



SubSeaSail[®], LLC

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“Long-Duration, Energy Harvesting & Storage USVs”

25 April 2023 – Presentation at NPS

SSS Proprietary includes SBIR Data Rights



The Need: Affordable, low signature ocean OBSERVATION & CARGO/ENERGY delivery/storage everywhere

General David H. Berger – US Marine Corps 38th Commandant's Planning Guidance, 2019:

“Calls for extensive use of 'Stand In' capabilities - autonomy, low to no signature and mobility...an unmanned, silent, low cost, near invisible platform that relies solely on alternative power and allows for indefinite operation.”

RADM Lorin Selby, ONR: *“...the small, the agile and the many.”* **WANT LOW OPEX WITH NEGLIGIBLE INFRASTRUCTURE NEEDS**

SSS Mission: Develop autonomous, disruptively affordable, easy-to-use, ultra-low signature, 100% energy harvesting, long-duration, submerging platforms capable above and below water & unique low SWaP sensors

Water represents 71% of
the earth's surface and
98% of habitable earth



SubSeaSail™

What makes SSS different?



Hull slapping + wake

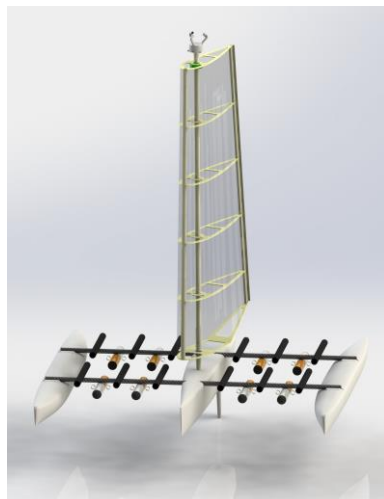


Heat, radar, sound, visual,
& wake signatures...heat
& wake visible from space

1. SSS doesn't make traditional monohull vessels
2. Affordable (low CAPEX), easy-to-deploy (low size & weight)
 - a. Facilitates fleets and swarms
 - b. **Low support & infrastructure footprint**
 - c. Launch from beach, dock, or vessel
3. Ultra-low signature: acoustic, heat, radar, visual
4. **100% energy harvesting** = clean, low OPEX, long duration
5. Submerging capability to hide, listen/monitor, etc.
 - a. New kind of buoyancy engine – ultra-quiet; hard to find
 - b. Creates new EW opportunities including decoy/deception
 - c. New offensive & defense CONOPS required
6. Designed for **low Total Cost of Ownership (TCO)**
7. HERMES™ cargo vessel
 - a. Traditional & non-traditional loads (e.g. tube launched)
 - b. HERMES-e for energy creation, storage, availability
 - c. Decentralized, offshore, secure cargo storage
 - d. Ability to deliver to the beach as needed



HORUS™ at 60-80 meters

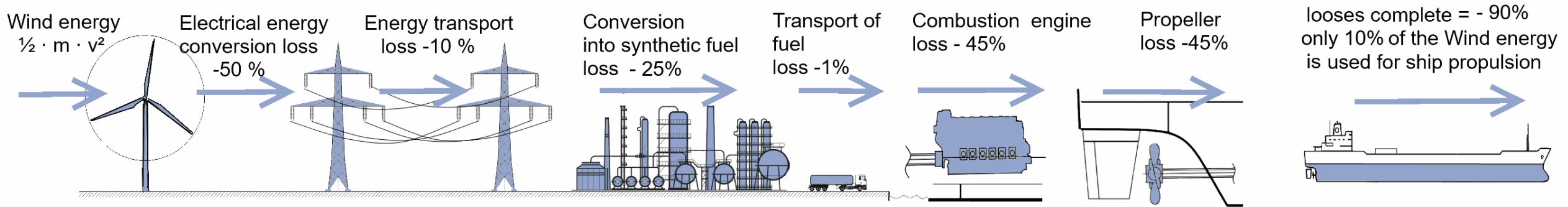


HERMES™ w launch tubes

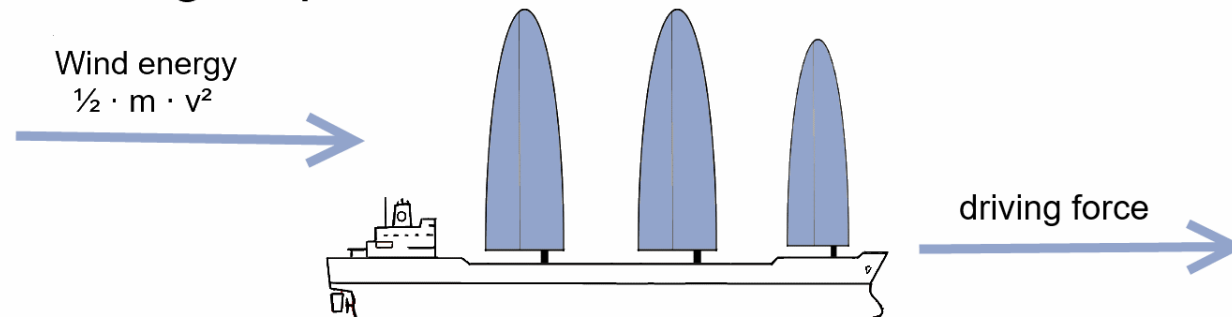
Energy Source 1 – current use

Wind: Highly efficient & “sustainable” compared to other “green fuels”

power 2 fuel concept: the long way from wind energy to driving force...



sailing ship : the short way from wind energy to driving force



advantages of a sailing ship:

- uses high wind potential on the open sea
- No losses due to energy conversion
- No losses due to energy transport
- No land-based infrastructure necessary
- One sailing ship replaces 10 land based wind power plants
- No fuel costs for the shipping company (wind is for free)
- less dependency of shipowners on fuel producers

Advantages: No cost, freedom from fuel, global, point-to-point transit

Energy Source 2 – current use

Solar: Highly efficient & “sustainable” compared to other “green fuels”

Solar power is energy from the sun converted into thermal or electrical energy. Its advantages are that it is a clean, abundant, globally available renewable energy source. Its disadvantages are that it is available during the day, during “good” weather and impacted by the latitude and time of year.

On SSS vessels, solar power represents a distributed generating capability that can be stored in on-board battery banks and used as needed above and below water.

Advantages: Low cost, freedom from fuel, global, point-to-point transit

Ocean Motion: Hydrokinetic ocean energy to be explored for SSS vessels

Hydrokinetic possibilities:

1. Motion absorbing generators: To be mounted in/on hulls. Could produce power above as well as below water when submerged
2. Hydrokinetic generators: A hydrokinetic generator can transform water flow energy into electricity with an alternator. Since HERMES is a sailing vessel, the thruster can be “back driven”, generating power when sufficient wind is present.

