The Ocean Worlds Working Group

Linking ocean world science to technology development

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Update on OWWG Activities

- On January 31st, the AGs (including working groups) were asked to stand down activities
  - The OWWG website was taken offline, along with the other AG sites.

- On March 25th, the OWWG chairs asked NASA whether the OWWG could resume activity
  - Henry Throop replied on March 27th stating “NASA is working on getting the working groups restarted, but that process has not been completed yet. I’ll let you know when I have an update on it.”
  - OWWG leadership has not yet received an update stating that we are cleared to resume work
  - A redacted version of the OWWG website came back online in mid-May.

- OWWG leadership has been continuing to think about OW exploration and technology development during this pause.

Impact of Current Policies

- Misha Zolotov stepped down as co-lead of the Science Goals subgroup in the Fall of 2024 and has not been replaced.
  - A candidate was selected and informed but has not been brought on board

- The OWWG leadership is in the process of setting up a non-redacted OWWG website and mailing list hosted by PSI.

- While it is difficult to think about the future of planetary science in the current climate, the OWWG is focused on the long-term exploration of Ocean Worlds.

Driving Science Questions for Ocean Worlds Exploration:

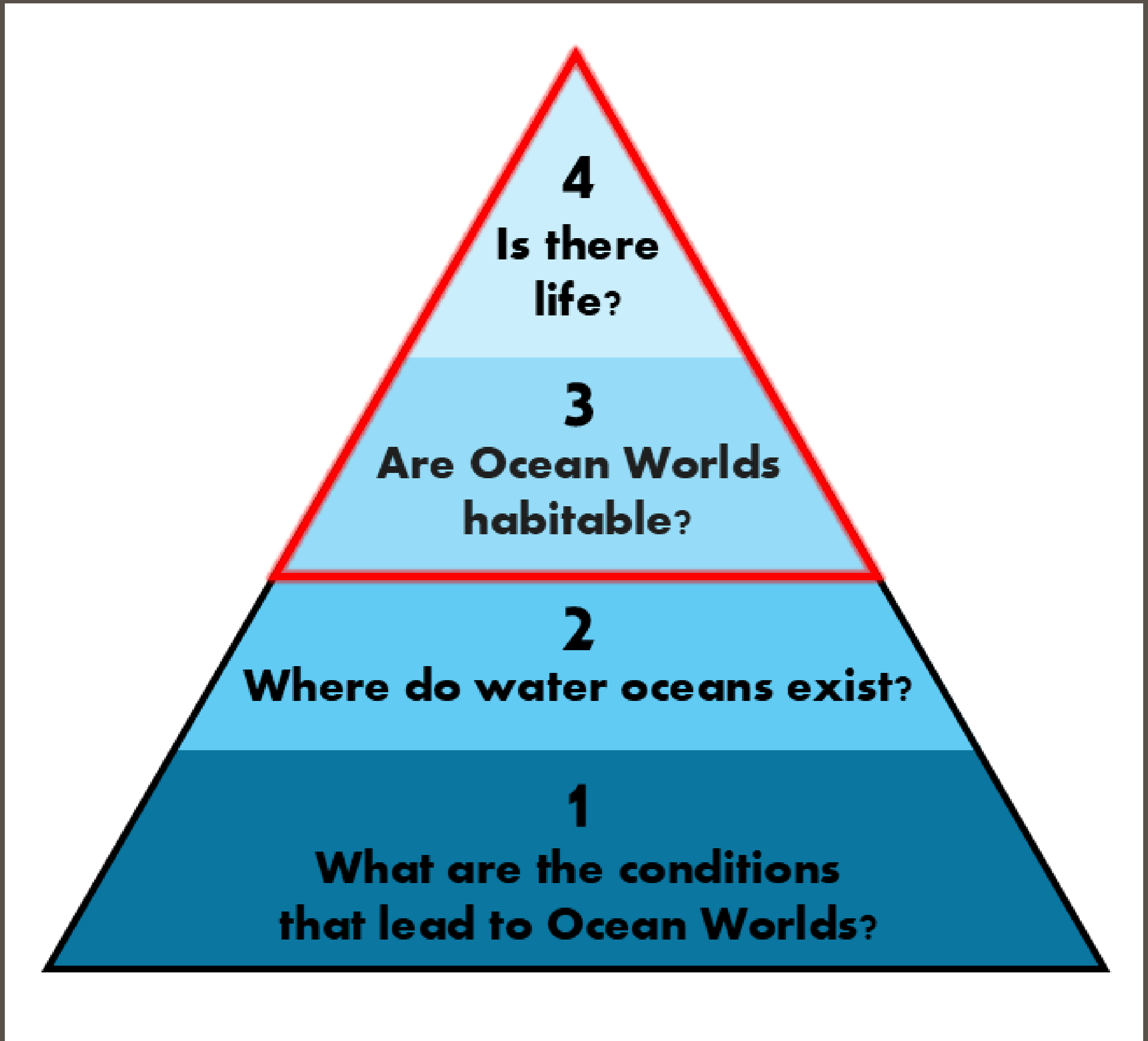
1. What are the conditions that lead to the formation of ocean worlds?

