National Aeronautics and Space Administration

Smart Grid Development Issues
for
Terrestrial and Space Applications

Technical Panel
IECEC Conference

Cleveland, Ohio
July 29, 2014

James F. Soeder
Senior Technologist for Power
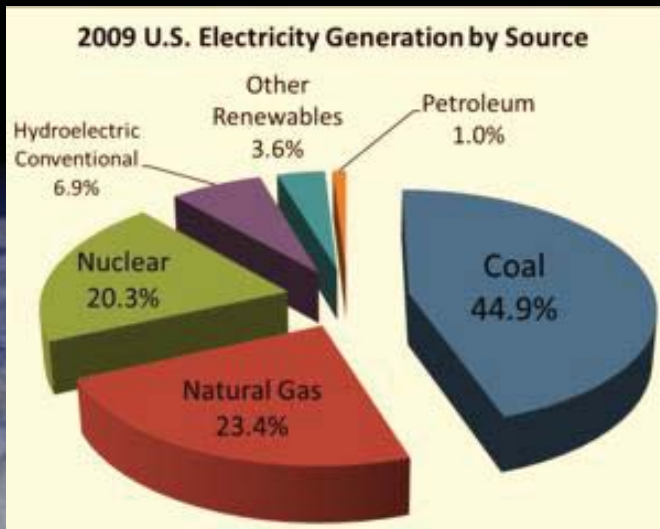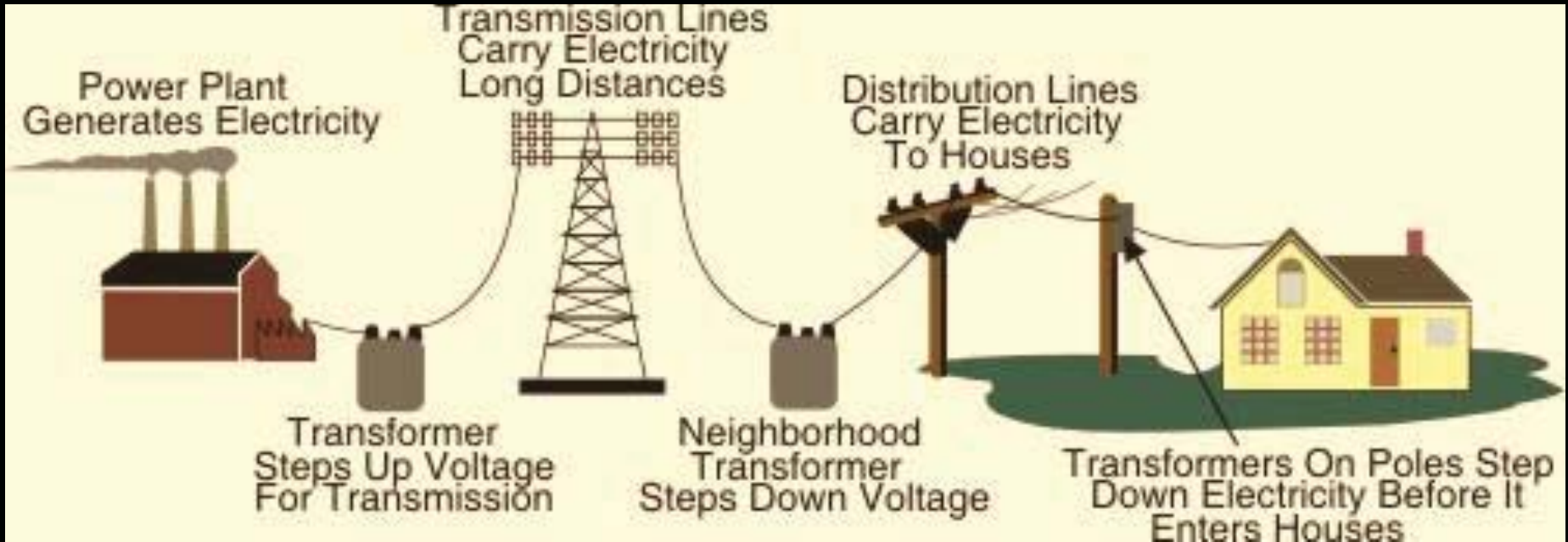**NASA Glenn Research Center**
Cleveland, Ohio

Discussion Topics

- **What is the "Smart Grid"**

- **Smart Grid Vision**

- **What is NASA's Interest in Smart Grid?**

- **Technology Development Needs**

- **Wrap Up**

Traditional Terrestrial Power Systems

What is the Smart Grid?