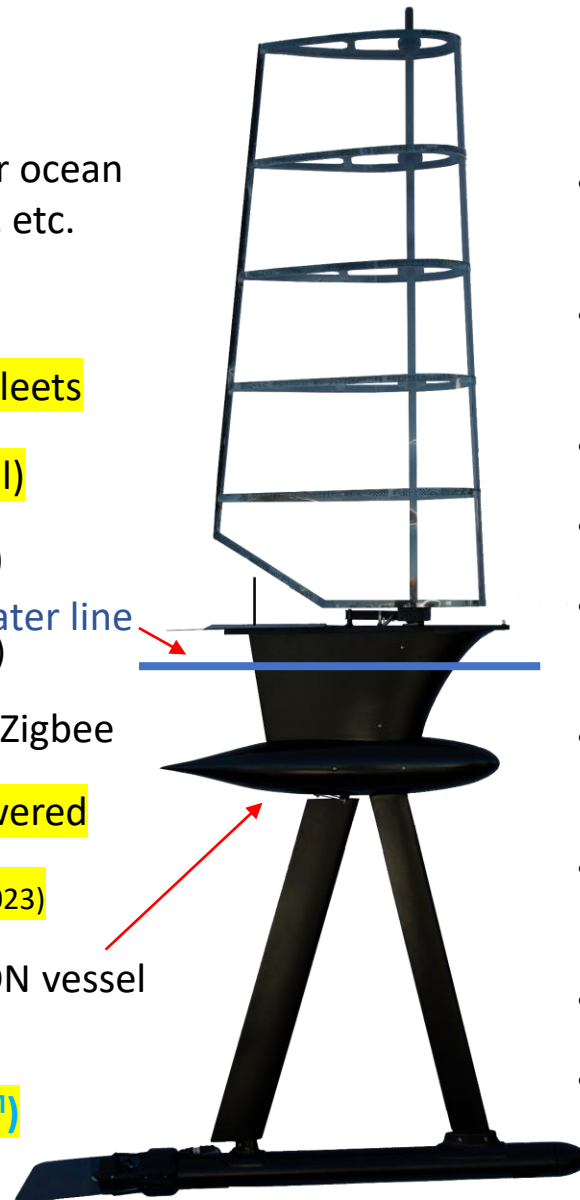
While not hydrokinetic, there are two additional possibilities:

1. Wind generators: Produce renewable electricity through an alternator.
2. Fuel cells: Longer term, possibly fuel cell producing power via chemical reaction.

We are entrepreneurs

5 ½ year-old Innovative Developer

- **Unique, autonomous platforms & sensors** for ocean observation, cargo delivery, comms gateways, etc.
- **Engineered for durability**, reusable platforms
- **Disruptively affordable** to permit swarming/fleets
- **Minimal signature** (acoustic, IR, radar & visual)
- **Highly scalable & variable systems** (standard)
 - HORUS™ = 1.65m long x 3m tall / 32kg
 - HERMES™ = 6.5m long/wide x 6.5m tall (TBD)
- **Communications:** via cellular, satellite, Wi-Fi, Zigbee
- **Long duration:** wind-propelled and solar-powered
- **Submerging:** Factory installed option (end of 2023)
- **1st to market:** Semi-submersible OBSERVATION vessel
- **Three lines of business:**
 - **Monohull OBSERVATION vessels (HORUS™)**
 - **Multihull CARGO vessels (HERMES™)**
 - **Unique sensors**



HORUS™

We dream. Innovate. Create

Platforms, Sensors and New CONOPS

- **Strong IP portfolio:** 5 issued US patents issued; 5 US patents pending + others in Australia & Europe
- HORUS™ at TRL 7-8. Updated HORUS™ **coming April 2023** *Lightweight≈32 kg. Easy-to-deploy & retrieve.*
- **Rigid acoustic arrays** (with Applied Ocean Sciences [AOS])
- **Heeling wingsail** (*Patent Pending – Nov. 2021*)
- **Submerging & righting capsized watercraft** (*Patent Pending – Dec. 2021*)
- **Depth control of submersible vessels** (*Patent Pending – June 2022*)
- **Two SBIR Phase I grants (DOE & NSF) + Phase II (DOE)** Looking for possible concurrent Phase II awards
- Collaborate with innovative sensor & payload mfgs
- Collaborate with defense contractors with ability to do classified work

Monohull Observation Vessel

HORUS™ = Sky God
Eye of HORUS stands for protection and knowledge

Wingsail: Transparent, hollow and lightweight. Floodable. Rotates around carbon fiber or kevlar mast.

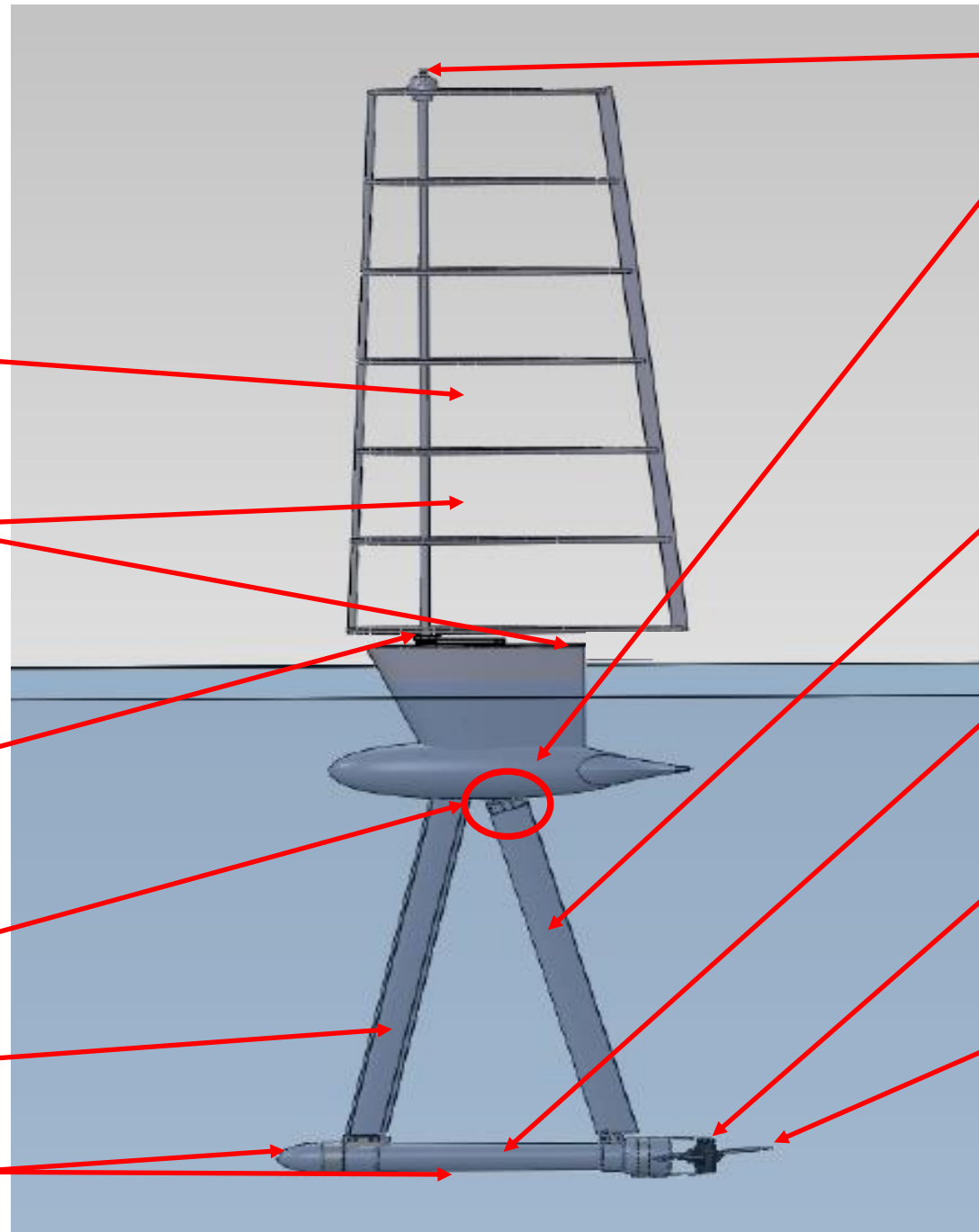
Solar Power Generation: Wingsail and “deck” options available based on power vs. stealth requirements.

