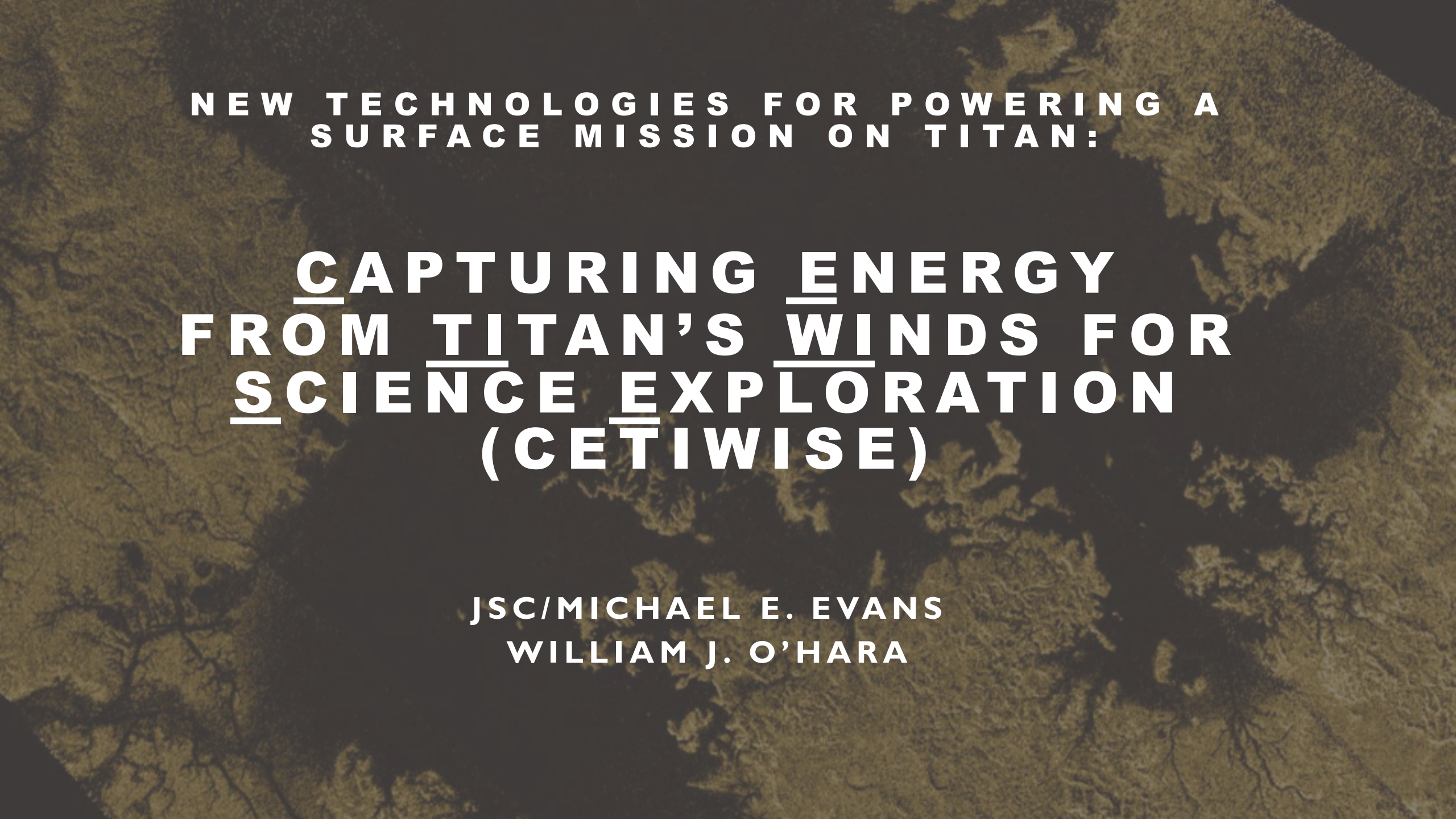

NEW TECHNOLOGIES FOR POWERING A SURFACE MISSION ON TITAN:

CAPTURING ENERGY FROM TITAN'S WINDS FOR SCIENCE EXPLORATION (CETIWISE)

