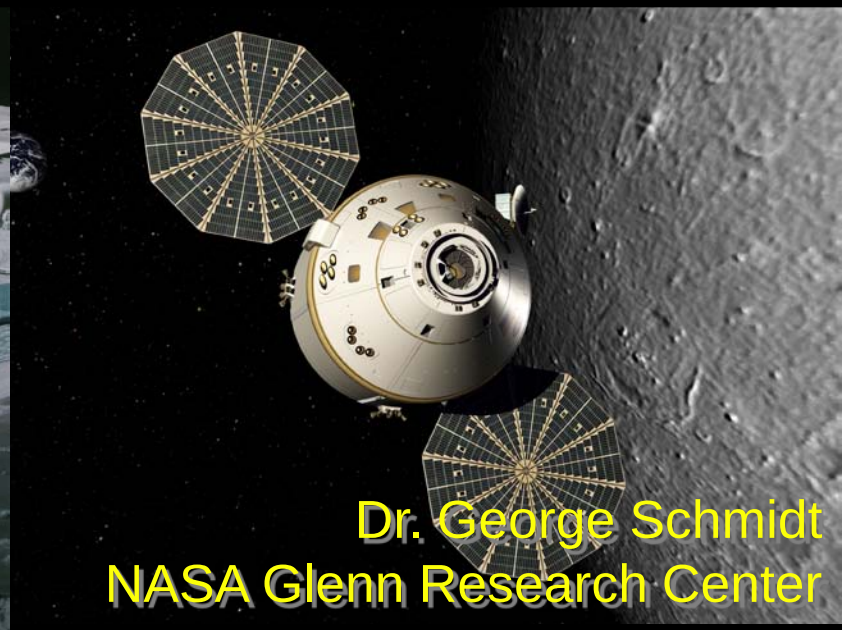
National Aeronautics and Space Administration

# Energy at NASA: Past, Present and Future



Dr. George Schmidt
NASA Glenn Research Center

www.nasa.gov

National Aeronautics and Space Administration

# Outline

- **Energy and Power for NASA's Missions**
- **NASA Glenn's Legacy in Alternative and Renewable Energy**
- **Current Activities in Alternative and Renewable Energy**

# Importance of Energy and Power to NASA Missions

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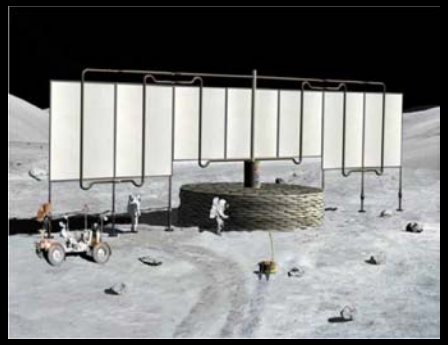
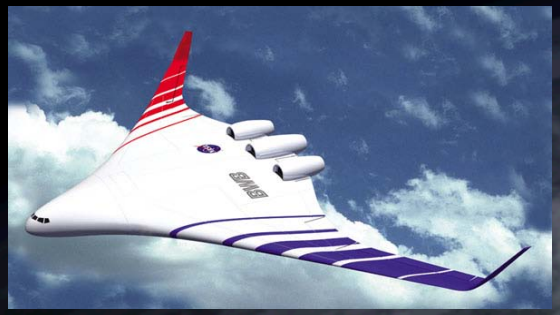
## Science

- *Robotic missions to planets, moons and destinations within solar system*
- *Spacecraft for observation of the Earth, Sun and Universe*



## Human Exploration

- *Crewed transportation to Space Station, Moon and Mars*
- *Operations on Moon and Mars surface*



## Aeronautics

*Improved technologies for future subsonic, supersonic, hypersonic and rotary wing aircraft*