Wingsail Control Mechanism: Patented all-mechanical module. Single point control – no lines, pulleys, or electronics.

Servo: manages the rudder (single electromechanical part in frequent use)

Structural Keel: Increases stability and structural rigidity.

Payload Areas: In the cone plus above & below the hull



Payload on the Mast: Antenna, camera, lights, weather station

Float Module: Buoyancy section. Upper region houses Inertial Measurement Unit (IMU) and electronics. *Lower section houses ballast tank system for submerging.* Additional potential payload area.

Rudder: Rotates around fixed carbon fiber shaft. Contains interconnect between hull, floats, and wingsail.

Hull: Contains ballast & NiMH batteries

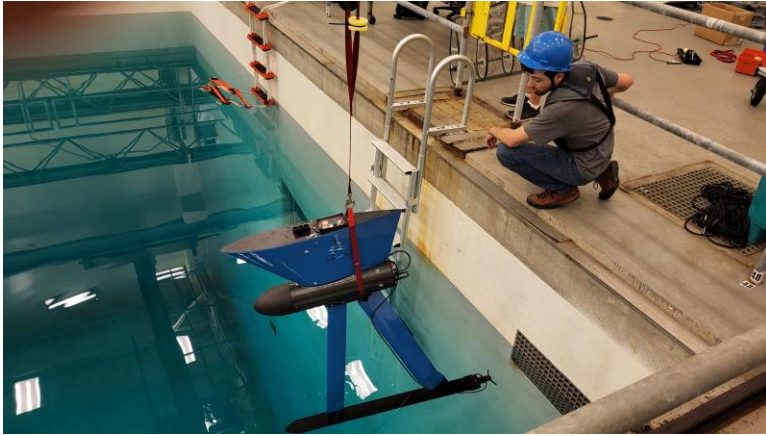
Thruster: Provides auxiliary power for maintaining position in pre-determined survey areas and near-shore navigation with light winds.

Stabilizer: Minimize pitch of platform in high sea states.



Submerging Capability being Developed

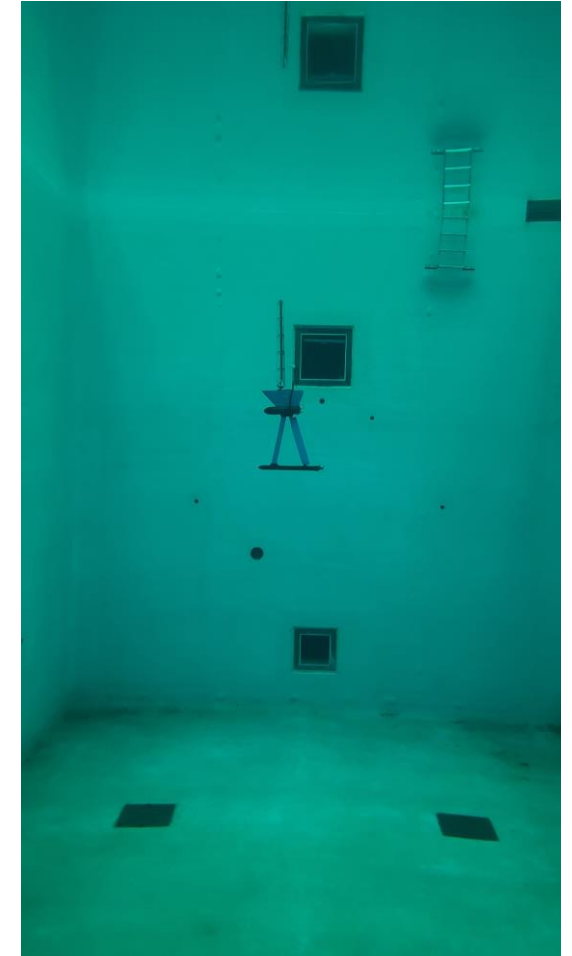
(Pictures from Phase I DOE – June 2022)



