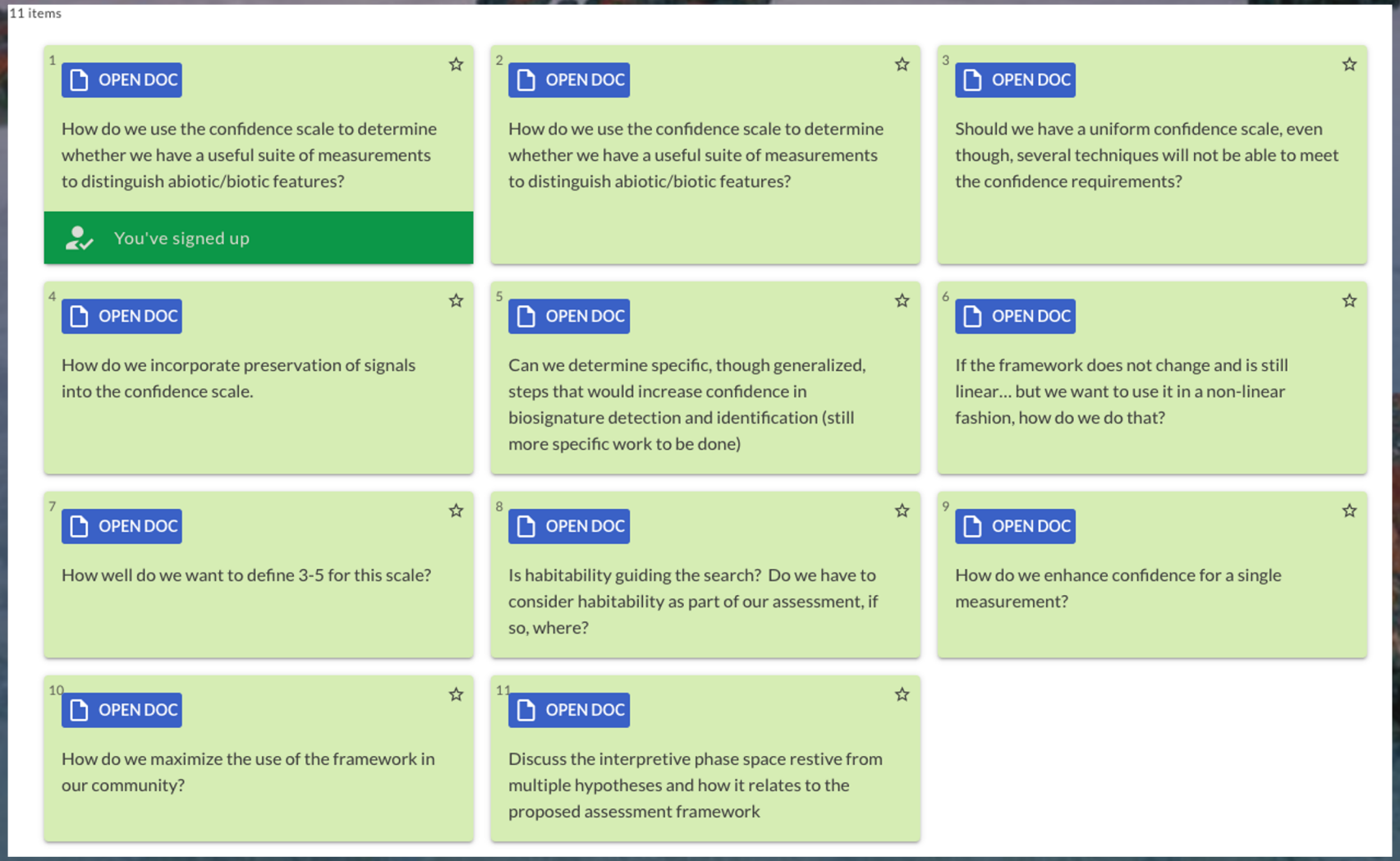
Outline writing groups: *Start expanding on the white paper outline for a chosen section*

Discuss reporting protocols for biosignature detection. *Identify challenges to an ideal process, and develop findings on best practices for reporting biosignature detection*

- *Step 1: Discuss attributes of an ideal reporting protocol (scientific and communication) and identify existing structures and incentives that support or work against those attributes*
- *Step 2: What changes to the incentive structure would be needed to support the ideal reporting protocol?*