2. Where do water oceans exist in the interiors of outer solar system bodies?

3. Do ocean worlds have past or present environments conducive to life?

4. Is there evidence for present or past life in plume material, on the surface, or in the interior of ocean worlds?

Driving Science Questions for Ocean Worlds Exploration:



Linking Science and Technology Development

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
						Mission Architecture							Ocean Worlds										
Science Question	Science Goal	Science Investigation	Measurements and Studies	Instrument	Instrument Tech Gap	Multiple Flyby	Orbit	Lander	Rover	Subsurface	Sample Return	Mission Tech Gap	Europa	Enceladus	Titan	Triton	Ceres	Pluto	Uranian Satellites	Mid-sized Saturnian Sats	Ganymede	Callisto	Other KBOs
Where do water oceans exist in the interiors of outer solar system bodies?	Reveal interior structures of icy worlds	Determine the thickness and composition of the outer ice layer	Directly measure the thickness of the ice shell	RADAR Sounding		X	X						X	X		X	X	X	X				
				Seismometer				X	X				X	X	X	X	X	X	X	X	X	X	X
				Passive EM				X	X				?	?	?	?	X	?	?	?			
				Magnetometer		X	X						X				?		?		X	X	
				In-Situ Traverse						X			X	X	X	X	X	X	X	X	X	X	X
			Measure the gravity field to constrain the thickness of the ice/ocean layer	Antenna array		X	X						X	X	X	X	X	X	X	X	X	X	X
				USO		X	X						X	X	X	X	X	X	X	X	X	X	X
			Measure the low-degree shape	Visbile Imaging		X	X						X	X		X	X	X	X	X	X	X	X
				RADAR Altimetry		X	X						X	X	X	X	X	X	X	X	X	X	X
				Vis/UV occultation		X	X						X	X		X	X	X	X	X	X	X	X
			Measure the rotation	Visible Imaging		X	X						X	X		X	X	X	X	X	X	X	X
			Measure the composition of the ice shell	IR Spectrometer		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
				Color Imaging		X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X
				UV Spectrometer		X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X
				In situ		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
		Determine the spatial extent of any liquid water reservoirs	Directly measure the thickness of the ice shell	RADAR Sounding		X	X						X	X		X	X	X	X				
				Seismometer				X	X				X	X	X	X	X	X	X	X	X	X	X
				Passive EM				X	X				?	?	?	?	X	?	?	?			
				Magnetometer		X	X						X				?		?		X	X	
				In-Situ Traverse						X			X	X	X	X	X	X	X	X	X	X	X
			Measure the gravity field to constrain the thickness of the ice/ocean layer	Antenna array		X	X						X	X	X	X	X	X	X	X	X	X	X
				USO		X	X						X	X	X	X	X	X	X	X	X	X	X
			Search for liquid reserviors within the ice shell	RADAR Sounding		X	X						X	X	X	X	X	X	X	X	X	X	X
				Seismometer				X	X				X	X	X	X	X	X	X	X	X	X	X
				Passive EM				X	X				?	?	?	?	?	?	?	?	?	?	?
		Determine the structure, density, and composition of the deep interior and how those properties change with depth	Measure the static gravity field to determine the bulk denisty and moment of inertia	Antenna array		X	X																