Deploying HORUS™ in
2- million-liter tank



Submerging

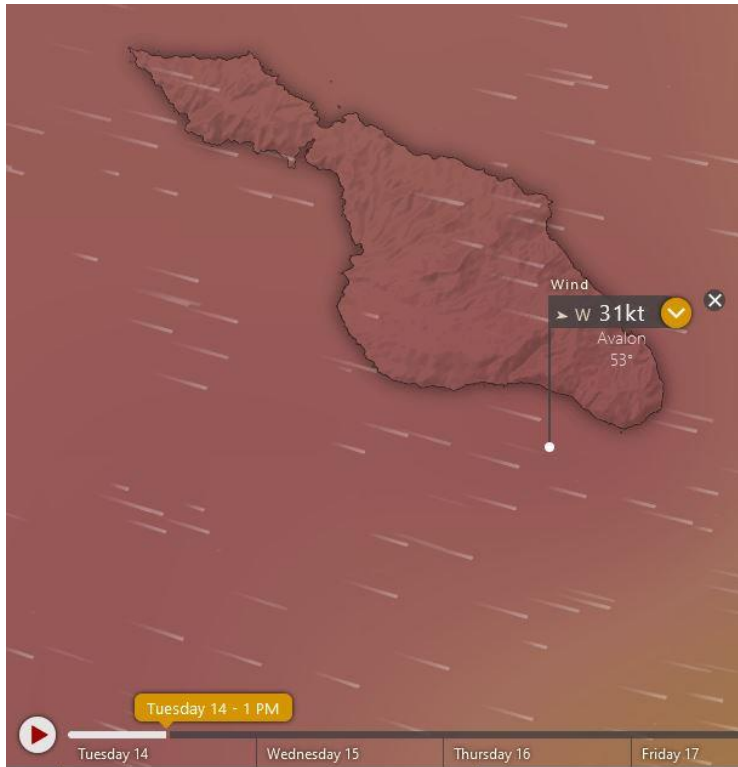


Holding position

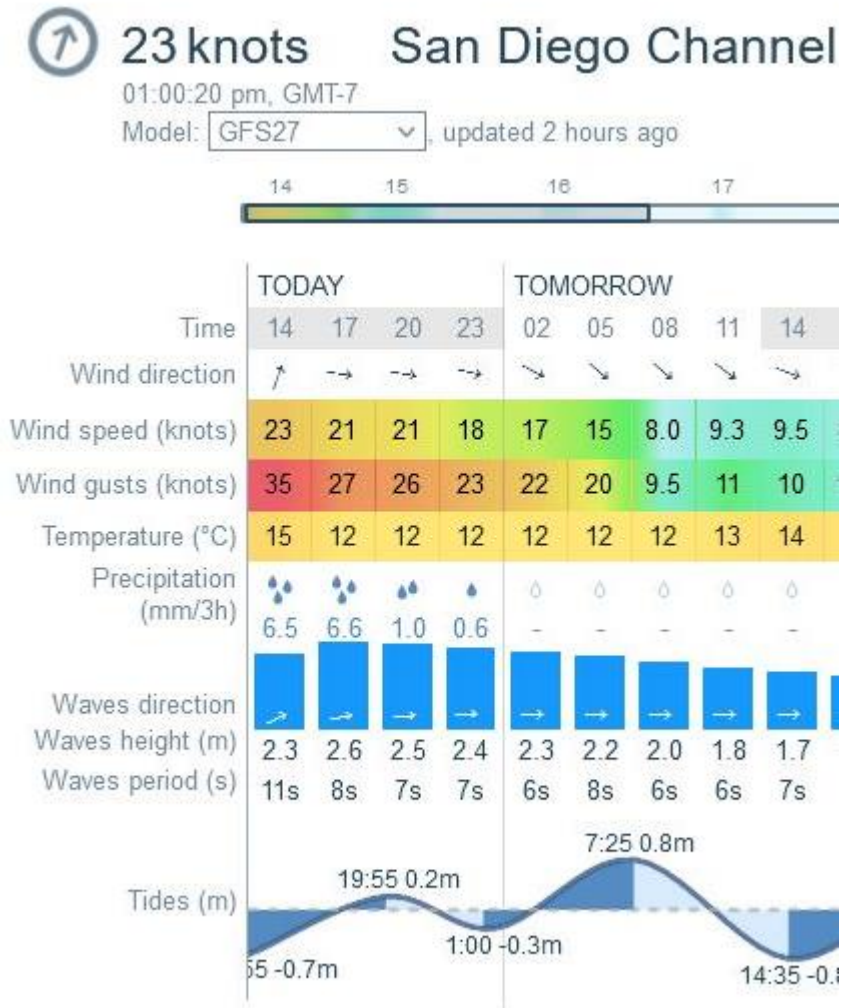
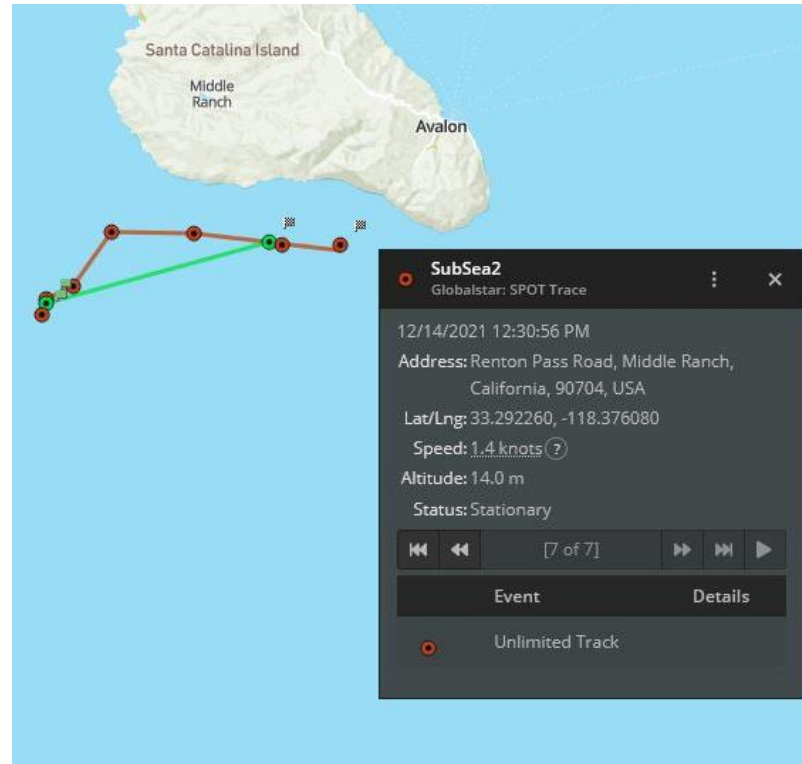
Submerging capability will allow vessels to hide from bad actors/weather and listen/monitor underwater

Long duration through good & bad weather

Storm: Tuesday, Dec. 14



Day 29: Gen7 location during storm



• **Launch of HORUS (Gen7) – Monday, Nov. 15, 2021. Recovery – Thursday, Dec. 16, 2021**

• **Storms:**

- Thursday, Dec. 9, 2021 (Day 24) – 19-23 kt winds
- Tuesday, Dec. 14, 2021 (Day 29) in NATO Sea State 5+
 - Sustained winds of 31 kts per hour (gusts of 35 kts). Source: Windy.com using Global Forecast System (GFS) weather model from NOAA National Centers for Environmental Prediction (NCEP) + windy.app
 - NATO Sea State 4 = wind speed 16-21 kts; wave height 1.5 – 2.5 meters
 - NATO Sea State 5 = wind speed 22-27 kts; wave height 2.5 – 4.0 meters
 - NATO Sea State 6 = wind speed 28-47 kts; wave height 4.0 – 6.0 meters