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# Solar Photovoltaics

*Energy from the Sun for Long Duration Missions*

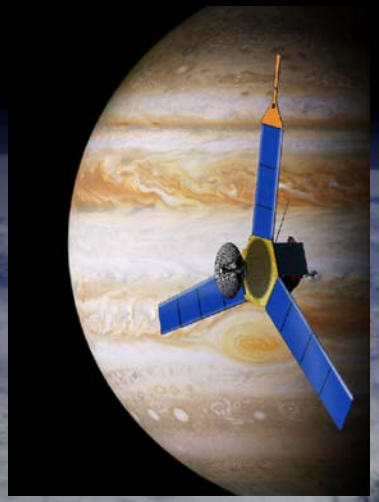
## PRESENT & FUTURE

## PAST

**Vanguard 1**
First solar-powered satellite
(launched in 1958)

**International Space Station**

**Mars Exploration Rovers**



**JUNO Mission to Jupiter**

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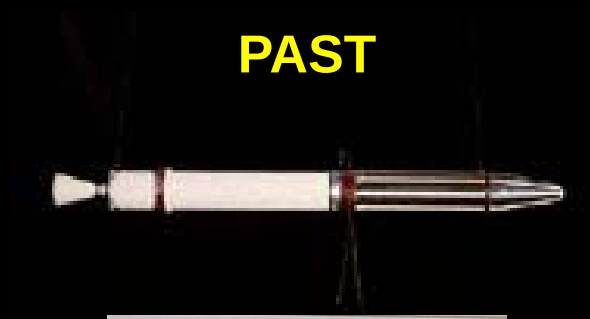
# Batteries

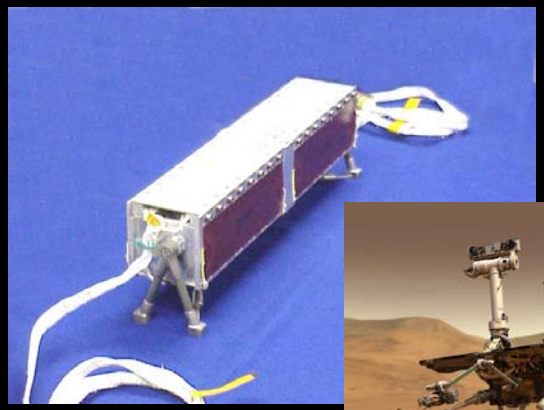
*Reliable and Cyclic Energy Storage*

## PAST



**Explorer 1**
First U.S. Satellite (1958) used Mercury primary battery for low power transmitter

## PRESENT & FUTURE



**Mars Exploration Rovers**
Rechargable Li-Ion Secondary Battery

**Desert Research and Technology Studies (RATS) Demonstration Battery**

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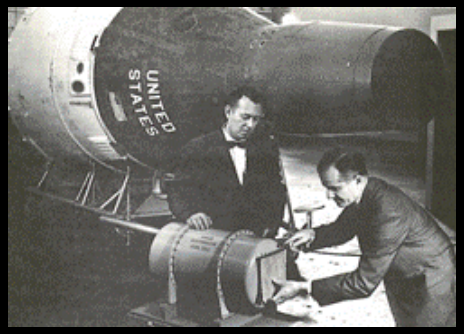
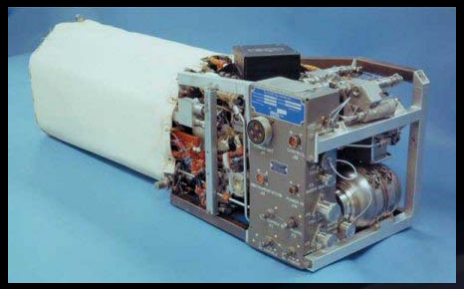
# Fuel Cells