				USO		X	X																
			Measure magnetic fields to search for the signature of a metallic core	Magnetometer		X	X																
			Measure seismic waves that travel through the deep interior	Seismometer				X	X														
	Examine the surfaces of ocean worlds to identify features indicative of an extant subsurface ocean	Search for the existence of warm features that are indicative of current geologic activity or near-surface liquids	Measure spatial variations in surface temperature	Thermal Imaging		X	X																
				IR Imaging		X	X																
				Visible Imaging		X	X																
		Assess whether the composition and spatial distribution of non-ice material reveals the existence of a present-day ocean	Measure the spatially variable composition of the surface	IR Mapping Spectrometer		X	X																
				UV Mapping Spectrometer		X	X																
				Visible Imaging		X	X																
				In Situ				X	X		X												
		Search for surface changes indicative of current geologic activity	Measure changes in surface feature morphology and morphometry	Visible Imaging		X	X																
				IR Imaging		X	X																
			Measure changes in topography	Visible Imaging		X	X																
				RADAR (SAR)		X	X																
		Evaluate whether surface geology is indicative of extant subsurface liquid water reservoirs	Characterize the mrophology of surface features	Visible Imaging		X	X																
			Characterize subsurface structures	RADAR		X	X																
	Explore atmospheres, exospheres, tori of Ocean Worlds	Detect and explore plumes to determine whether they connect to subsurface liquid reservoirs	Search for plumes	Magnetometer		X	X																
				UV Spectrometer		X	X																
				Visible Imaging		X	X																
				Plasma Detector		X	X																
				Dust Detector		X	X																
			Measure the composition and density of plume material	Mass Spectrometer		X	X																
				Dust Detector		X	X																
				UV Spectrometer		X	X																
		Investigate the sputtered atmosphere to understand the composition of the surface and links to an ocean.	Measure the spatially variable density and composition of the sputtered atmosphere	Dust detector		X	X																
				Mass Spectrometer		X	X																
		Determine whether the exosphere of Ocean Worlds is indicative of an extant ocean.	Measure the composition and physical proeprties (e.g., density) of the exosphere	Plasma		X	X																
				Magnetometer		X	X																
		Determine whether the tori associated with Ocean Worlds are indicative of an extant ocean.	Measure the composition and physical properties of the tori	Plasma		X	X																
				Magnetometer		X	X																