Secure Data Comm.

Renewable Generation

Energy Storage

Asset Optimization

Autonomous Controls

Smart Meters

Enhanced Decision Making Tools

Increased Observability

Micro-grids

Blind Men Describing the Elephant

Smart Grid Universe

Evolves with the integration of all these elements and more

Secure Data Comm.

Smart Meters

Renewable Generation

Asset Optimization

Energy Storage

Autonomous Controls

Increased Observability
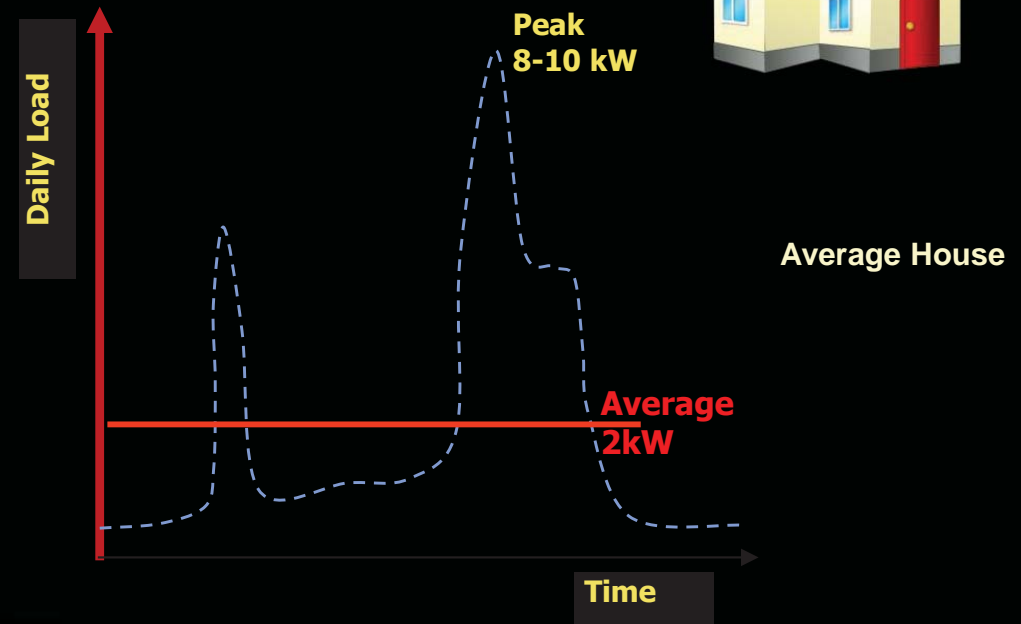
Micro-grids

Enhanced Decision Making