HORUS™ able to transit hundreds of miles and/or station keep on position



...in light wind & calm sea



...in heavy wind & high sea state

Submerging capability will allow vessels to hide from bad actors/weather and listen/monitor underwater



ASGUARD™: Advanced SeaGoing & Underwater Research Device

Adding submerging & EMF monitoring capabilities to HORUS™

SSS DOE SBIR Phase I (June 2021-June 2022)

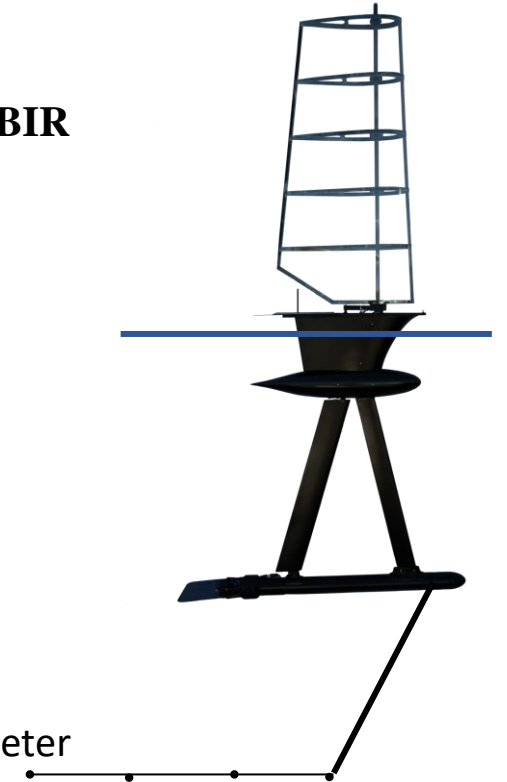
“DoE is seeking low-cost, user-friendly environmental monitoring and resource characterization tools for Marine and Hydrokinetic (MHK) ocean energy installation sites”. In June 2020, SSS received a \$200,000 SBIR Phase I grant to conceive ASGUARD™. Phase I ended on June 27, 2022.

- Designed submerging vessel to 30 meters with new **unique buoyancy engine** (Patent Pending);
- In Phase I, SSS demonstrated a prototype submerging capability in a 2-million-liter tank.

SSS DOE SBIR Phase II (Aug 2022-Aug 2024)

\$1.15 MM 2-year award

- Creating Electromagnetic Force (EMF) dual sensor (electric field [E-field] and magnetic fields [B-field]) detector (marine life reacts to two different kinds of EMF).
- “Mast Head Electronics” (MHE) with navigation lights + 360° color cameras w classifiers + GNSS + anemometer
- Extend vessel & sensors submerging capability to 100 meters (typically to below thermocline)

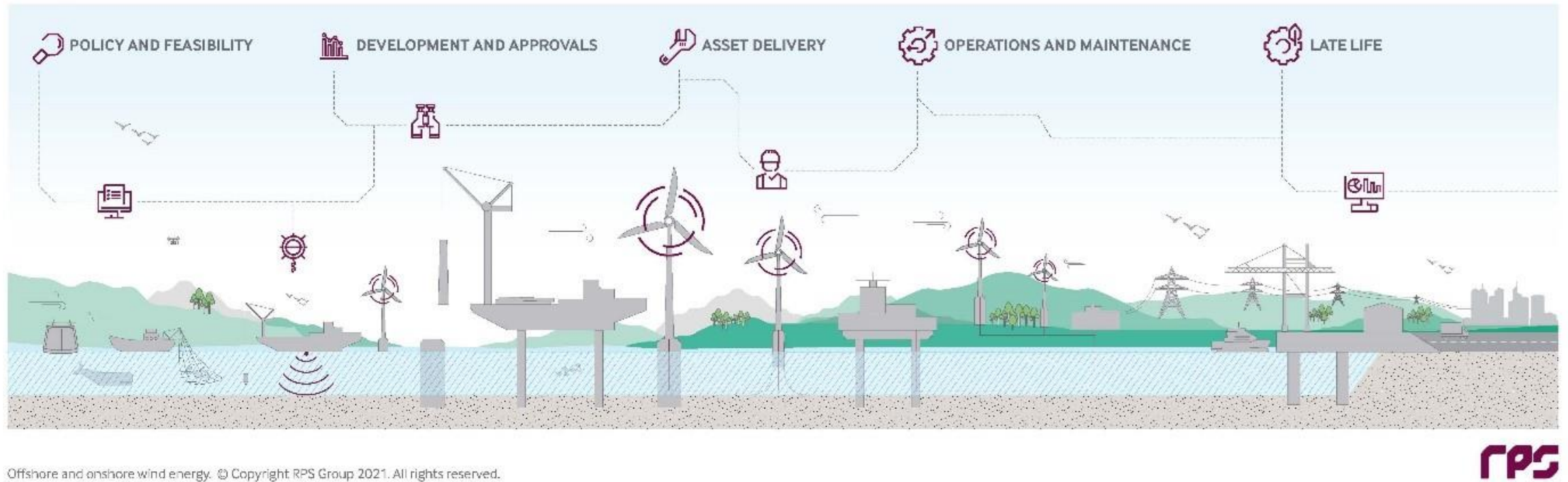


HORUS with extended semi rigid acoustic array

ASGUARD™ will monitor/classify with acoustics, e-field & b-field sensors above + below water



ASGUARD™: Monitoring around offshore renewable energy farms



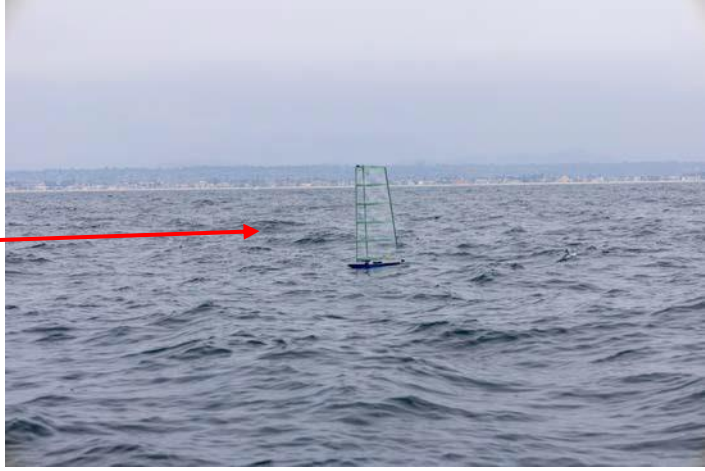
“Fisheries and Offshore Wind Interactions: Synthesis of Science” – NOAA March 2023 (388 pp.)

