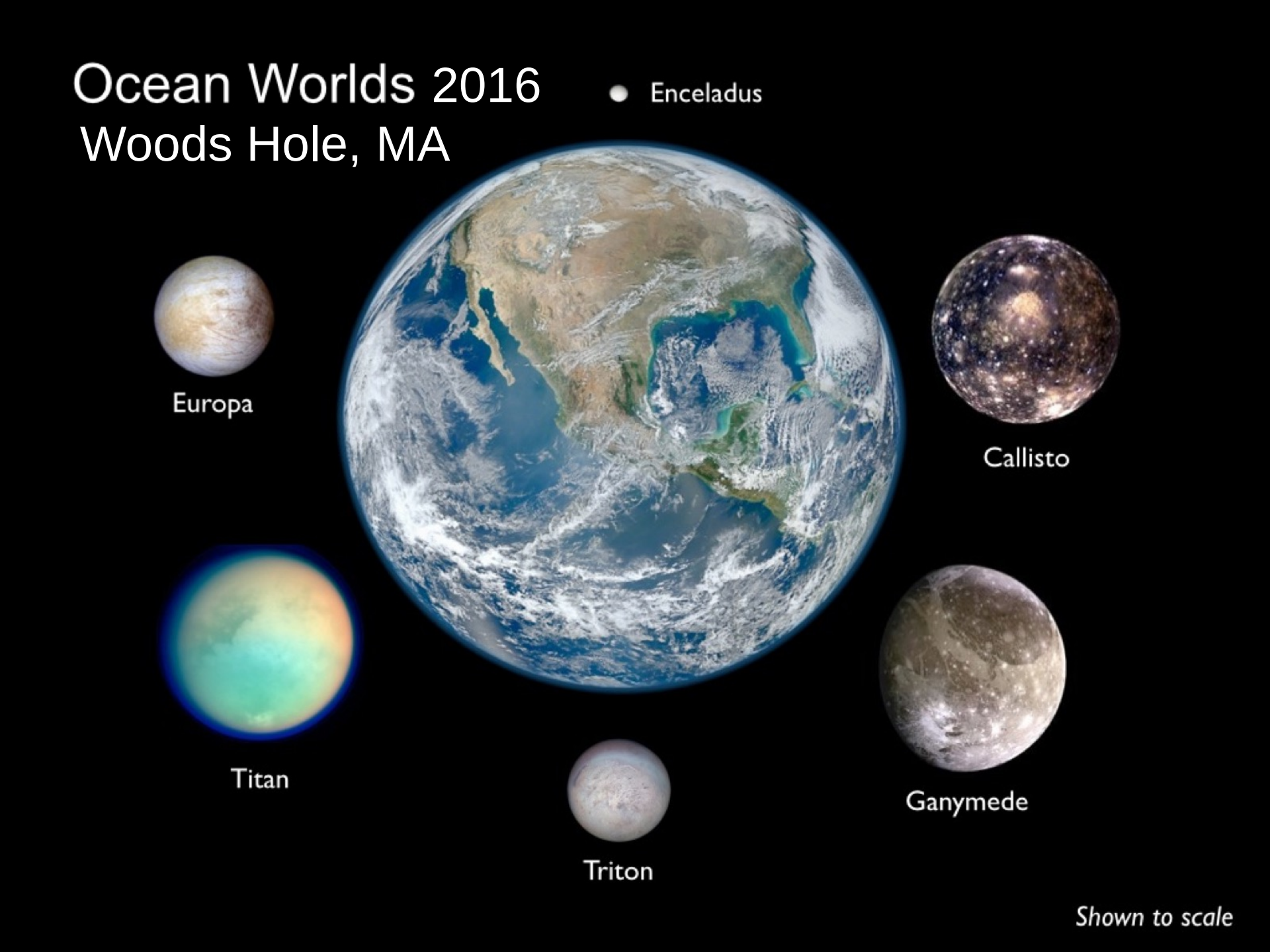
Ocean Worlds 2016
Woods Hole, MA



Ocean Worlds 2015

- ~40 attendees from various disciplines and institutions.
- Held at the National Geographic Society for 1 day.
- Focus was on bridging Earth ocean exploration and the exploration of ocean worlds beyond Earth, with some time spent on strategic considerations for missions and Earth exploration in the next 20 years.

