NASA Perspectives on the Importance of Reform in Electric Energy Systems Education

Reforming Electric Energy Systems Curriculum With Emphasis on Renewable/Storage, Smart Delivery, and Efficient End-Use

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Agenda

- The Changing Face Of NASA
- Exploration and Return to the Moon
- Lunar Base Power Systems
- ISS Power Systems
- Applications to Terrestrial Power
- Education Implications
- Summary

The Changing Face of NASA

Space Shuttle

Soyuz / Commercialization

ISS Build-up

ISS Complete

Constellation

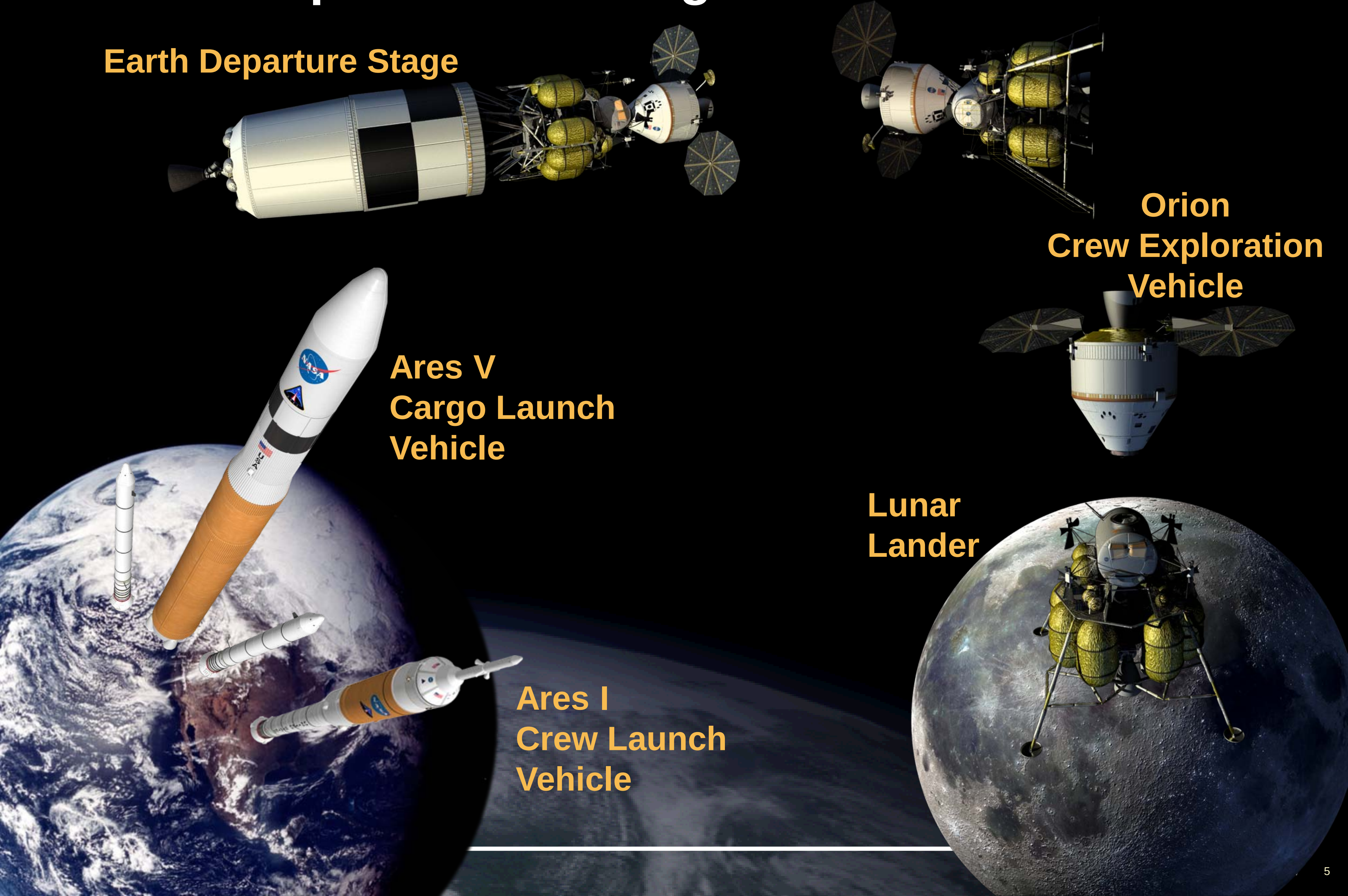
?

- Technology
- STEM
- Energy

The Moon
The Next Step in Human Exploration

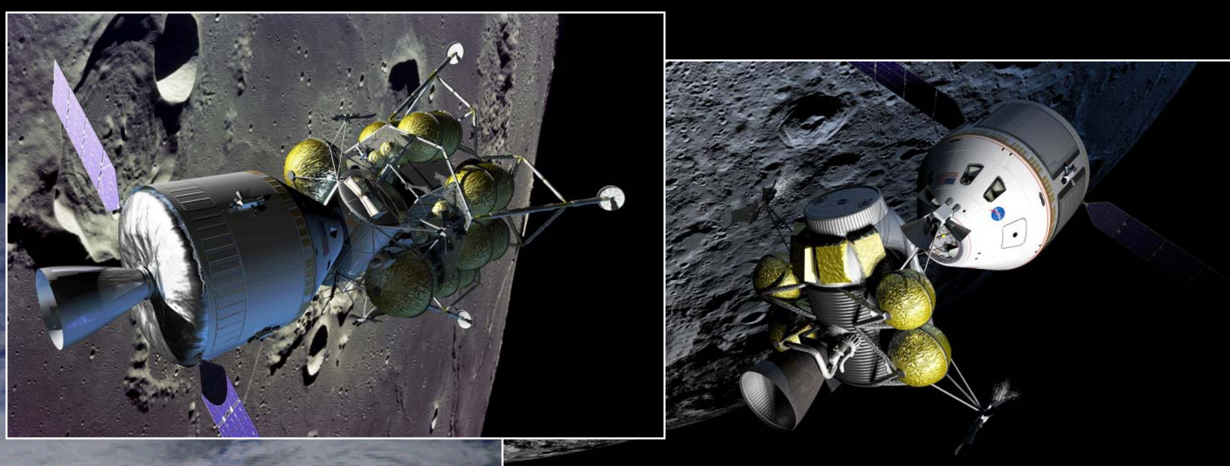
- **Gaining significant experience in operating away from Earth's environment**
  - Space will no longer be a destination visited briefly and tentatively
  - "Living off the land"
  - Human support systems
- **Developing technologies needed for opening the space frontier**
  - Heavy lift launch vehicle
  - Earth ascent/entry system – Crew Exploration Vehicle
  - Advanced Lunar / Mars surface power systems
- **Conduct fundamental science**
  - Astronomy, physics, astrobiology, historical geology, exobiology