5.2.4.1.4 Monitoring and Review Recommendations (on page 221). Major impact factor monitoring include acoustics & EMF

- **Pre-Construction Monitoring to Establish Baseline:** Conduct comprehensive surveys in lease areas prior to construction
 - **Monitor during Construction**
 - **Monitor during 20+ year Operational period**
 - **Monitor during & after Decommissioning**
- TOTAL = 25–30 years monitoring need**

Hard to find unless you know where it is.

Easy-to-Recover



SSS vessels designed to easily incorporate sensors...

Third party sensors successfully deployed:

- CTD (Conductivity, Temperature, and Depth) sensor - with US Army Corps of Engineers (USACE)
- Leaking explosive detection – with USACE
- Turbidity sensor – with USACE
- UUV carried (to simulate future deployment) – ANTX Gulfport 2019
- Video (GoPro cameras) – with USACE in Viejas, Puerto Rico

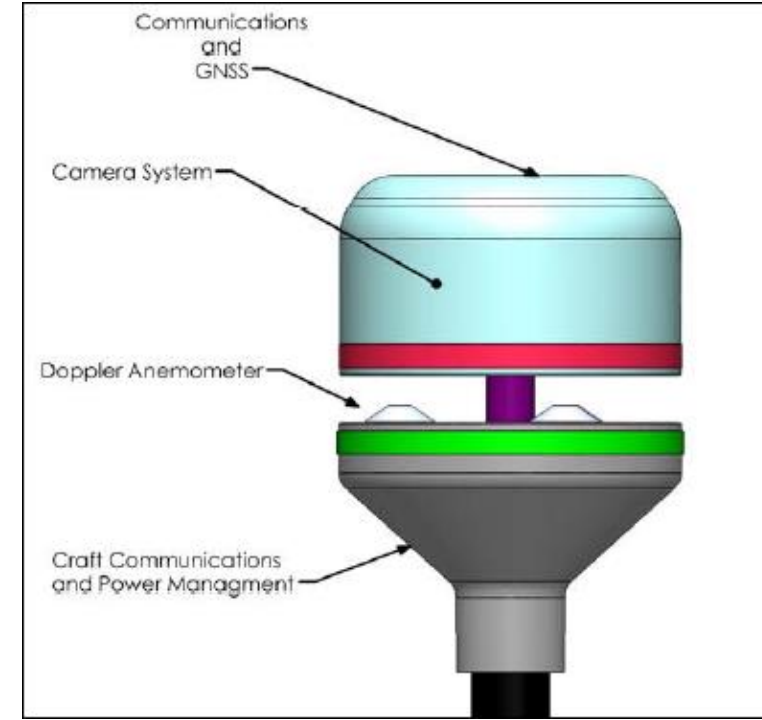


SSS Sensors (to take advantage of unique HORUS vessel attributes) (acoustic equipment developed with partner Applied Ocean Sciences)

1. Multiple rigid & semi-rigid Passive Acoustic Array (PAM) arrays
2. PAMELA™ (Passive Analog/acoustic Monitoring Electronic Logging and Acquisition) on-board processing DAQ

3. Mast Head Electronics (MHE) with 100M operational dive depth:

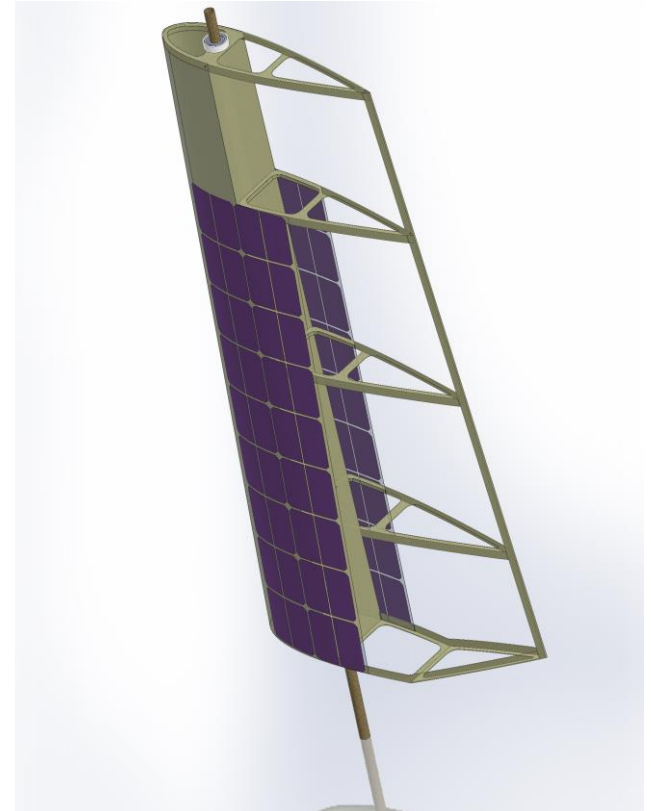
- Acoustic Doppler Anemometer (*for weather, not wing control*)
- AIS (Automatic Identification System) Class B Transponder
- Navigation and Location Lighting
- GNSS; Iridium/Cellular/WiFi/ZigBee Communications Options
- Electronic Gyro and Compass
- 6 Head Color Camera System
- Lightning Detector
- iMX8 Compute Platform with Neural Engine
- Dead Reckoning Navigation
- Video Classifier
- Communications Management
- Heater for Cold Climes



Dramatically upgraded HORUS™ being introduced April 2023

Same look & weight but far more capable and submersible to 100m:

- Batteries (NiMH) & power management: bigger, better NiMH system
- Command & Control: Integrated autonomy encompassing single vessel to multi-vessel fleet operations. API to plug into broader C&C systems.
- Communications: Four full duplex serial interfaces. Dedicated link capacity 920mbps. Coming: high-capacity Iridium Certus
- Computer box & vessel management: all new (*see right*)
- Edge computing: 12 on-board microprocessors for on-board processing to exception-based reporting reduces comms cost and discoverability.
- Mast Head Electronics (MHE): shown page earlier
- PAMELA: Sensor hub to easily integrate sensors & 3rd party boards
- Payload: Independent dedicated power, comms & hardware signaling. Raw – 48VDC up to 100W / Programmable – 4 each 6VDC to 42VDC
- Servicing: Field repairable / designed for fast on/off
- Solar sail: Lighter, stronger, lower radar cross section with fiberglass + polycarbonate sail with pocket ideal for EW antennas (*see right*)