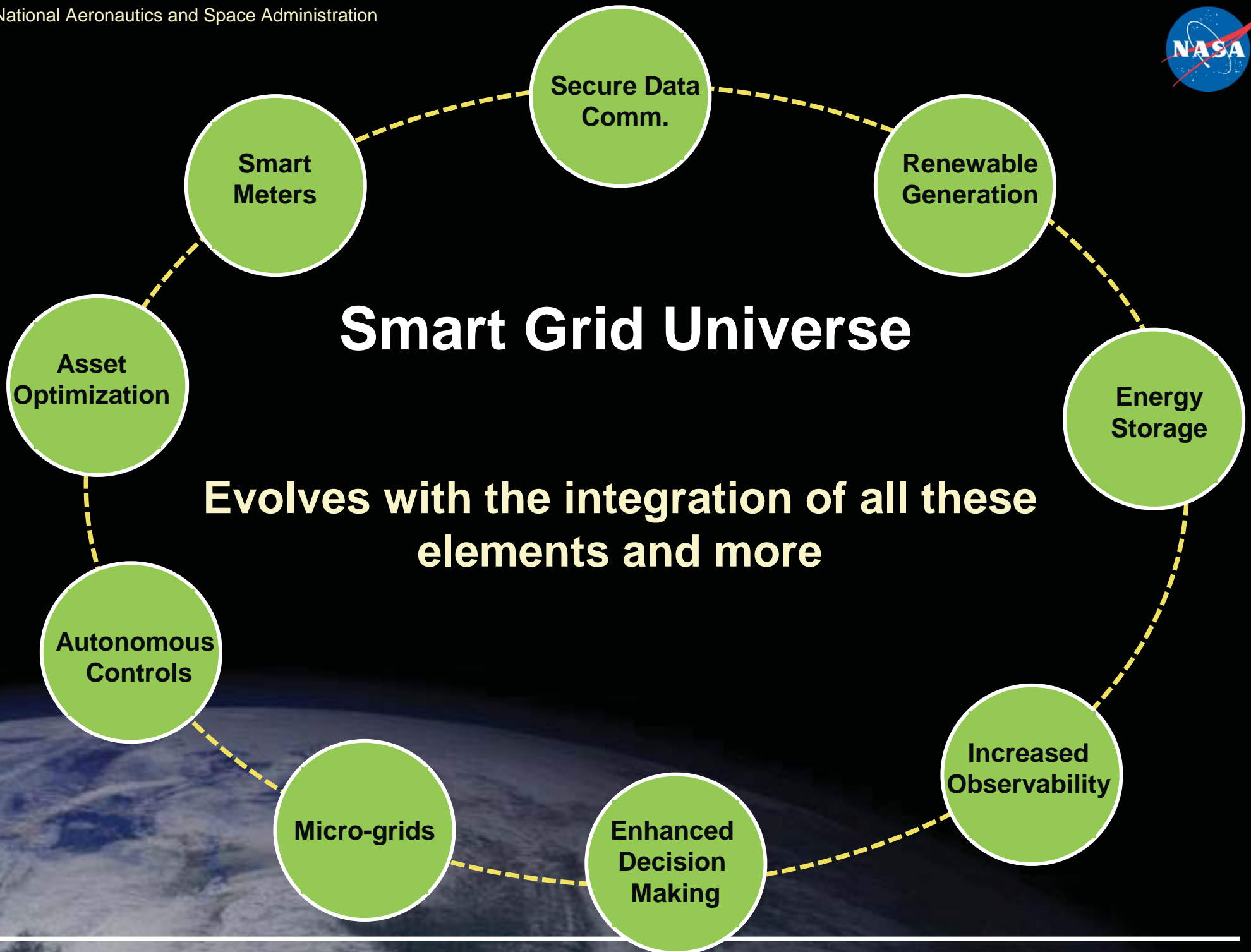
# Smart Grid Vision

Advanced Power Grid Needs

Key Needs:

- **Accommodate the increase in user power requirements**

- **Meet peak power requirements from generation to load at all times**

- **Improve grid security and sustainability**

- **Reduce the impact on the transmission infrastructure**

Daily Load

Peak
8-10 kW

Average House

Average
2kW

Time

Solution: Introduce distributed generation & storage to enable base load operation of grid assets