Components of Program Constellation



Orion and LSAM Lunar Mission

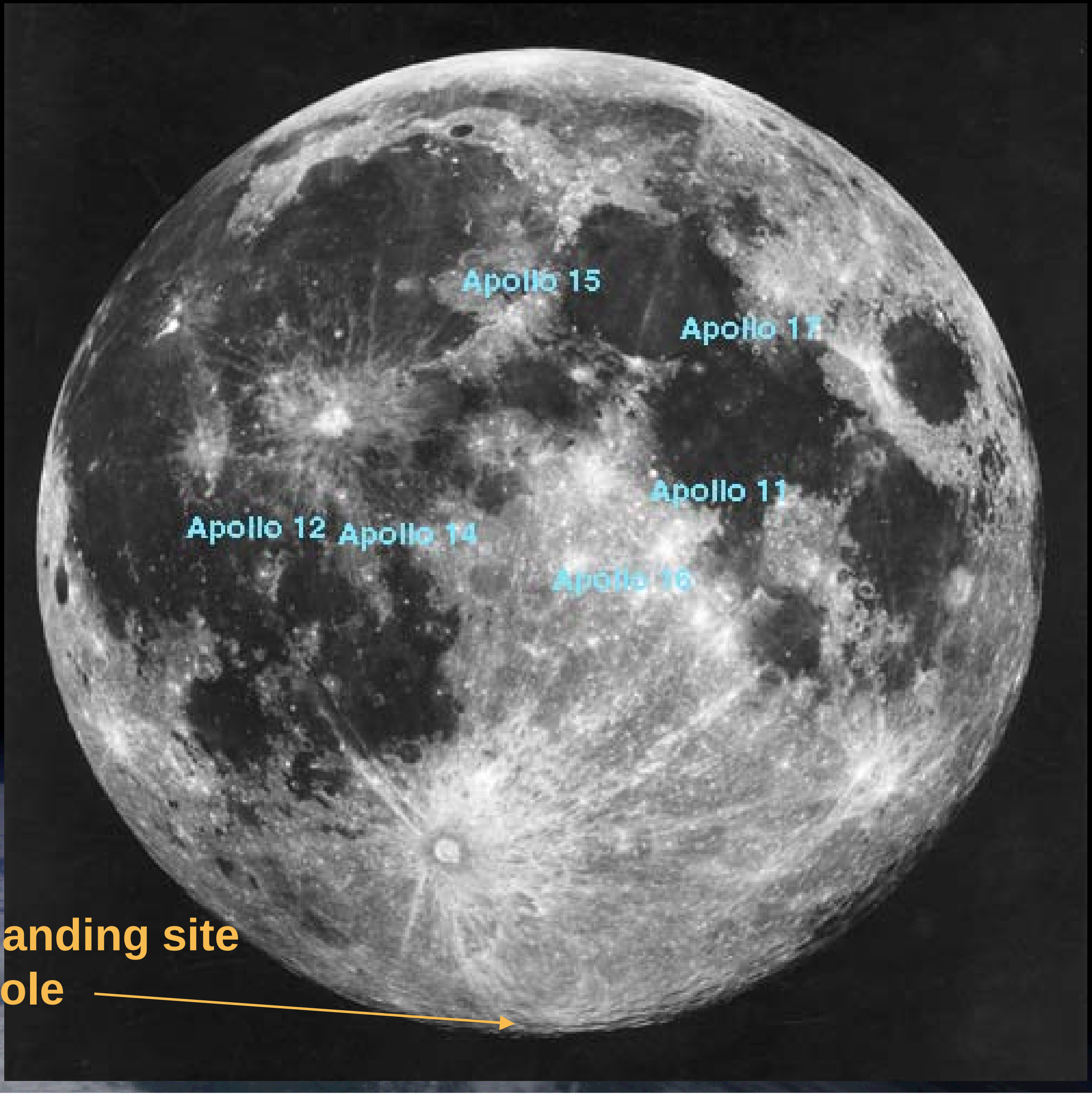
Orion mates with pre-launched Earth Departure Stage (EDS) and is boosted to lunar trajectory