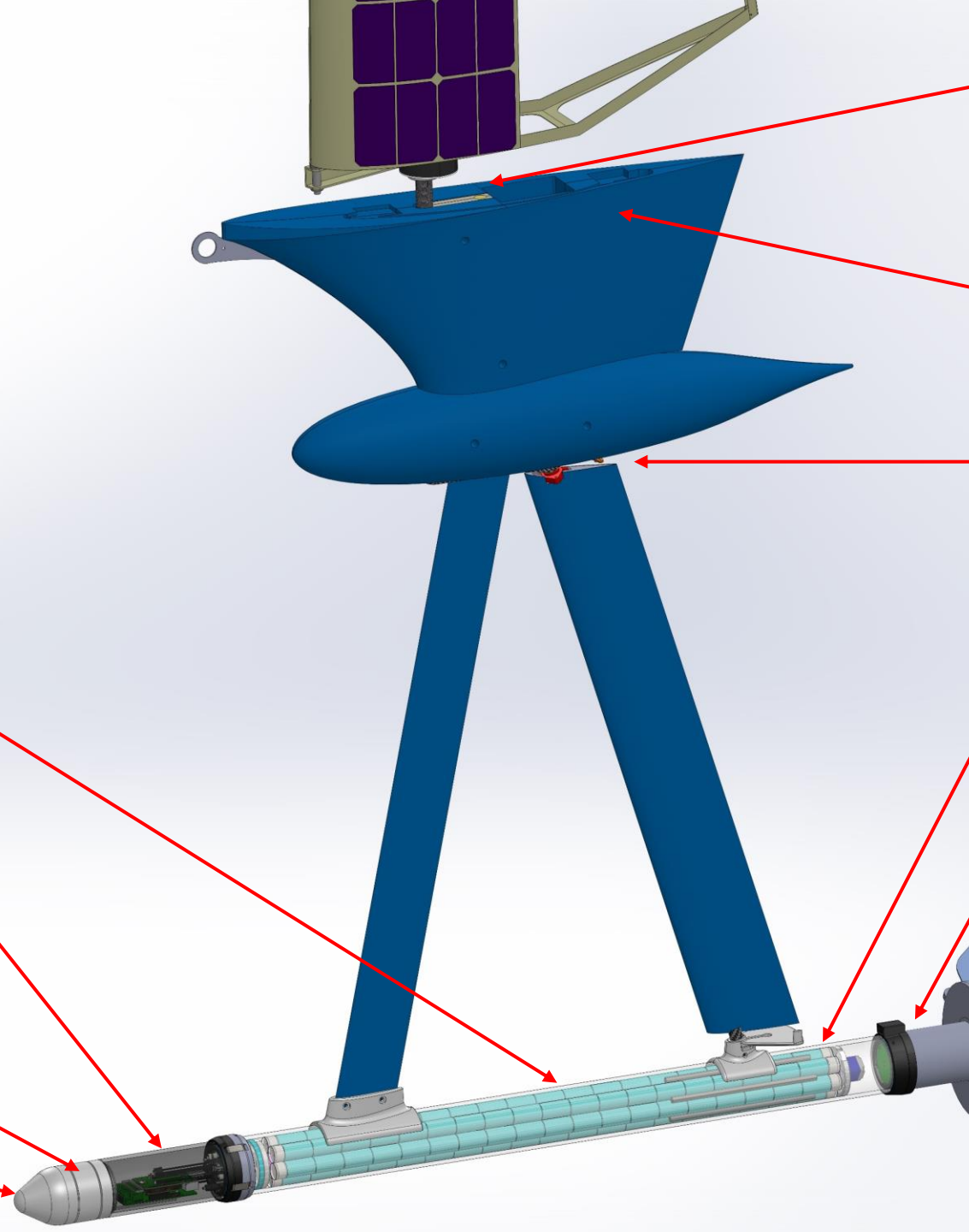
Dramatically upgraded HORUS™ - April 2023

Batteries (NiMH) & power management: bigger, better NiMH system with power management system & low decay rate

PAMELA: Sensor hub to easily integrate sensors & 3rd party boards

Sensor "slices": easily add external sensors & boards that can utilize vessel power & comms

Flooded cone: for sensors



Hermetically sealed craft computer box: uses a cable bundle with external connector pad

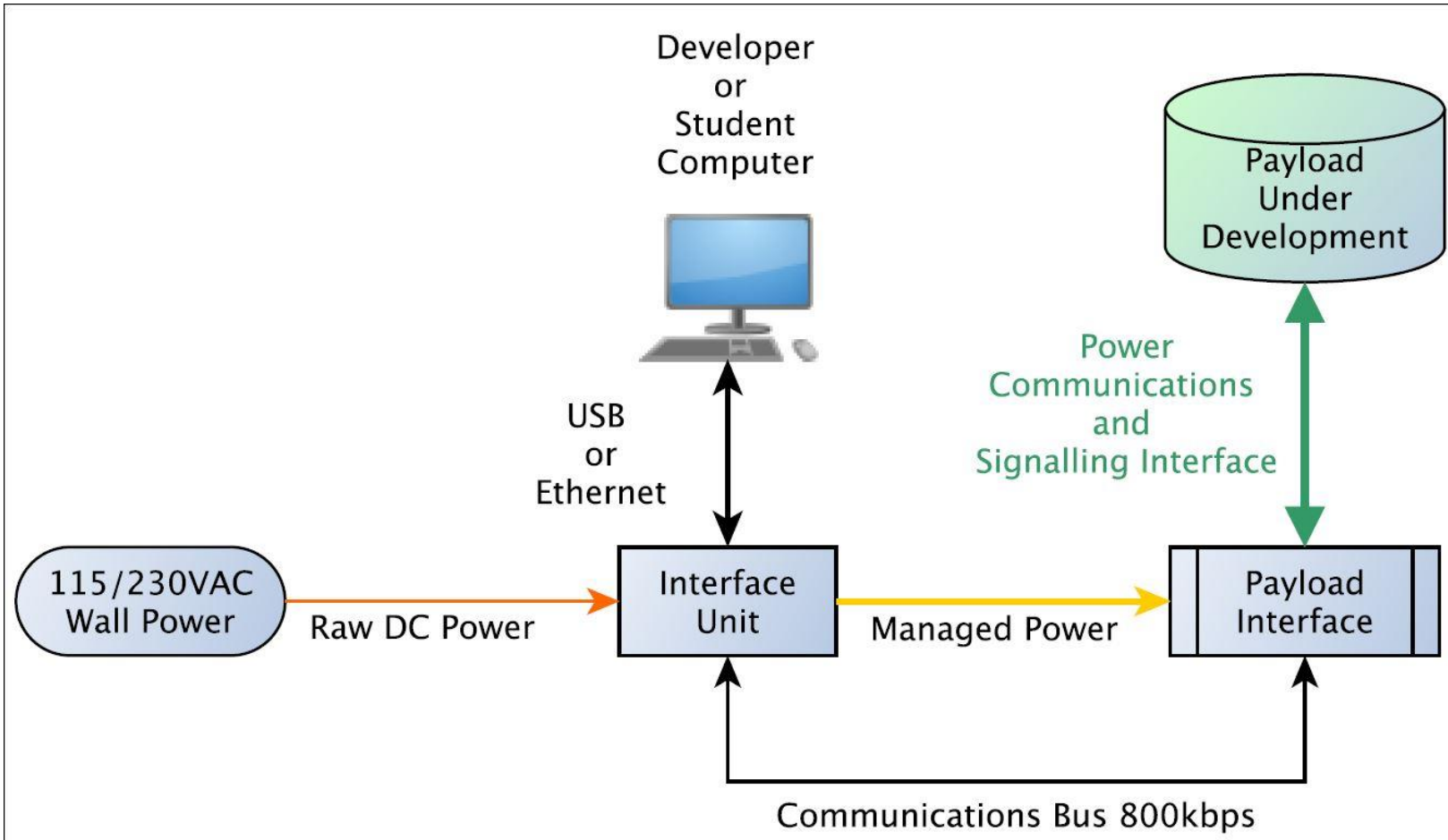
Iridium Certus capable: high capacity Certus for speed