Linking Science and Technology Development

Science Question	Science Goal	Science Investigation	Measurements and Studies	Instrument	Instrument Tech Gap	Mission Architecture: Multiple Flyby	Orbit	Lander	Rover	Subsurface	Sample Return	Mission Tech Gap	Ocean Worlds: Europa	Enceladus	Titan	Triton	Ceres	Pluto	Uranian Satellites	Mid-sized Saturnian Sats	Ganymede	Callisto	Other KBOs
	Reveal interior structures of icy worlds	Determine the thickness and composition of the outer ice layer	Directly measure the thickness of the ice shell	RADAR Sounding		X	X						X	X		X	X	X	X				
				Seismometer				X	X				X	X	X	X	X	X	X	X	X	X	X
				Passive EM				X	X				?	?	?	?	X	?	?	?			
				Magnetometer		X	X						X				?		?		X	X	
				In-Situ Traverse						X			X	X	X	X	X	X	X	X	X	X	X
			Measure the gravity field to constrain the thickness of the ice/ocean layer	Antenna array		X	X						X	X	X	X	X	X	X	X	X	X	X
				USO		X	X						X	X	X	X	X	X	X	X	X	X	X
			Measure the low-degree shape	Visbile Imaging		X	X						X	X		X	X	X	X	X	X	X	X
				RADAR Altimetry		X	X						X	X	X	X	X	X	X	X	X	X	X
				Vis/UV occultation		X	X						X	X		X	X	X	X	X	X	X	X
			Measure the rotation	Visible Imaging		X	X						X	X		X	X	X	X	X	X	X	X
			Measure the composition of the ice shell	IR Spectrometer		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
				Color Imaging		X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X
				UV Spectrometer		X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X
				In situ		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
		Determine the spatial extent of any liquid water reservoirs	Directly measure the thickness of the ice shell	RADAR Sounding		X	X						X	X		X	X	X	X				
				Seismometer				X	X				X	X	X	X	X	X	X	X	X	X	X
				Passive EM				X	X				?	?	?	?	X	?	?	?			
				Magnetometer		X	X						X				?		?		X	X	
				In-Situ Traverse						X			X	X	X	X	X	X	X	X	X	X	X
			Measure the gravity field to constrain the thickness of the ice/ocean layer	Antenna array		X	X						X	X	X	X	X	X	X	X	X	X	X
				USO		X	X						X	X	X	X	X	X	X	X	X	X	X
			Search for liquid reservoirs within the ice shell	RADAR Sounding		X	X						X	X	X	X	X	X	X	X	X	X	X
				Seismometer				X	X				X	X	X	X	X	X	X	X	X	X	X
				Passive EM				X	X				?	?	?	?	?	?	?	?	?	?	?

Linking Science and Technology Development

						Mission Architecture							Ocean Worlds										
Science Question	Science Goal	Science Investigation	Measurements and Studies	Instrument Type	Instrument Tech Gap	Multiple Flyby	Orbit	Lander	Rover	Subsurface	Sample Return	Mission Tech Gap	Europa	Enceladus	Titan	Triton	Ceres	Pluto	Uranian Satellites	Mid-sized Saturnian Sats	Ganymede	Callisto	Other KBOs
	Search for organic signatures of present or past life	Determine the level of complexity in organic molecules.	Comprehensive inventory of organic molecules that include both volatile & condensed phases, as well as soluble and insoluble fractions (e.g. kergogen) and abundant & trace species	Vibrational spectroscopy (IR, Raman, SERS Raman)	Ability of non-sampling instruments (VS or FS) to address this science objective at the necessary sensitivity for ocean worlds missions has not been demonstrated by any team. The results from the SHERLOC instrument on the Mars Perseverance mission are			X	X		X		X	X	X		X						
				Flouresence spectroscopy				X	X		X		X	X	X		X						
				GCMS	This science objective requires the analysis of organics that are not volatile, such as the critically important amino acids, which are water soluble, and they simply decompose if heated to the temperatures used by the			X	X		X	The key technology gap for HRMS is sample preparation - all the S-MS techniques mentioned here would benefit from a higher resolution mass spectrometer. However just because an MS has intrinsically high mass resolution does not signify that it is necessarily sensitive to organics, or is capable of creating inventories of organics present. The sensitivity of a mass spectrometer system is dictated by the amount of material from the environment that can then be separated from its natural sample matrix, ionized, and then transferred into the mass analyzer region of the mass spectrometer. If this	X	X	X		X						
				Liquid seperation MS	There are various technology gaps associated with the use of liquid-based S-MS instrumentation which is currently at TRL-5. The challenges with HPLC and LC variants stem from the need to			X	X		X		X	X	X		X						
					The need for operating electrospray ionization during spaceflight. This technique is used to transfer liquids from the separation column or capillary into the mass spectrometer, and in doing so, ionizing organics present. Ths process of ionization requires the			X	X		X		X	X	X		X						

Moving Forward (Pending Restart)

- OWWG Leads will be finalizing the draft traceability
    - Spring 2025
- OWWG Leads will reach out to community members for specific input
    - Summer 2025
- Preliminary draft traceability released to the community for comment
    - Fall 2025
- Draft publication
    - Winter 2025