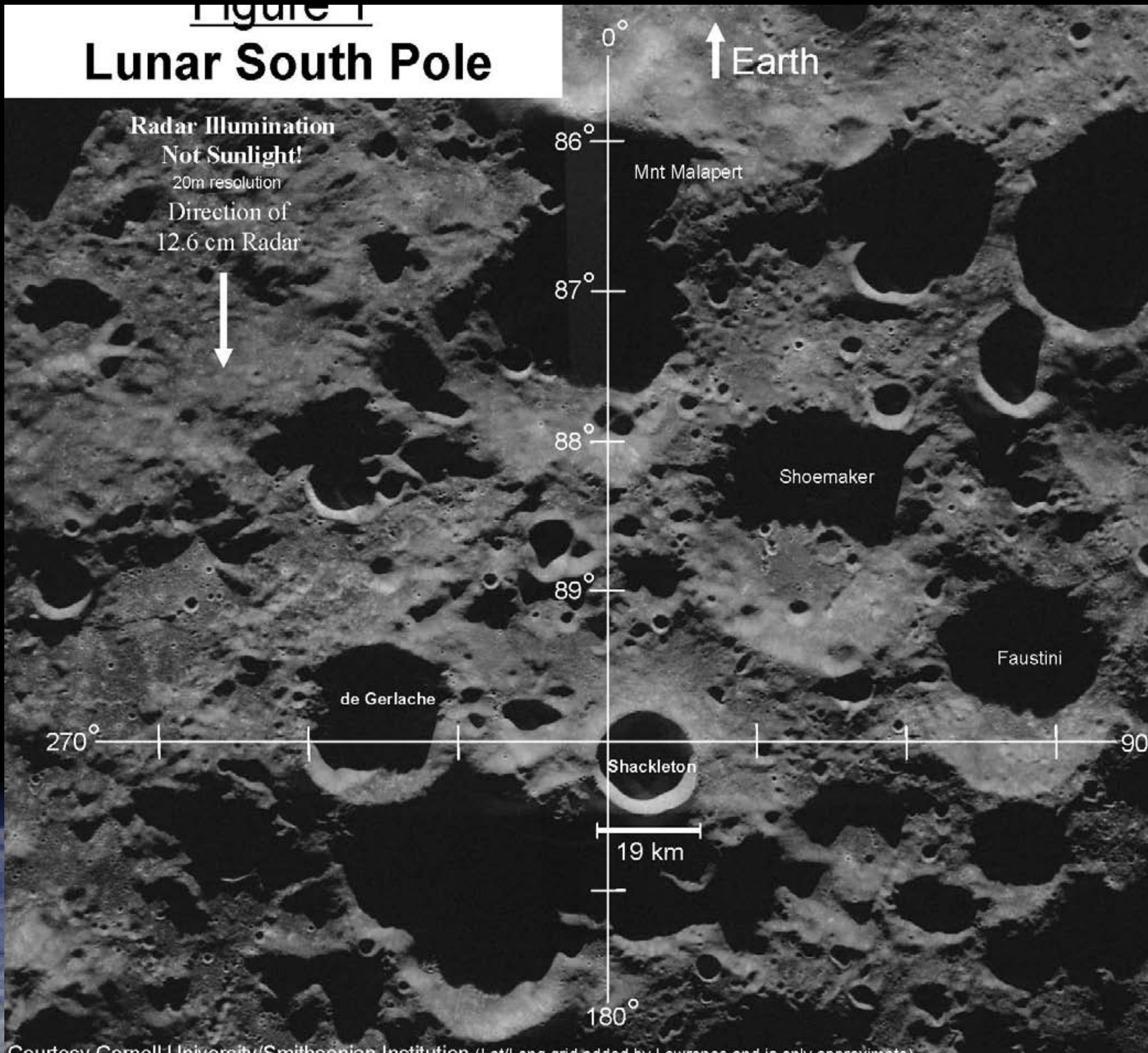
Orion and LSAM enter lunar orbit

LSAM ascent stage returns to Orion in lunar orbit

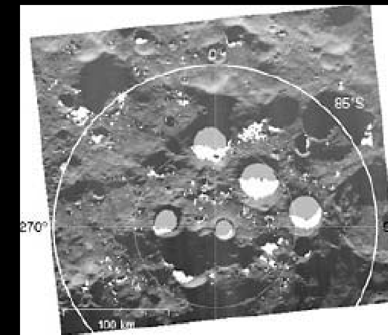
Lunar Landing Sites

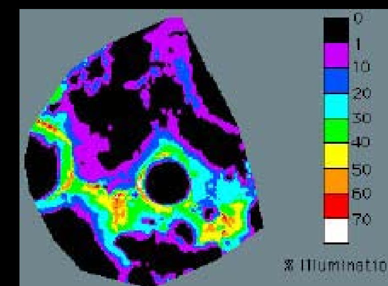


Constellation landing site
Lunar South Pole



Cold Trap Areas (In white)





AMIE (Visual) ESA/Space-X

NASA Lunar Architecture & Power Systems

Human Landers and Surface Rovers

Human Lunar Access
Short-term Habitation
Human Exploration
Outpost Development
Surface Mobility

Power Systems

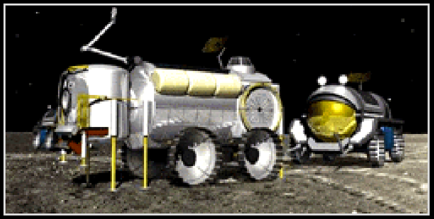
Re-gen fuel cells
Photovoltaic
Battery energy storage

Challenges

- High energy density
- Portable energy storage
- Rechargeable systems
- Thermal & dust environment

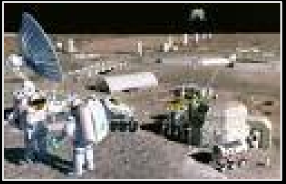
Lunar Outposts and Resource Processing

Long-term Habitation
Large Surface Power Gen.
Oxygen/Water Processing
Materials Processing
Fuels Processing