*High Power for Crewed Missions*

## PAST & PRESENT



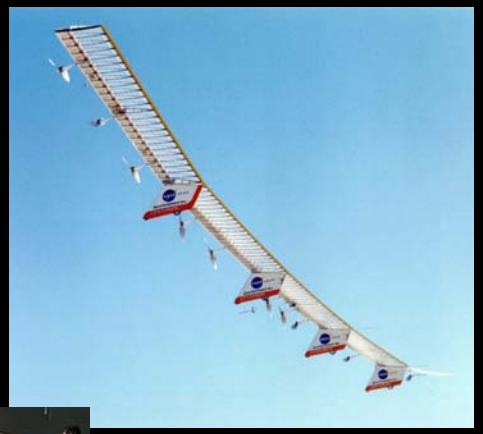

Gemini Fuel Cell (1961)



Shuttle Orbiter Fuel Cell (≥1981)

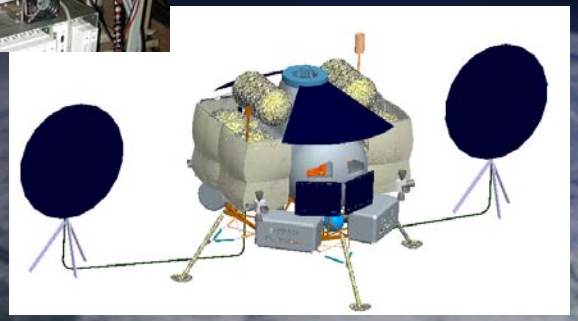
## FUTURE

**ERAST Helios Prototype** (2001)



Teledyne Upgraded Multi-kW Breadboard

Regenerative fuel cell power system for near-term lunar missions (>2020)



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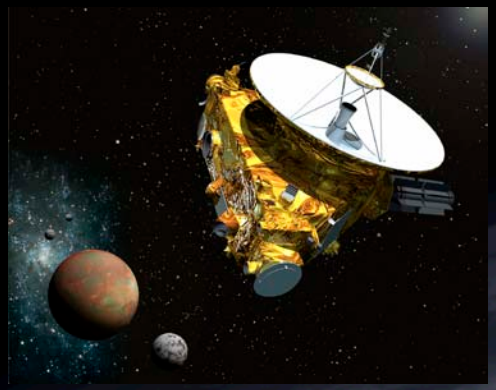
# Radioisotope Power Systems

*Long-lived Power Independent of Sun*

## PAST & PRESENT

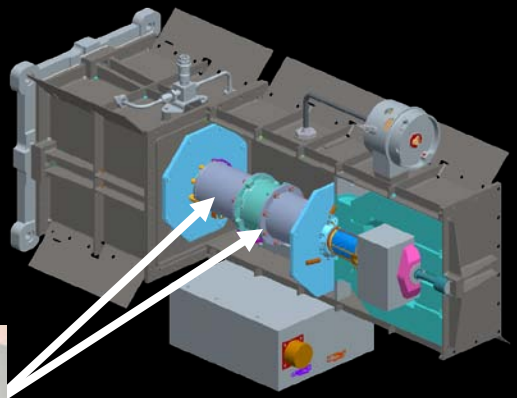
**SNAP-3 Demo Unit**
Polonium-powered RTG meets the President (1959)



