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”: CETWISE 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”
• 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
ABSTRACT REFERENCES