Power Systems

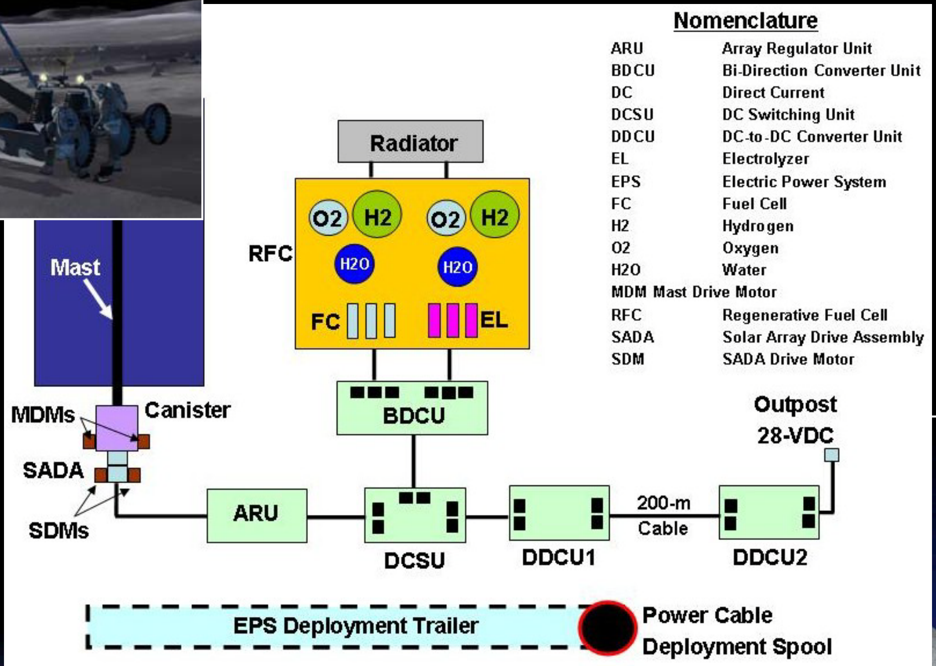
Fission Generator
Large Array Farms
Re-gen Fuel Cells
Flywheels

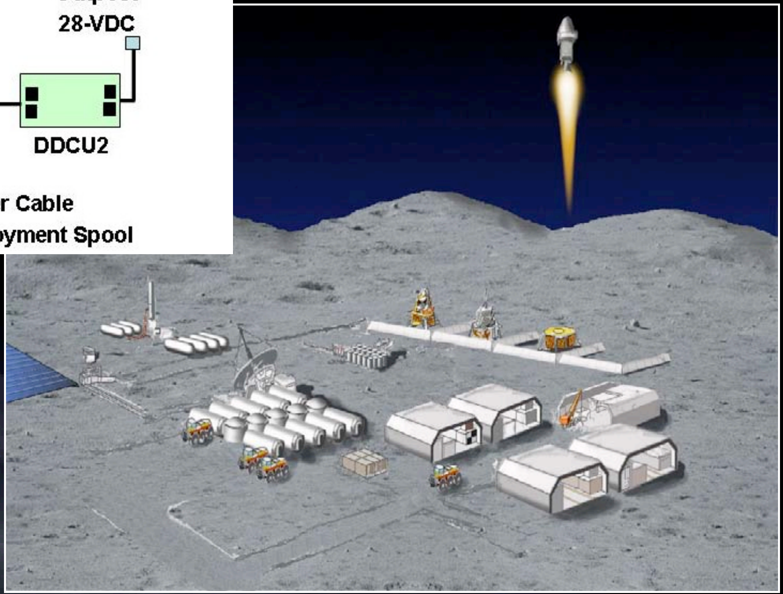


Challenges

- Incremental build-up
- Long term untended operation
- Diverse power sources
- Large distributed energy storage