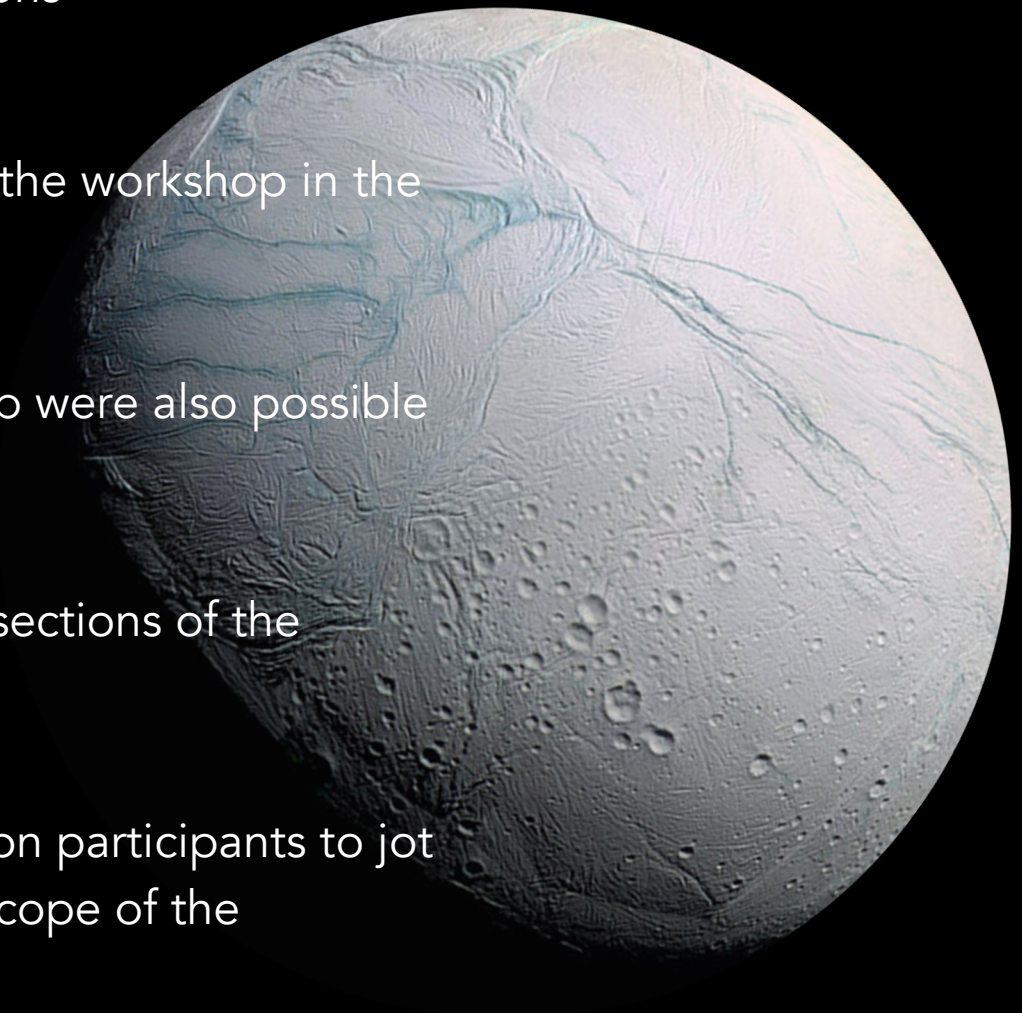
The Biosignature Assessment Framework

- *Goal: work through any issues identified in the consensus assessment framework and discuss solutions to the identified problem.*