Servo in improved waterproof housing: tested to 150 m; rated to 100 m

Auto-leveling ballast: located inside batteries with stepper motor

Thruster motor & controller: new, ultra-low noise thruster

Developer & Student Ready



Development and Education ready:

A distributed communication architecture has been developed for SSS vessels.

Craft and operation scenario simulations running on a local computer:

1. represent a digital twin of a vessel deployed in a real operations scenario;
2. real payloads can be developed and exercised as if they were deployed.

The Interface Unit between local computer and connected payload under development through the Payload Interface unit:

1. mimics the actual electrical and digital connectivity on a vessel.
2. It allows payload development that can be moved directly to the vessel

The hardware and software will be available in two distinct offerings:

1. one targeting detailed lab development scenarios; and
2. A second simplified version for classroom use by students with multiple payload development at one or more institutions.





SubSeaSail LLC

Revolutionary, Autonomous, Long-Duration,
Multi-Hulled Sailing Cargo Vessel

SSS Multihull Cargo Vessels **HERMES™ = God of Commerce**

Hermes™ (HERMetric Expeditionary Sailvessel) = new SSS cargo line based on various issued and pending U.S. patents

“Innovation Award” received at TechConnect Global 2021 (Oct. 2021)

Effective 15 March 2022, SSS received a \$256,000
Phase I SBIR grant from NSF



Technological innovations: 1) affordable, autonomous, fast, low signature, long-duration, multihulled, cargo-carrying vessels to deliver point-to-point globally; 2) ability to submerge to hide from bad actors/weather & represent decentralized, offshore storage.

Radically change the economics of cargo vessel production (CAPEX) and operation (OPEX) for many applications and destinations.

Ideal for expeditionary forces supply, humanitarian aid (60-80% of cost is delivery), inter-island and remote island delivery.

Multi-function capabilities include cargo, carry/deploy UUVs, tube-launched UAVs, landing pad/re-charging quadcopters, etc.



SubSeaSail®

“Future Music”: HERMES™ (Greek God of Commerce) Cargo Vessels



1. Heeling Wingsail to Prevent Capsizing (Patent filed Nov 2021)
2. System for Submerging & Righting Capsized Multi-hull (Patent filed Dec 2021)
3. Apparatus & Method for Depth Control of Submersible Vessels (Patent filed June 2022)

NSF SBIR Phase I \$256,000 received
effective March 15, 2022

NEED PHASE II) FUNDING

A “Game Changer” for cargo

HERMES™ (HERMetic Expeditionary Sailvessel) = new SSS cargo line

Expeditionary forces supply – advantages include:

1. Multihull vessels are attractive due to speed & load-carrying but are at **risk of catastrophic capsizing**, which is mitigated by Patents Pending
2. Ability to submerge to hide from bad actors/weather or perform tasks;
3. If multihull capsizes, ability to right itself, re-surface and sail again;
4. Disruptively attractive CAPEX, OPEX and total cost of ownership allows fleets of smaller vessels to **de-risk the supply chain**;
5. Ability to sail into damaged ports;
6. **Ability to act as secure, offshore storage** when they arrive ;
7. **Ability to deliver to the beach** (when needed);
8. **Multi-use platforms**
 - Cargo delivery
 - Communications gateway
 - Data gathering sensor packages
 - UAV/quadcopter landing & UUV delivery/docking with re-charging



HERMES with rolled rig in response to heeling moment

**TRL 5-6 = USV Trimaran HERMES
4’x4’ functioning prototype**



Impact: ability to sail low-signature **cargo vessels** quickly to location, hide underwater as needed, deliver to port/shore

HERMES™ functional prototype in development (TRL 5-6)



Left: SSS partners with 4'x4' prototype. Self righting from any possible capsizing. Note keel & flotation in wing.



Right: HERMES deck showing solar panels + tube launched possibilities.



Left: HERMES with rolled rig in response to heeling moment **increased resistance to capsizing**

Right/below: Traditional capsizing risk for multi-hull vessels limits their usage.



HERMES-e – Concept Vessel

Powering the Blue Economy!

HERMES-e could be built to any size. Assuming 100% dedication to energy creation and storage with lithium-ion batteries, the following vessel characteristics provide a rough linear order of magnitude of electrical capacity on four different size vessels:

1. 15ft. LOA (Length Over All) X 15ft. BOA (Beam Over All)
 - Total solar area = 80 sq. ft. 1,500 watts peak
 - Lithium-Ion battery storage = 250 lbs. 10kWh
2. 20ft. LOA X 20FT. BOA
 - Total solar area = 165 sq. ft. 3,000 watts peak
 - Lithium-Ion battery storage = 500 lbs. 20kWh
3. 30ft. LOA X 30ft. BOA
 - Total solar area = 336 sq. ft. 6,300 watts peak
 - Lithium-Ion battery storage = 750 lbs. 30kWh
4. 40ft. LOA X 40ft. BOA
 - Total solar area = 660 sq. ft. 12,000 watts peak
 - Lithium-Ion battery storage = 1,000 lbs. 40kWh



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