Surface Power System Evolution



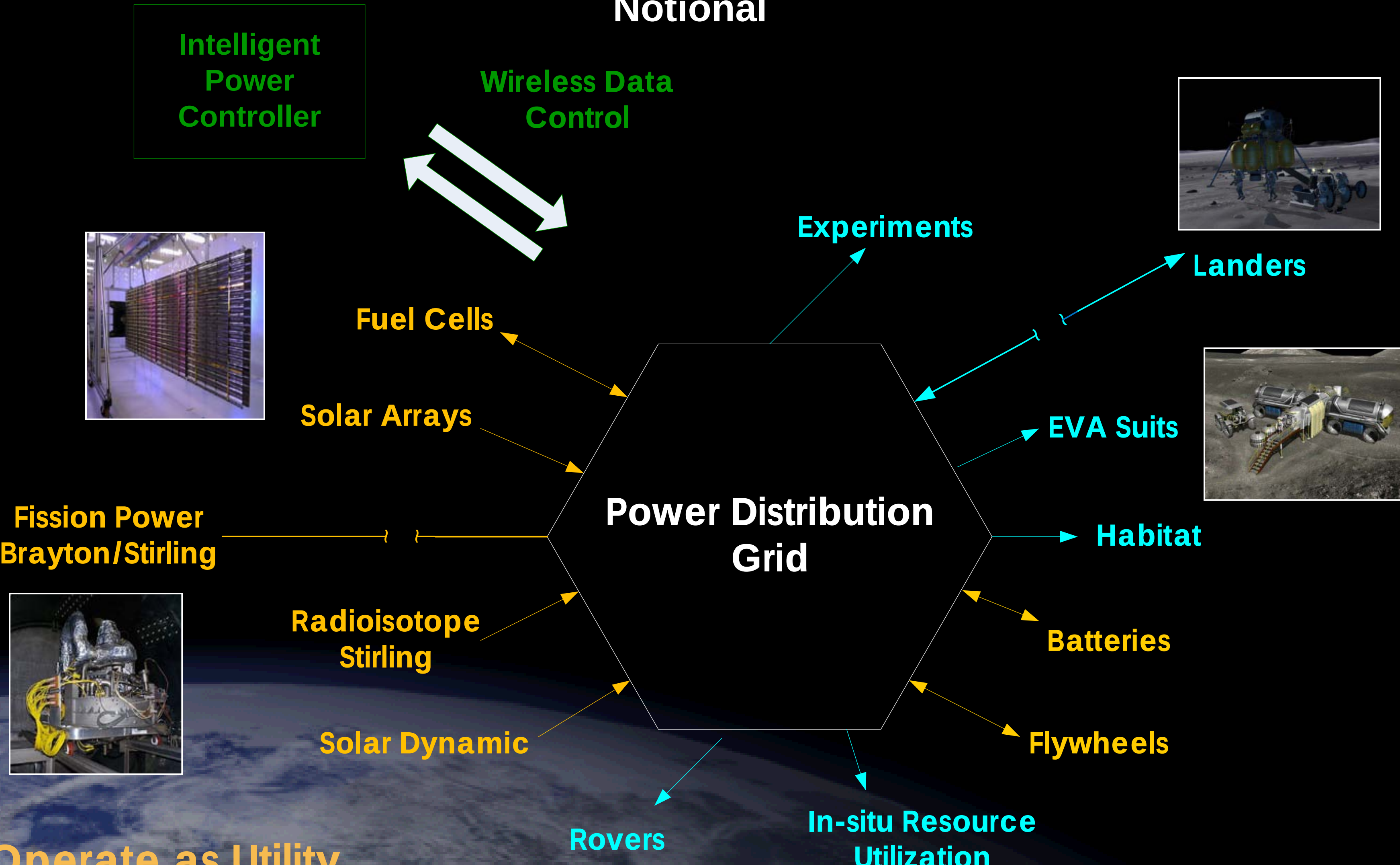


Challenge

- Provide seamless evolution from a lander, rover and power cart to a lunar base with an operating power utility.