**New Horizons Mission to Pluto** (2006)

## FUTURE

**Advanced Stirling Radioisotope Generator (ASRG)**



Stirling Convertor developed by Sunpower Technologies

**Titan Orbiter Flagship Mission** (~2018)

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# Fission Surface Power

*Robust, Long-lived Power for Crew Habitation*

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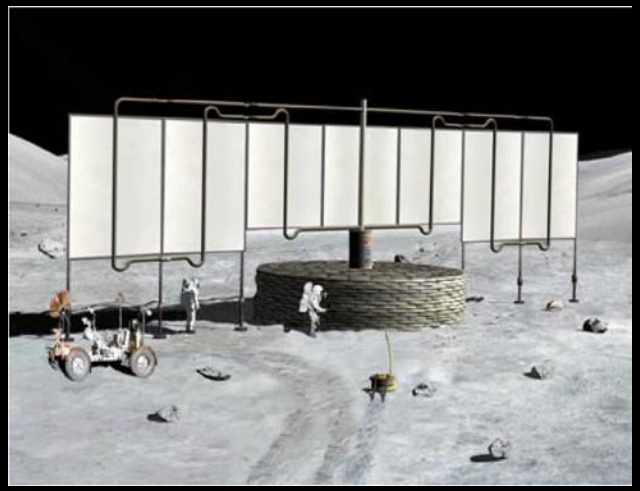
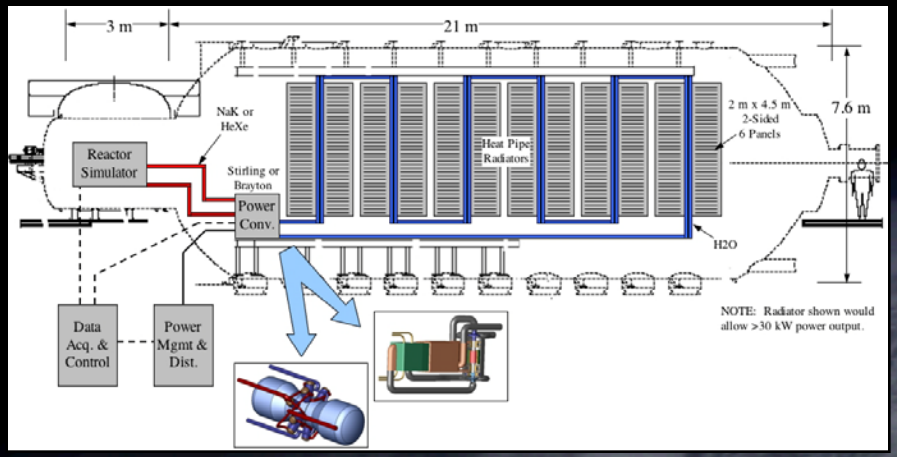


50-kilowatt nuclear power system for lunar surface operations

2-kilowatt Brayton converter subsystem




Planned non-nuclear integrated system test using simulated reactor in GRC Tank 6 facility

3-kilowatt Stirling converter subsystem

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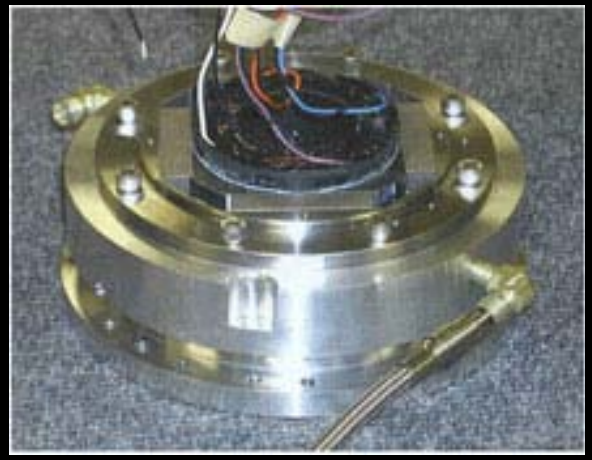
# Flywheels

*Efficient, High Specific Power Energy Storage*



- High energy density storage
- High speed motor/generator
- Magnetic bearings
- Integrated energy storage and attitude control
- Motor/inverter controls

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# Green Automotive Systems

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Nickel zinc batteries for electric vehicles

Stirling auto engine (1986)

- **1970: NASA Lewis establishes the Automotive Systems Office funded by the EPA**
- **Initial focus is to develop gas-turbines as cleaner-burning automobile engines**
- **Later Stirling engine and electric-powered cars were developed and demonstrated**

Electric EVA Pacer

# Wind Turbine Technology

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**Mod-0**
100 kW Experimental Wind Turbine in Sandusky, Ohio

**Mod-0A**
200 kW wind turbine in Puerto Rico, and 3 more in R.I., N.M. and Hawaii

**Mod-1**
2.0 MW wind turbine in North Carolina pioneered urban use

**Mod-2**
Clusters of 2.5 MW wind turbines in the states of Washington and California

**Mod-5B**
3.2 MW (100 m diameter – largest in world) wind turbines on the island of Oahu, Hawaii

# Terrestrial Applications of Photovoltaics

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Schuchuli, Arizona, USA, 1978