…the Grid of the Future?*

Storage

Fuel Cell

Wind

Industrial

Residential

Solar

Commercial
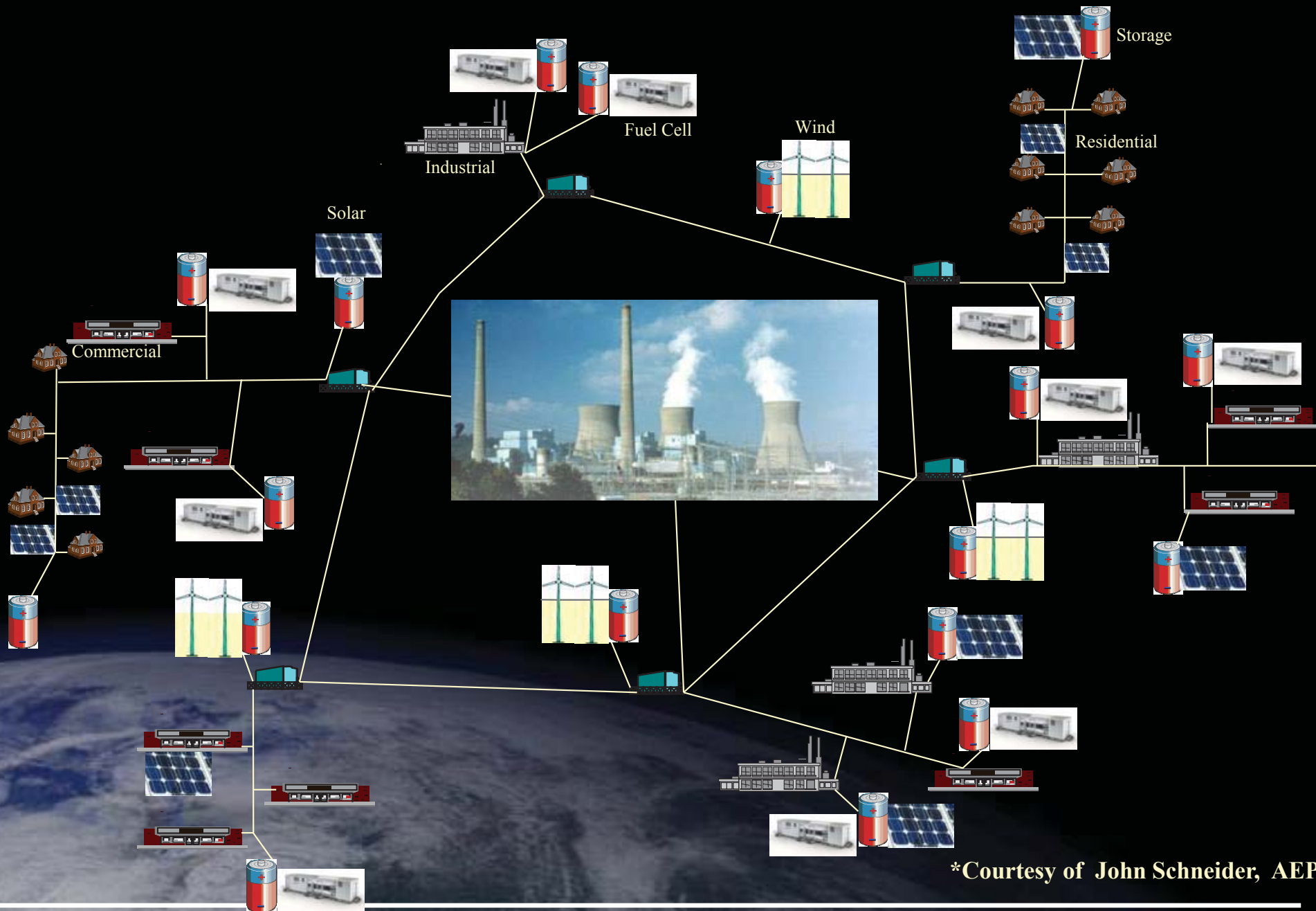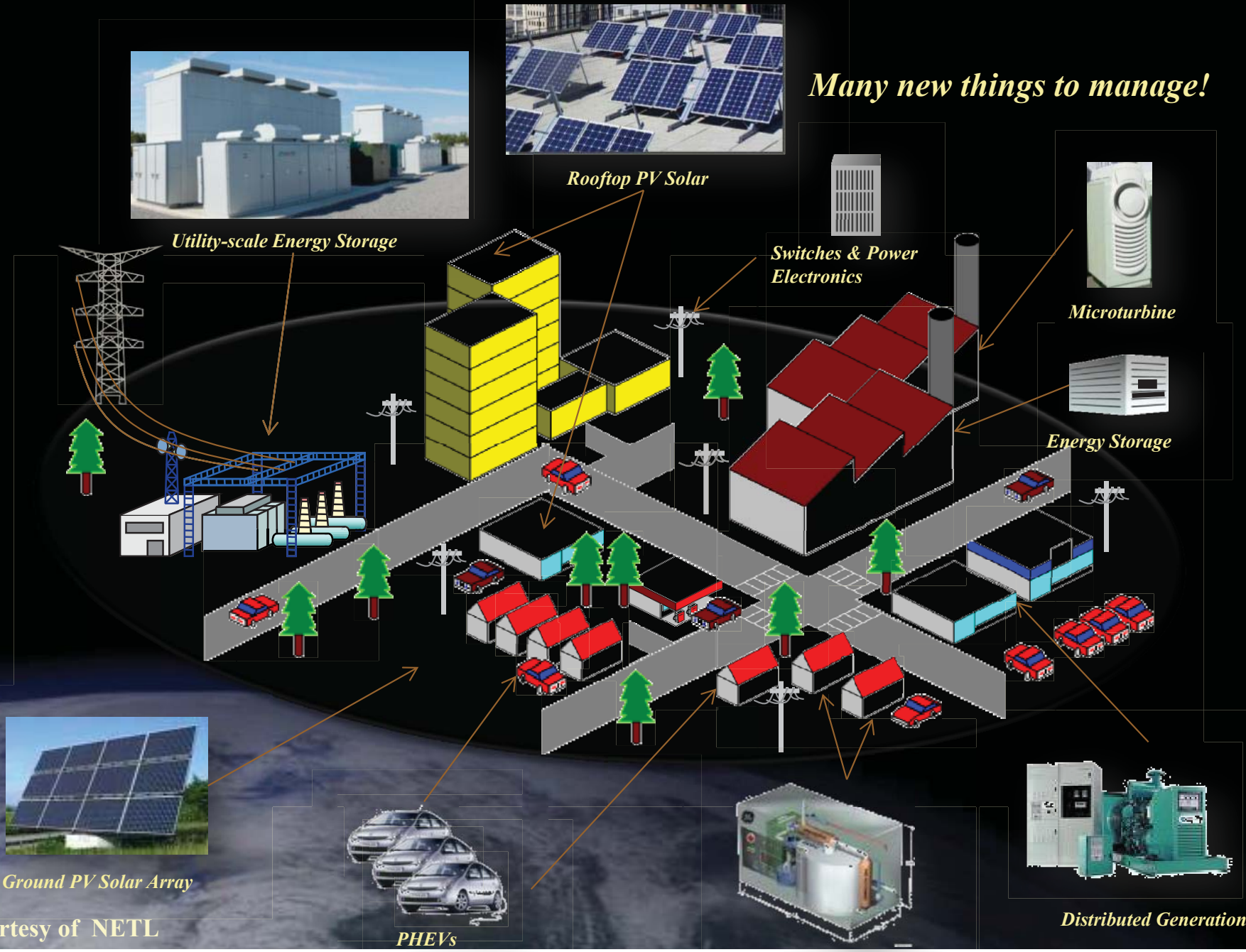
*Courtesy of John Schneider, AEP