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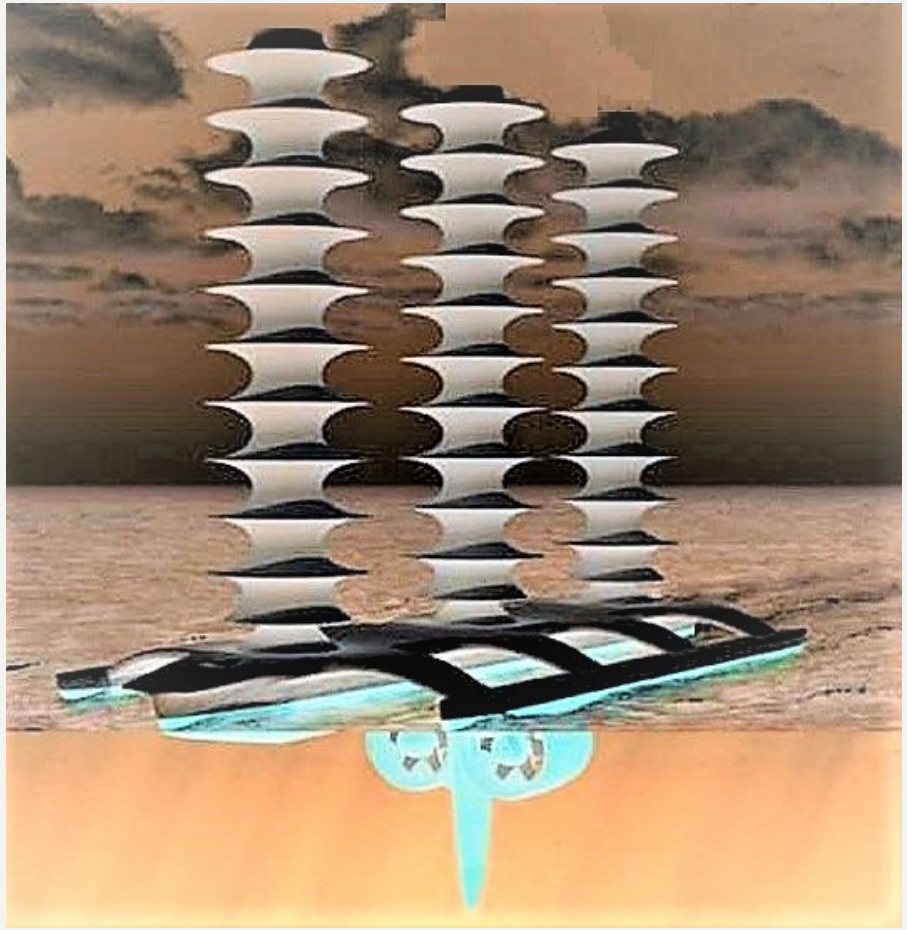
MOTIVATION

- Expanded exploration of Titan is desirable to research:
  - Potential for formation of biological organisms
  - Earth-like hydrological cycle using Methane
  - Surface features resembling rivers and lakes
- However, Titan is a harsh world
  - Surface temperature of ~94°K (-180°C) and surface pressure 1.5x of Earth places the air near the triple point of methane
  - Distance from Sun and thick, hazy atmosphere combine to provide very little sunlight at the surface;
  - Batteries are inefficient because they require heaters to function and thus drain the power storage
  - Any mission to this great distance from the sun requires significant time and funding investment
- To maximize the time and expense of sending a robotic vehicle to Titan an architecture must be developed to enable long duration, robust exploration of the solid and liquid surfaces