Ocean Worlds 2016

- ~70 attendees, across science, technology, Earth, and planetary science.
- Held at WHOI for 2 days, with facility tours.
- Presentations focused largely on ocean-seafloor interactions and the technologies to access seafloors and to get through ice shells.
- Website & Agenda: http://www.whoi.edu/marinerobotics/2nd-annual-ocean-worlds-meeting

Agenda: Day 1

10:00 – 10:50	**Key scientific aspects of Oceans on Earth (1)** *(Chair: Chris German)* *3 talks (12 min + 4 min Q&A = 48 min)*
• Paul Falkowski	Biogeochemical Evolution of a Life-Sustaining Planet
• Julie Huber	Life in the Extreme: Seafloor Fluid Flow and Chemosynthesis
• Mark Skidmore	Life in the Extreme: Microbiology at the Ice-Water Interface
10:50 – 11:10	Coffee break
11:10 – 12:00	**Key scientific aspects of Oceans beyond Earth (1)** *(Chair: Christophe Sotin)* *3 talks (12 min + 4 min Q&A = 48 min)*
• Carolyn Porco	The Geysering World of Enceladus
• Bill McKinnon	Geophysics of Ocean Worlds
• Krista Soderlund	Ocean Circulation Beyond Earth

Agenda: Day 1 (cont.)

13:15 – 14:20	**Ocean Worlds Technologies: Core components** *(Chair: Heidi Perry)* *4 talks (12 min + 4 min Q&A = 64 min)*
• Pete Girguis	Sensors for Investigating the Oceans *In Situ*
• Henrik Schmidt	Acoustics for Interrogating the Oceans Remotely
• Dana Yoerger	Robotics for Ocean Exploration
• Bob Pappalardo	Mission to Europa
14:20 – 15:10	**Key Scientific Aspects of Oceans on Earth (2)** *(Chair: Julie Huber)* *3 talks (12 min + 4 min Q&A = 48 min)*
• Everett Shock	Energetics to Drive Chemosynthesis
• Beth Orcutt	Life *Beneath* the Seafloor
• John Priscu	Subglacial Lake Investigations
15:10 – 16:00	**Key Scientific Aspects of Oceans beyond Earth (2)** *(Chair: Sarah Horst)* *3 talks (12 min + 4 min Q&A = 48 min)*
• Wes Patterson	Tectonics on Icy Moons
• Jason Goodman	Ocean Circulation Effects on Europa
• Chris Glein	Geochemical Modelling for Enceladus's ocean
16:00 – 17:00	**Day 1 Discussion**
17:00 – 17:15	**Break**
17:15 – 18:45	**Happy Hour & Ocean Worlds "Karaoke"** 1 slide per person, 60 seconds to present.

Agenda: Day 2

9:10 – 10:30	**System-wide Approaches to Ocean Exploration on Earth** *(Chair: Kevin Hand)* *4 talks (15 min + 5 min Q&A = 80 min)*
• Chris German	Nested Exploration Strategies for Seafloor Fluid-Flow
• Jim Bellingham	Coordinated Use of Multi-Platform Systems
• Heidi Perry	Latest Updates on Unmanned Underwater Systems
• John Delaney	Ocean Observatories & exploring Ocean Worlds
10:30 – 10:40	**Break**
10:40 – 12:00	**Key technologies for Ocean Exploration beyond Earth** *(Chair: Gregg Vane)* *4 talks (15 min + 5 min Q&A = 80 min)*
• Tom Cwik	What Constrains Payload/Power/Accessing Ocean Worlds?
• Ralph Lorenz	Sensor Suites for Ocean World Exploration: Huygens
• Kevin Hand	Planetary Sampling
• Bill Stone	Accessing Oceans Beneath Ice

Goals

- Goal #1: There are no goals.
- Goal #2: There are no products.
- Goal #3: Mind the caveats.
  - Caveat #1: Find some Findings.
  - Caveat #2: Write some writing.