Tangaye, Upper Volta, Africa, April 1979

Tunisia (Northern Africa), July 1983

Indonesian photovoltaic satellite Earth system, Wawatobi, Sulawesi, Indonesia, May 1985

# Stirling Cycle-based Power Systems

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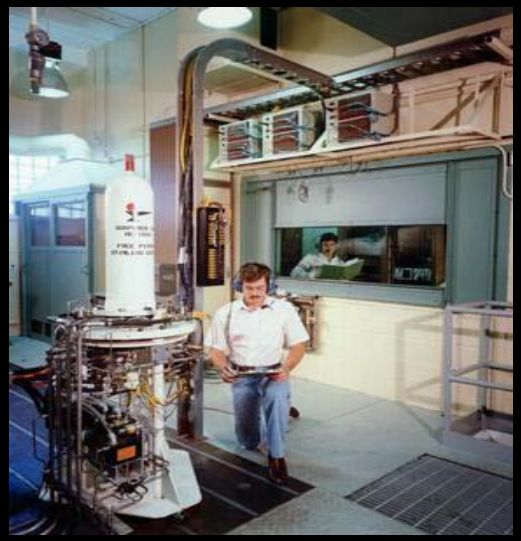
Space Administration



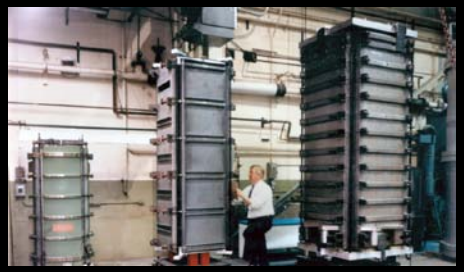
Free piston Stirling test cell

1979: Solar Stirling power system

2007: GRC advises Stirling Engine Systems on a 5 MW Stirling utility project in Southern California.

# Fuel Cell Systems

National Aeronautics and Space Administration



Fuel Cell Stacks

Gas Reformers

Power Management

**Commercial Installations of PC25 Phosphoric Acid Fuel Cell Systems**

Bank in Omaha, NE

Verizon Telecommunications

Police Station, Central Park, NY

Sewage Treatment Facility

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# Outline

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# Alternative Coal and Bio-derived Fuels for Aviation

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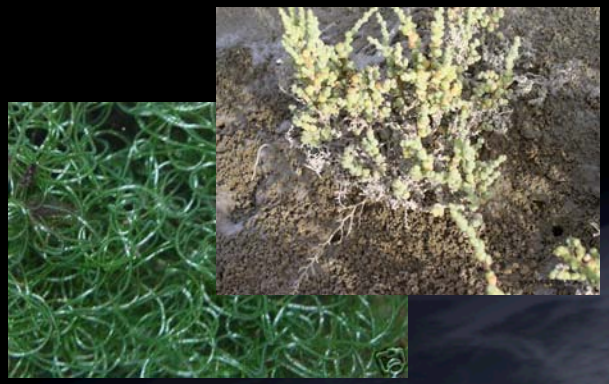
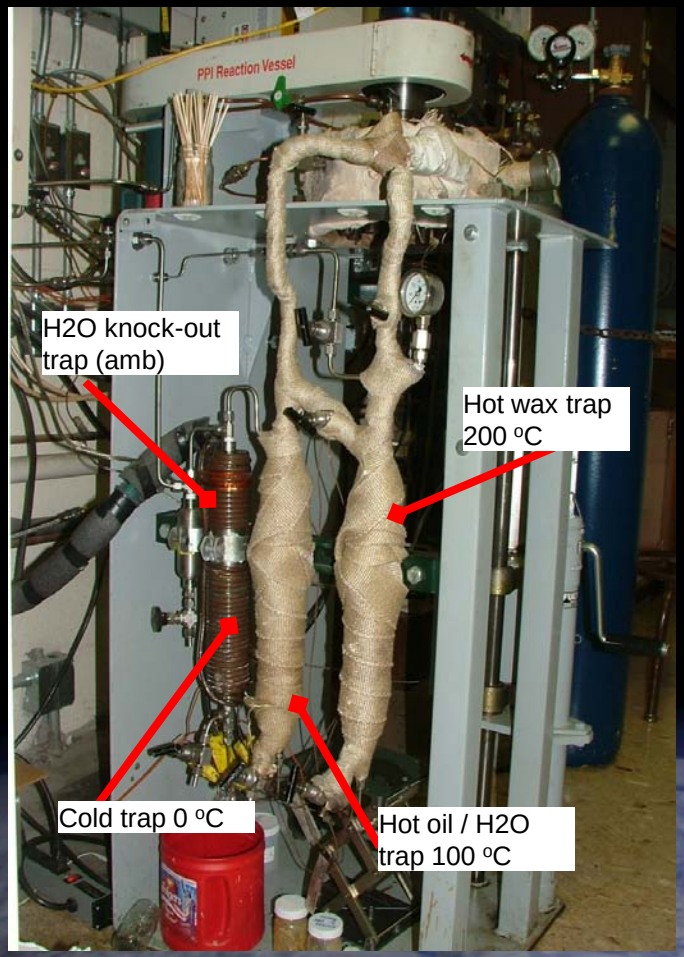
Greenhouse for research of bio-material production techniques