Utility Based Surface Power System

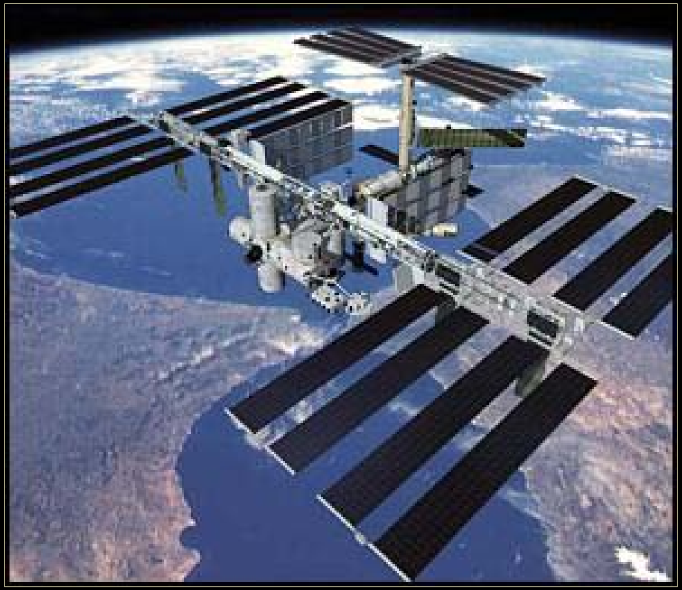
Notional



Operate as Utility

ISS Power Systems

International Space Station



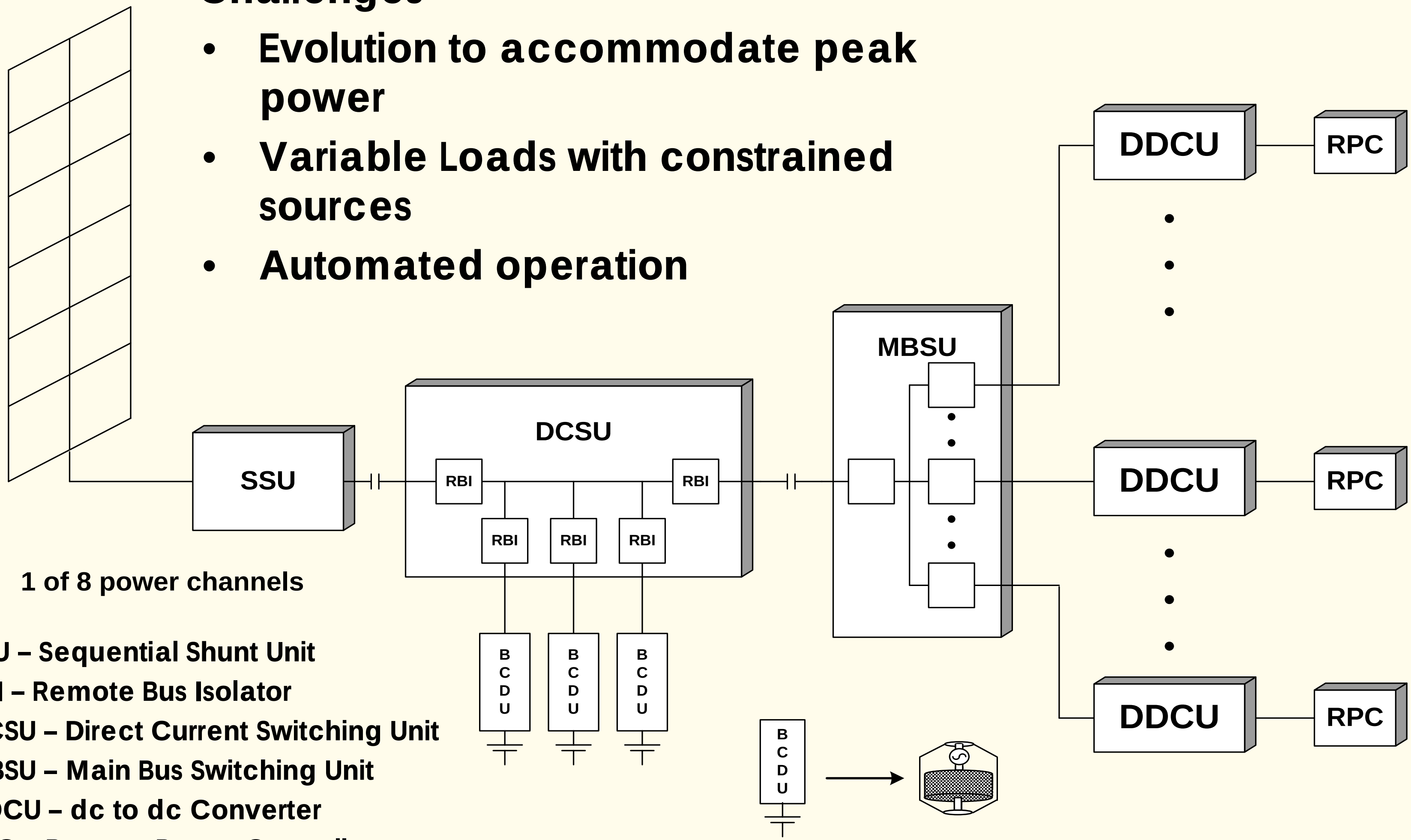
Power System Characteristics

- Power 75 kW average
- Eight power channels
  - Planar silicon arrays
  - NiH battery storage
- Distribution
  - 116 - 170 V primary
  - 120 V secondary
- Contingency power > 1 orbit
- System lifetime of 15+ years

ISS Power Architecture

Challenges

- Evolution to accommodate peak power
- Variable Loads with constrained sources
- Automated operation



SSU – Sequential Shunt Unit
RBI – Remote Bus Isolator
DCSU – Direct Current Switching Unit
MBSU – Main Bus Switching Unit
DDCU – dc to dc Converter
RPC – Remote Power Controller

NASA Space System Power Needs

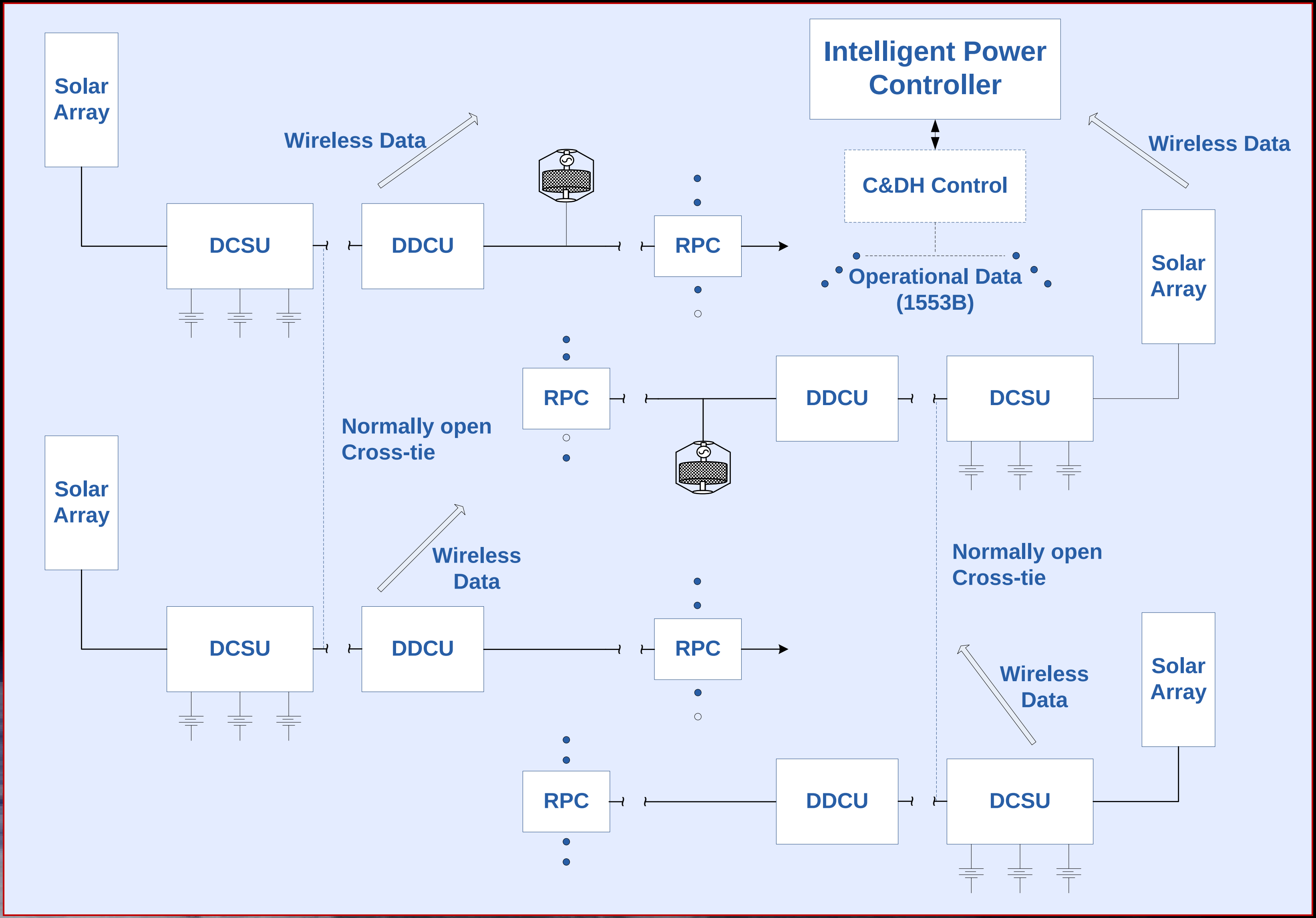
Planetary Surface Power

- Accommodate diverse power sources & loads.
- Long Term operation with minimal human intervention
  - Automated Failure detection and Correction
  - Variable load demand under constrained generating capacity
- Permit incremental build-up and seamless growth.
- Simple straightforward interfacing strategy
- Support large amount of distributed energy storage.