CETWISE ASSUMPTIONS

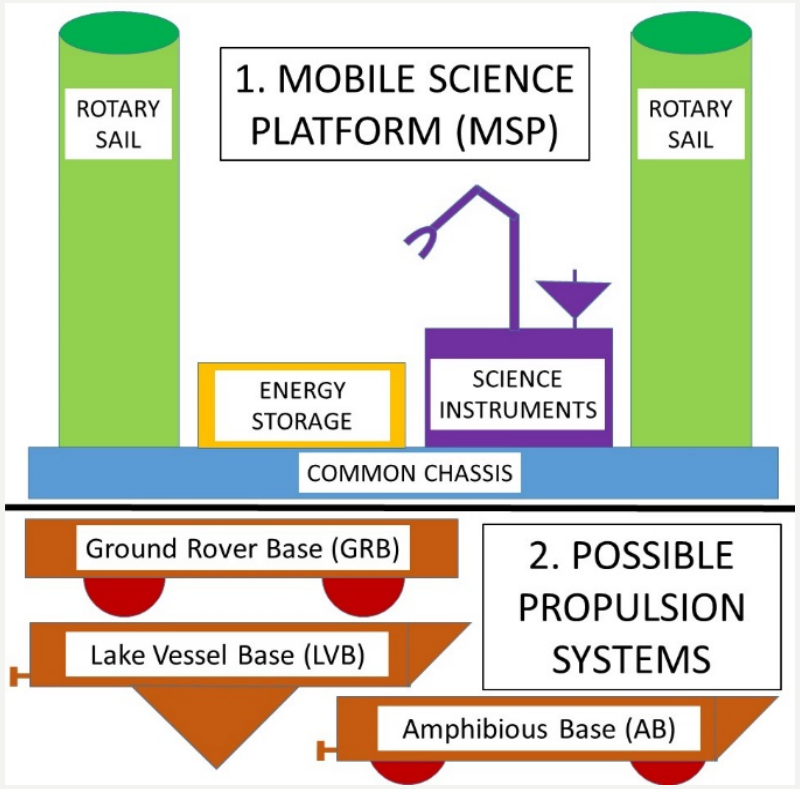
- "Going Green on an Orange Moon": CETIWISE proposes the use of renewable energy from Surface Wind
- Based on two assumptions:
  - Thermo-nuclear power sources may not be available (long development cycle and high expense):
    - Fission waste heat causes sublimation/evaporation of methane resulting in a persistent, thick fog around any surface (land or sea).
    - Submarine vehicles with nuclear power create hull heating that boils the fluid, reducing buoyancy.
  - Surface winds on Titan are persistent and predictable based upon Global Circulation Models. Winds could be localized (based on surface topography) and seasonal (summer/winter)

BASED UPON TERRESTRIAL TECHNOLOGY



CETWISE CONCEPT

- CETWISE employs an exploration architecture composed of
  - Mobile Science Platform (MSP) including wind power generator
  - Mobile base options including Ground Rover Base (GRB) or Lake Vessel Base (LVB) or Amphibious Base (AB)
- Novel and exciting technologies for exploring Titan, include:
  - Energy capture from the atmospheric winds (rotary sails and direct drive electrical generator using superconductive materials)
  - Electrical energy storage using superconductive coils at cryogenic Titan surface temperature
  - Biology instruments to detect possible microbial life in liquid hydrocarbons, lakebed sediments or lakeshore regolith
  - Scientific instruments to measure liquid hydrocarbon lake profiles, meteorology, and subsurface geological structures

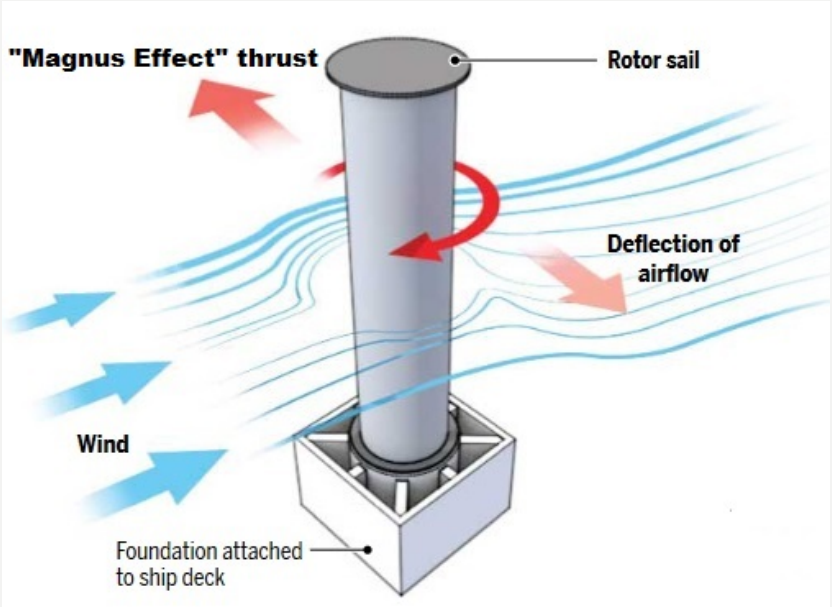


MISSION ARCHITECTURE

- Combined Lander and Titan Orbiter launched on Space Launch System (SLS)
  - Similar in architecture to Cassini-Huygens
  - Key difference: Orbiter is placed in an orbit around Titan
- Titan Orbiter provides communications relay and mapping functions
  - Minimal capability to minimize power requirements
  - Solar powered, similar to Juno spacecraft to Jupiter (adding an additional array)
- Lander vehicle separates and enters Titan's atmosphere
  - Descent performed using ablative heat shield and parachutes modeled after Huygens
  - Heat shield is released
  - Landing performed directly on wheels/tracks for rover or directly into methane sea for water craft
- Lander deploys antenna and makes contact with the orbiter
- Begin long mission to explore the surface for signs of biological life and geological or sea properties