Example biofuel stock – saltwater algae and seed plants that grow in salt-rich habitats (Halophytes)




Fischer-Tropsch Reactor trap at GRC Alternative Fuels Lab

# Prototype 2-kW PV System at NASA Glenn

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- System recently installed at GRC to provide facility power
  - Connected directly to utility distribution grid
  - Facility power can be obtained from the utility system as normal
  - PV system is synchronized with the utility system
  - PV system provides power for the facility, and excess power is provided to the utility system
  - The system has generated in excess of 3,000 kWh since its activation in July, 2006

- Provides approximately 10 watts of AC power per square foot of area

System at GRC's West Area

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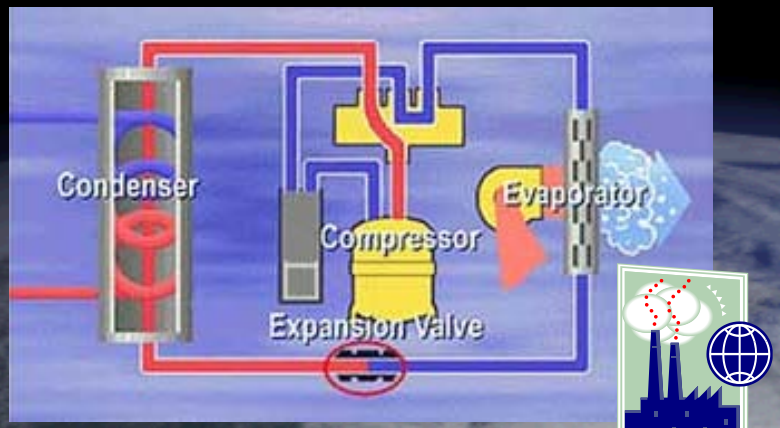
Space Administration

# Solar Powered Ground Source Heat Pumps

- A coupled solar power and advanced ground source heat pump system will be incorporated in 5 center buildings beginning in 2008
- Nearly 3/4 of CO2 emissions and energy use in cities comes from commercial buildings
- Effort complements NASA mission goal of reducing energy requirements for surface exploration of the planets
- ***Partnerships with industry, academia and government are sought for system deployment***