Advanced ISS Power

- Accommodate diverse power sources and loads
- Minimize operator interactions of the long term.
  - Automated Failure detection and Correction
  - Variable load demand under constrained generating capacity
- Accommodate peak load demands
- Support large amounts of distributed energy storage

Advanced ISS Power Architecture



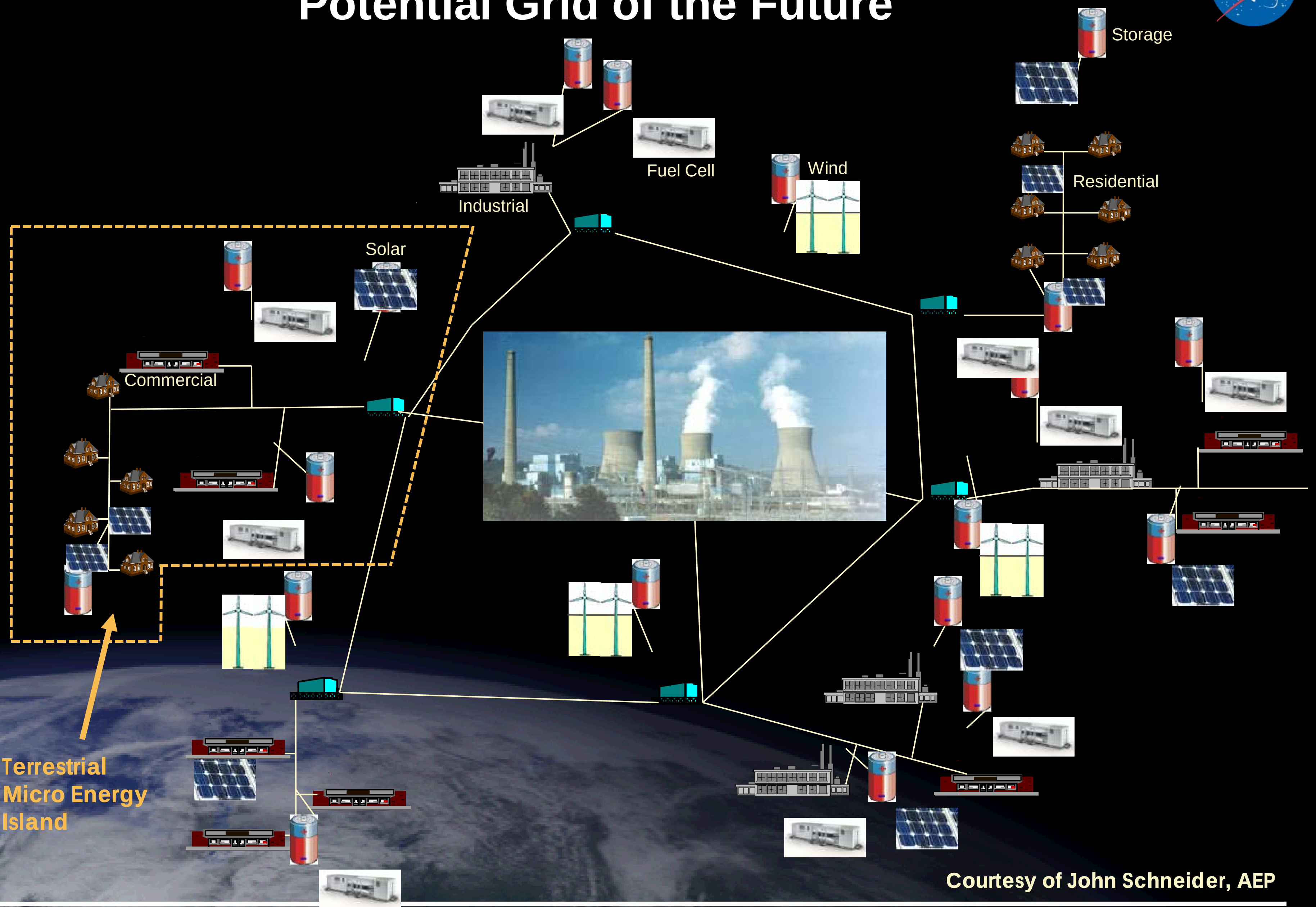
So Why Is This Important For Terrestrial Systems?

Intelligent Power Rationale

- **NASA Future Needs**
  - Humans living for long periods of time in space away from earth, or for long periods with intention of extended settlement need reliable renewable power systems that can manage themselves
- **Terrestrial Needs**
  - Terrestrial power grid(s) need upgrading to accommodate a diverse set of renewable sources, address increased security requirements, facilitate networking of control centers, improve operator effectiveness, and permit the users to intelligently make decisions regarding power usage
- **Both space and terrestrial power share many of the same future goals, needs**

Common technologies and demonstrations can be developed and applied to address both problems.

Potential Grid of the Future



Courtesy of John Schneider, AEP

Space Power Systems and Terrestrial Micro Energy Islands

- **Both areas share many of the same needs:**
  - Utilization of diverse power sources especially renewables
  - Incorporate large amounts of distributed energy storage
  - Long term untended operation
    - Rapid Fault Detection and Reconfiguration
    - Failure diagnostics and prognostics for power components
    - Variable Load Demand Accommodation
  - Common Power / Data Interface Standards
  - Insure self-sufficiency
    - Terrestrial Energy – Minimize or eliminate impacts on the utility base load and improve sustainability
    - Space Systems – Provide for continuous operation for survival