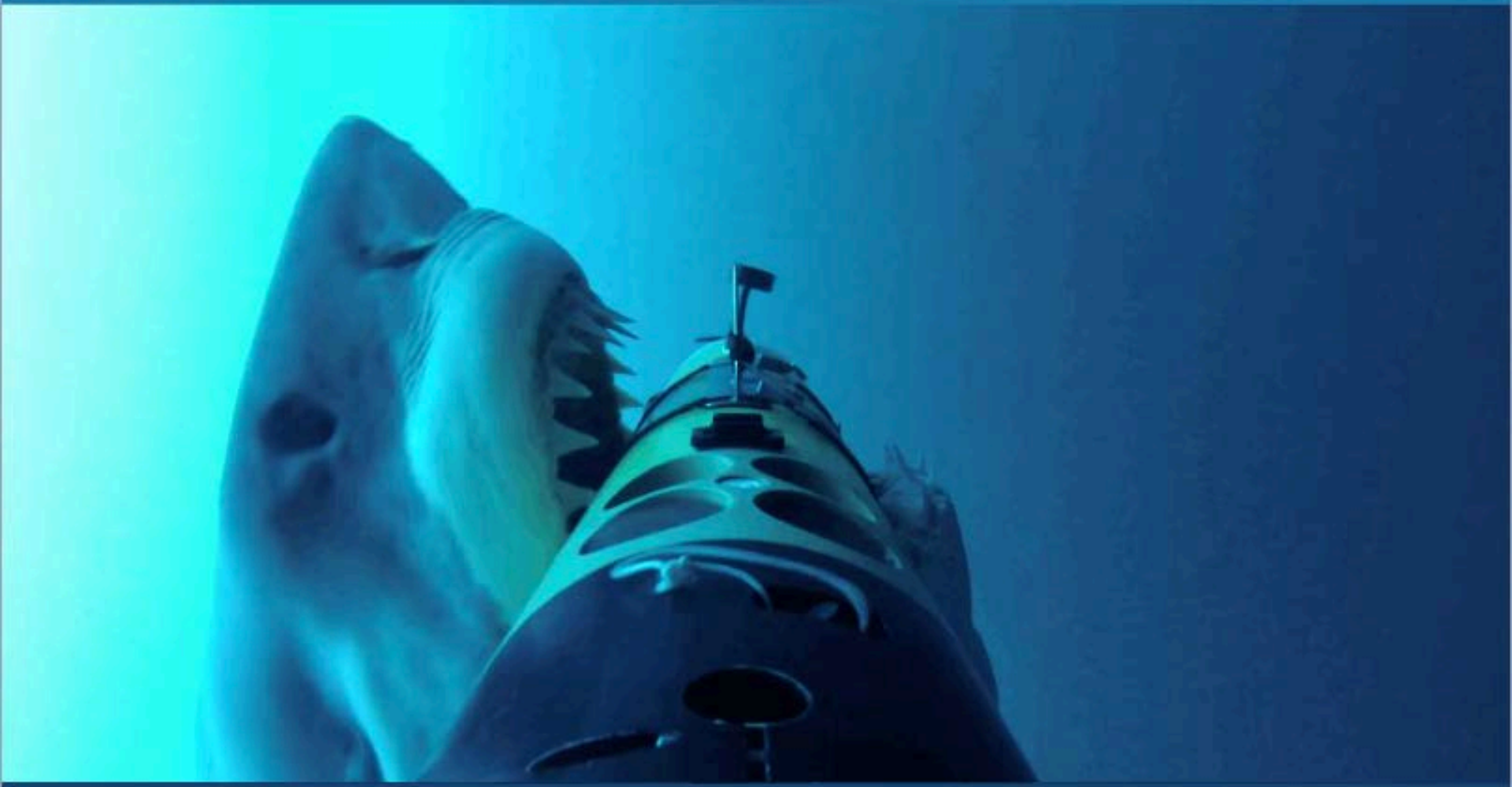
Findings: Technology

- What technologies for what scale
  - Time, space & mass?
- Instrumentation
  - Which tools are serve multiple purposes?
  - What are the science drivers? E.g. GCMS
- How useful has remote sensing been for Ocean Exploration?
  - What if the oceans were transparent?
  - Radio energies: Titan's sea are transparent – seafloor maps can be acquired from orbit
- Clipper payload – earth ocean community thoughts on selected payload. Making the most of the datasets that we will generate
- Experiments that can be done in the lab will be better informed once this community better understands the payload
- Getting people less involved in the PS community into the field
- Lander goals – input from this community would be useful
- Lander: productivity, what's the right trade in autonomy versus GITL so as to optimize sample selection.
- Replace specialized sensors with additional computation – is that a way to optimized limited resources? Event detection
- What are the technology taboos? E.g. nuclear systems. Reintroduce these kinds of ideas/technology.
- EO: Limitations on imaging – data rates; storing and then forwarding
- Analog research has intrinsic 'offsets' whereas vents may well be more 'authentic' than what we used to
- Boots on the ground experience has benefited the Mars community greatly;
- Antarctica is low hanging fruit and moving too slowly – collaborative effort across agencies

Findings: Science

- Habitability & Chemical Disequilibrium vs Chemical Equilibrium and Biosignatures: What is the energetic biosignature of an inhabited system?
  - Anomalous equilibrium as a biosignature
  - Abiotic methane is a key link between ocean worlds
  - New vents, new chemistries: Abiotic organics versus biological materials, e.g. Lost City, FT synthesis
  - Mineral evolution and diversity; higher mineral diversity on earth is linked to life; Roughly half of earth's minerals
- Ocean modeling/circulation –
  - How does tidal heating affect ocean circulation?
  - Are these oceans stratified?
  - What experiments are needed to advance the models?
- Humans use the same sensors for navigation/autonomy as we do for 'science'; i.e. exploration payload = science payload.
- Advances in Earth ocean capabilities are making the idea of getting into Europa's ocean seem more feasible than even just 10 years ago.

My new favorite biosignature



WHOI SharkCam

Reaching a Broader Audience

- Washington Post summary article
  - https://www.washingtonpost.com/news/speaking-of-science/wp/2016/09/02/looking-for-aliens-on-ocean-worlds-youd-be-in-denial-to-believe-there-isnt-life-out-there/