Subsurface heat exchanger coils




Heat pump system schematic

# Hydrogen Fuel Cell Vehicles and Fueling Stations

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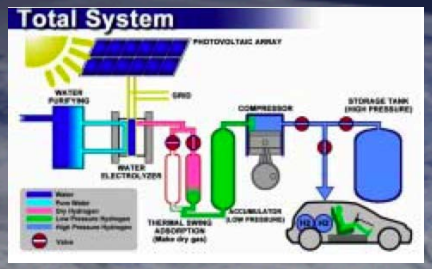
Potential fuel cell-powered bus rapid transit vehicle in Cleveland, OH

Honda's solar-powered H2 production, storage and fueling station in Torrance, CA

System schematic of solar-powered H2 production and fueling facility

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# Advanced Wind Turbine Concepts and Technologies

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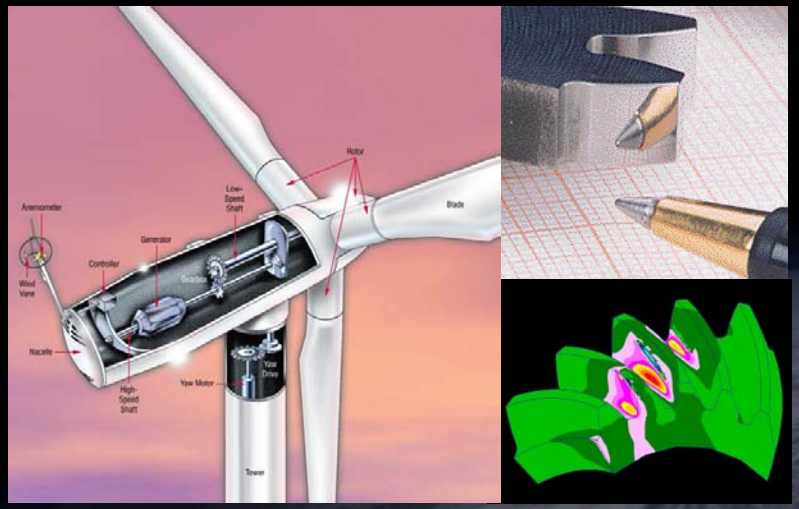
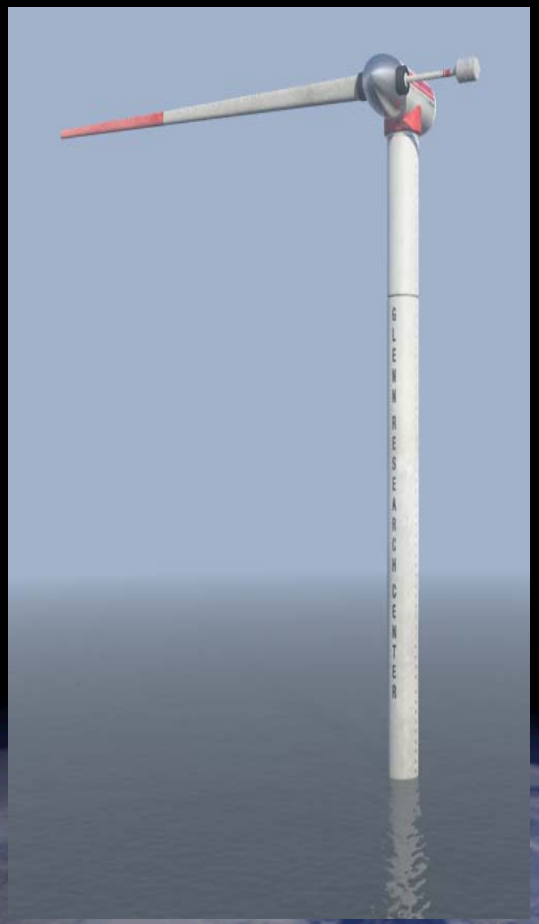
- Revolutionary aerodynamic and system configurations to improve performance, reliability, and ease of remote assembly
- Renewable energy is key to addressing climate change. Significant market growth expected world-wide in off-shore systems.
- ***Partnerships with industry & academia are sought for commercialization.***




Advanced, high-reliability gearbox components utilizing aerospace-developed transmission technologies