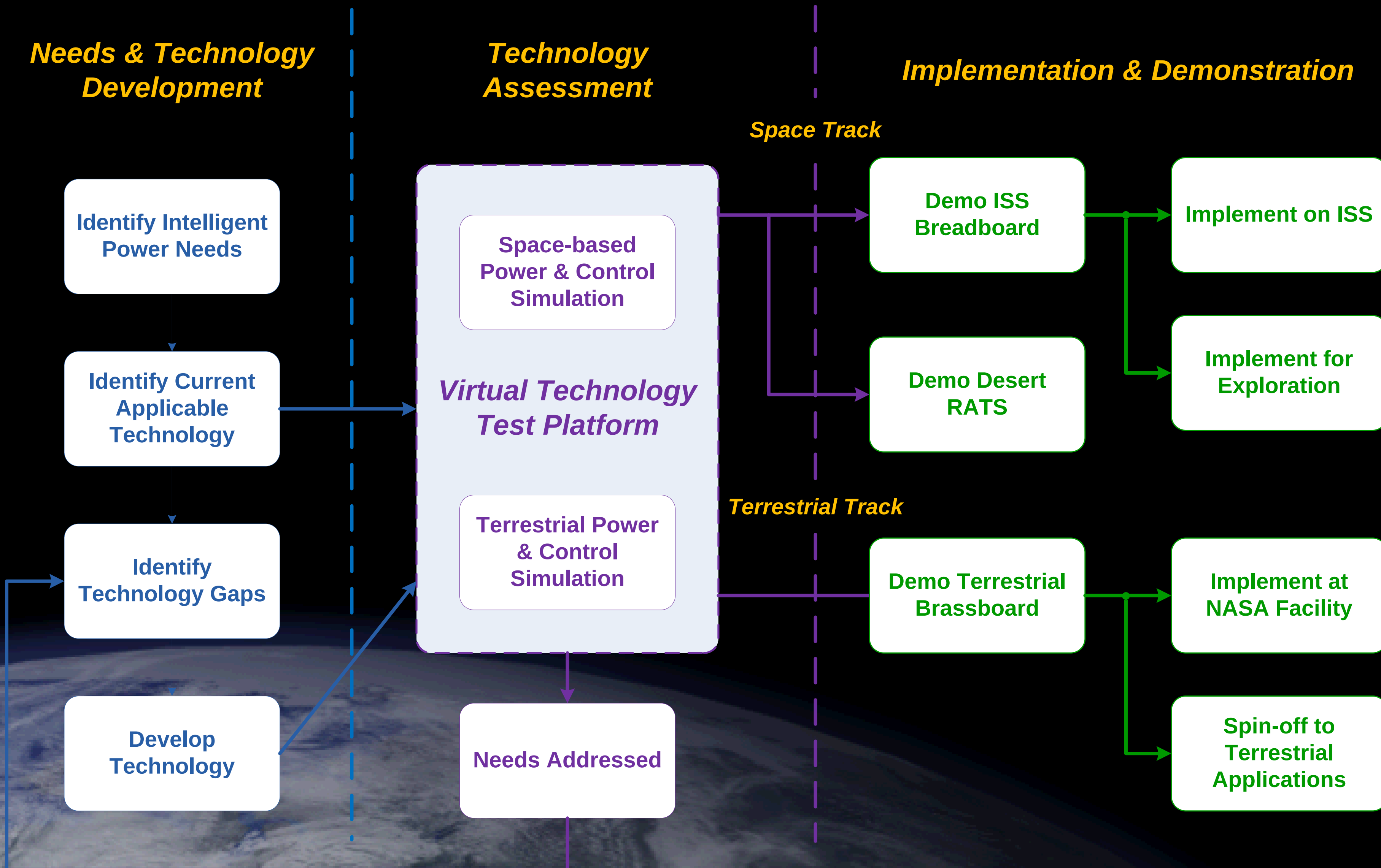
Potential Technologies

- **Automation and Controls**
  - Optimization algorithms
  - Adaptive control algorithms for changes in plant and input parameters
  - Distribution system diagnostics using state estimation
  - Automated Fault recovery
  - Prognostics to identify faulty sources and loads
  - Economic negotiation of load demand
  - Non-linear control for grid stability
- **Decision support tools**
  - Data Fusion
  - Autonomous and human-agent operations in high information density environments for advanced data integration and presentation
- **Communication**
  - Wireless data transmission
  - Secure data interchange

Potential Technologies

- **Sensors**
  - Intelligent Sensors with integrated data transmission and energy harvesting
- **Simulation of power systems**
  - Load flow / dynamic models for technology development and operation
- **Intelligent Distribution Hardware**
  - Intelligent switching centers to enable distributed hierarchical control
- **Intelligent Controller Hardware**
  - Digital controls for power converters to enable load side intelligence and economic negotiation of load demand
- **Intelligent Interface Standards – Power**
- **Intelligent Interface Standards – Data**

Technical Development Approach for Intelligent Power

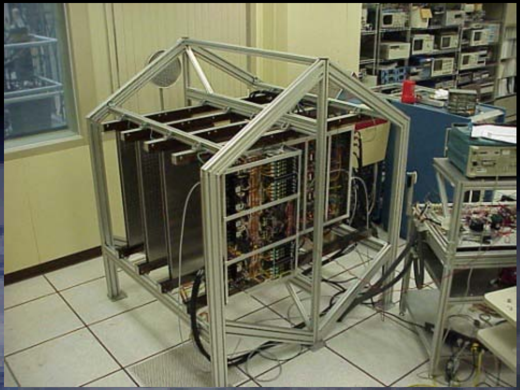


Potential Terrestrial Micro-Energy Island

Intelligent Power Testing Platforms for Space

ISS Power Test Platform

Constellation Power Platform



Lunar Power Test Platform

ISS Integrated Power Lab

Education Impacts

- Students must understand electrical engineering basics.
- Appreciation of systems technology and its impact on large power systems – electrical, mechanical, thermal.
- Capability for design and synthesis as opposed to analysis.
- Good writing and presentation skills – media driven culture.
- Ability to work as part of a team.
- Understand the political as well as the technical component to all solutions.

Students need to have a broad skill set beyond a narrow technical specialty to be successful.

Take Aways

- **Need to realize and make student aware that power systems can be exciting:**
  - Development and innovation is and will continue to drive many areas in power – "It's not your father's power discipline "
  - The future of power is working in concert with the disciplines of automation, controls, computers, communications, ergonomics, data fusion, etc.
  - Good opportunities are available given the aging workforce in power.
  - Development of power not only enables humans to explore colonize the solar system but also preserves civilization on Earth.