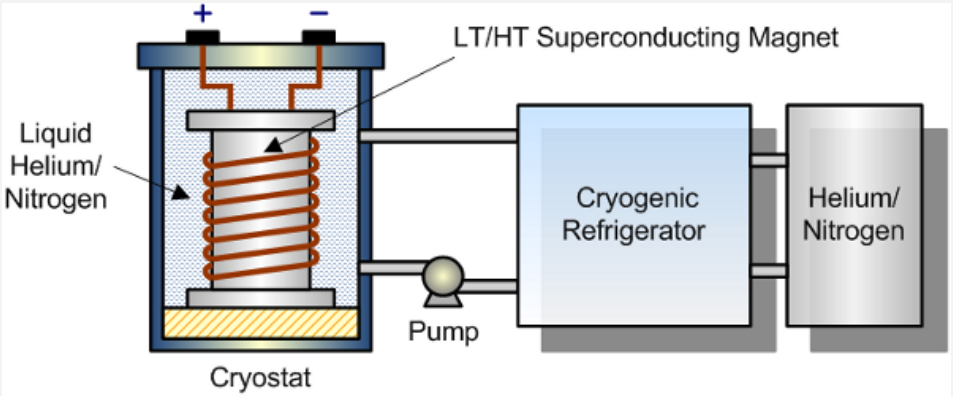
SURFACE WIND ENERGY CAPTURE

- General Circulation Models (GCM) of the near surface environment suggest wind speeds of 0.4 – 0.7 m/s
  - Long seasons
  - Diurnal Heating
  - Infrequent Storms
- While not a fast wind, it can be enough for power generation
  - The higher density air (4.5x Earth) has greater momentum
  - Lower gravity (0.14g) provides for less rotational friction
- Rotary sails mounted on a Mobile Science Platform (MSP)
  - Captures wind energy from any direction to generate electricity
  - Creates a "Magnus Effect" thrust
  - Based on terrestrial "Flettner Rotors"



CRYOGENIC ELECTRICAL ENERGY STORAGE

- Electrical energy can be stored in a chemical form in:
  - Batteries (require heaters for cryogenic temperatures),
  - Electrical Field such as a capacitor.
  - Superconducting Magnetic Energy Storage (SMES)
- Recent advances in materials have identified "high temperature" superconducting ceramic oxides with a T_c at 127°K.
  - On the Titan surface at 94°K, superconducting wires in a coil configuration could support a persistent current thus storing energy in the resultant magnetic field.
  - Titan cryogenic fluids are readily available
  - This technique has been demonstrated at colder temperatures and will be investigated with new "high temperature" superconducting wire types for the Titan surface.



BIOLOGICAL SURFACE INSTRUMENT

- The MSP includes
  - a spectrometer atop the rotary sails to search for color changes in the nearby surface as an indicator of possible microbial life (similar to chlorophyll mapping of oceans from Earth orbit)
  - The robotic arm to capture liquid or solid samples for analysis
  - An instrument, based on the ISS mini-DNA sequencer used on the International Space Station, to identify potential marker for identification of life on Titan.
  - The MSP also includes camera equipment and meteorology instruments for navigation and measurements of atmospheric temperature, pressure, humidity, winds and precipitation.
- The LVB and AB option includes
  - Sensors for Bathymetry measurements, waves and currents, liquid chemical and physical profiles at depth
  - A sediment grabber to capture samples from the lake floor for biological analysis.
- The GRB and AB option includes
  - Deployable geological instruments to measure surface and subsurface structures with seismometers and a magnetometer.

SUMMARY

- Viable mission architecture, and optimized system for expected Titan environment can enable long surface missions to Titan
- Titan Orbiter
  - Solar power generation
  - Communications relay satellite in orbit around Titan, with a versatile, sensor equipped lander on the surface
  - Instrument design for science and navigation based upon power budget
- Lander is optimized for the environment to provide long duration operations
  - Innovative wind energy capture for power generation
  - Energy storage using *insitu* cryogenic temperatures for superconductive materials
- Lander craft can be configured for land and/or sea landing with a common Mobile Science Platform
  - Detection of biological life signatures
  - Meteorology, Geology and Oceanography tailored sensor options

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