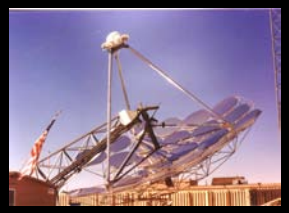



Offshore, single-blade wind turbine concept

# Where NASA Can Make a Difference

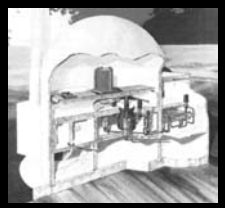
## NASA-led Activities and Major Support Areas

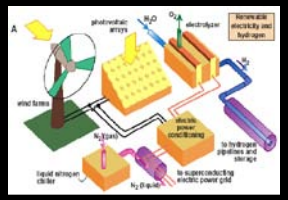
Solar Photovoltaic & Solar Thermal Systems



Biofuels & Biomass

Green Aviation


Nuclear Subsystems


Energy Storage & Distribution

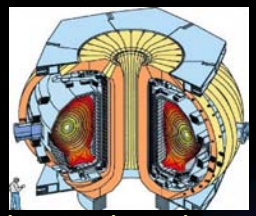
Wind

Hydrogen Utilization

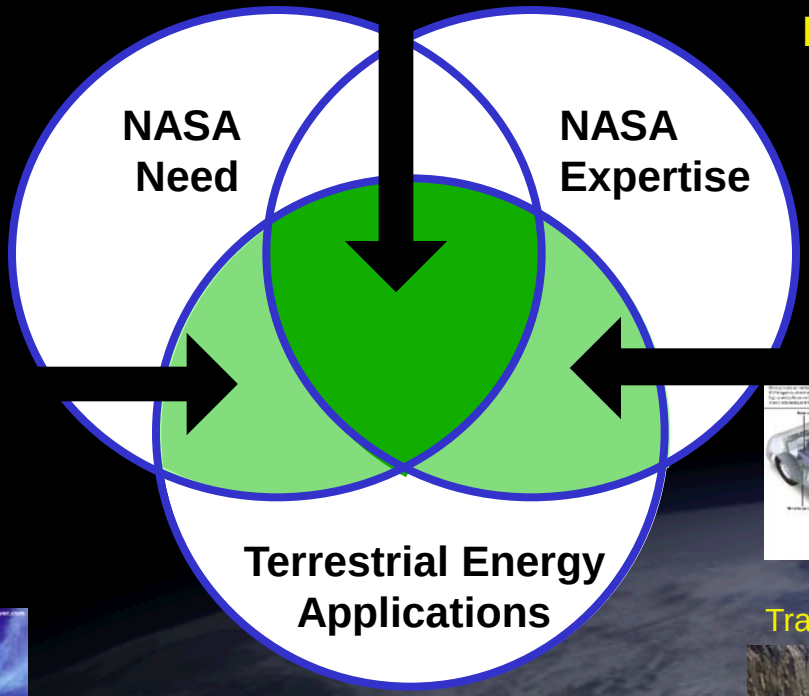
## NASA Leadership, Support or Monitoring

Space Solar Power

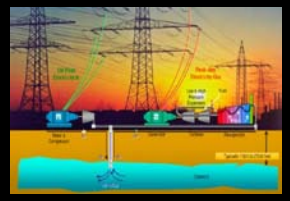
Supergrids


Advanced Nuclear & Energetics

High Altitude Wind




## NASA Support of Projects Led by DOE and Others


Carbon Mitigation

Green Transportation

Geothermal

Efficiency & Co-Generation

Wave, Tidal & Ocean

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# Summary

- NASA's technology expertise is well-matched to the needs of the energy industry.
- The nation would benefit from using all its resources – organizations, experts, facilities, multiple energy technologies - to solve our energy problems.
- NASA missions require advanced energy solutions, which will produce "spin-offs" for terrestrial applications.
- NASA looks for partners in all its endeavors, in order to leverage resources and capitalize on specialties in diverse organizations.