Documenting the Discussion Outcomes

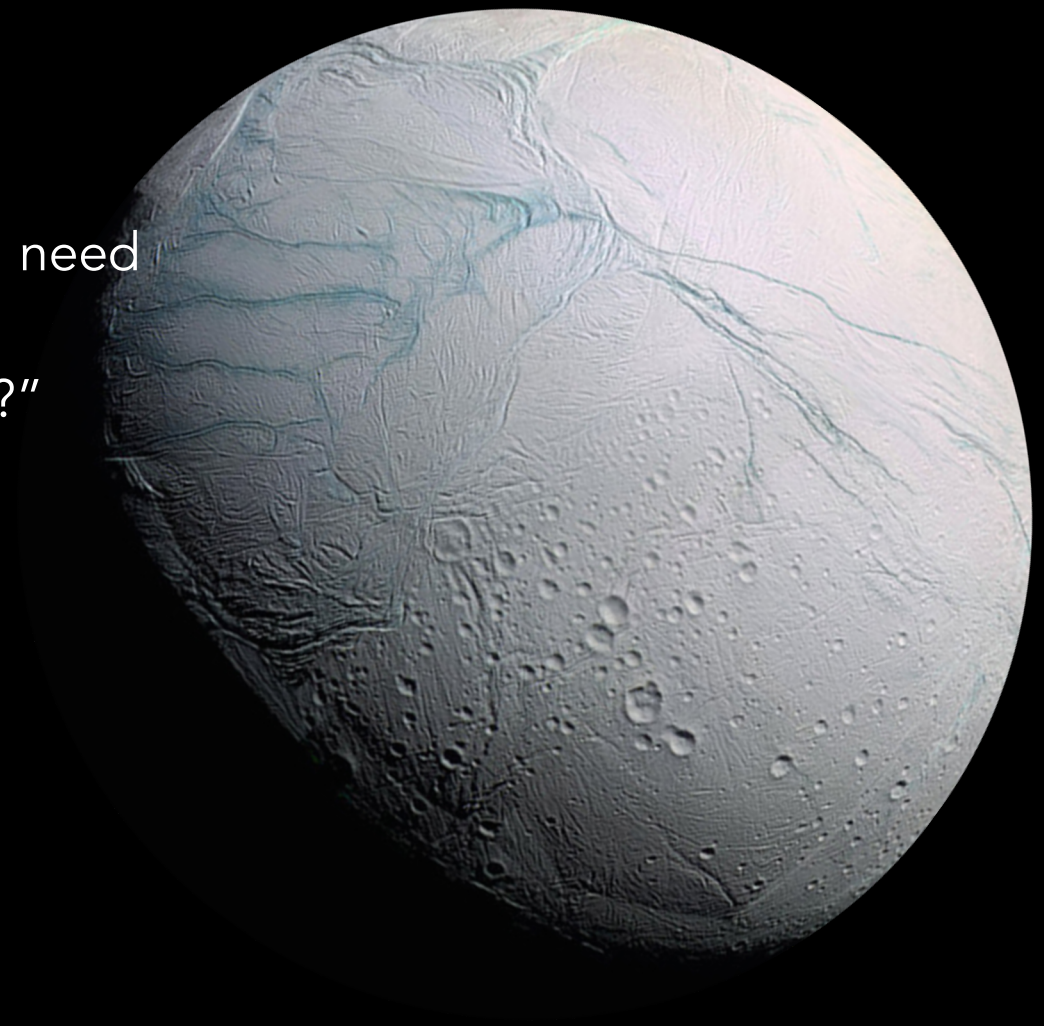
- All breakout groups took notes on key aspects of their discussions
  - We now have ~379 pages of notes!
- Each group prepared a summary slide to share with the rest of the workshop in the plenary report-out after each breakout session.
- Comments on the report-out and other aspects of the workshop were also possible and encouraged in Slack for all participants.
- The writing teams used the notes and comments to draft their sections of the whitepaper.
- A ”Future Ideas” area in the KIStorm Platform allowed discussion participants to jot down ideas and future workshop topics that were outside the scope of the workshop’s discussions.



Example Applications of the Framework

- Placing a discovery on a spectrum of confidence
- Conveying uncertainty in a discovery
- Helping to communicate what we know and what we still need to know, to increase confidence in the detection

  "How excited should I be about this discovery?"
- Determining whether a given measurement or mission advances our life detection goals



Applications of the Framework to Mission LifeCycle

Question 1: confirmation of a detected signal requires planning and knowledge of calibration, background noise sensitivities, resolution, operations and instrument behavior

Question 2: requires understanding sources that could impact data interpretation. These detection requirements encourage the use of

- pre-flight analog testing and modeling
- stringent contamination control
- procedures to distinguish artifacts and false positives

Questions 3 and 4: Recognition of false positives can be enhanced by:

- performing pre-flight laboratory, field and theoretical work to identify false positives
- understanding whether the instrument is configured to have the wavelength range, resolution and sensitivity to detect false positive discriminants in the measurement environment.

Best practices suggest a Science Traceability Matrix that includes measurements to assess key aspects of habitability and environmental context–to both assess the likelihood that false positives are present, and that the biosignature being assessed is likely to be produced in that environment.

The STM can also include assessment of sample concentration and preservation.

Question 5: Places an emphasis on ensuring that the STM and the instrument suite supports accessibility of multiple independent lines of evidence to assess whether biological or abiotic formation is more likely.

Example given of the LUVOIR/HabEx development.