Community Micro-grid*

Many new things to manage!

Utility-scale Energy Storage

Rooftop PV Solar

Switches & Power Electronics

Microturbine

Energy Storage

Ground PV Solar Array

* Courtesy of NETL

PHEVs

Home Energy System

Distributed Generation

What is NASA's Interest In Smart Grid?

**Technology for NASA mission requirements**

Technology synergy

Technology for U.S. smart grid

NASA and the smart grid both need autonomous controls.
When we solve one problem, we solve both problems

Glenn's Existing Infrastructure

Glenn Research Center has the existing physical assets, and engineering expertise that can be leveraged to solve many of the problems facing the development of micro-grids as well as enhancing facility sustainability
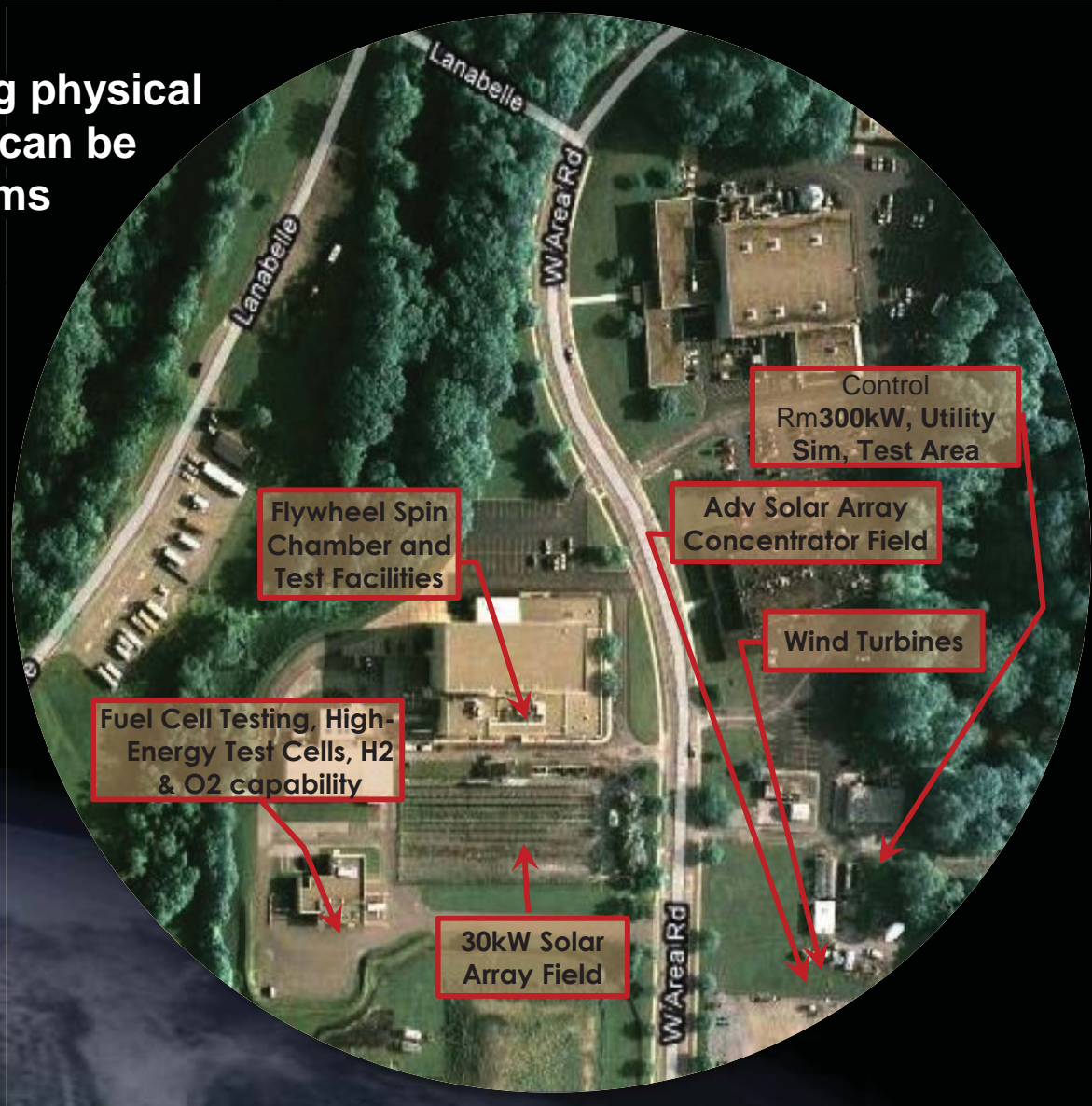
Smart Grid Systems Technology Development

Technology Development Needs

- **Systems Technology**
  - **Routine operation with a high percentage of energy storage**
    - **Demonstrate real and reactive power control using energy storage**
    - **Distributed vs centralized energy storage for renewables**
  - **Understand the benefits of DC vs AC interconnections for sources and storage**
- **Simulation Technology**
  - **Load flow / dynamic models for technology development and operation**
  - **Analytical models of micro-grids that can be replicated and run in real time and faster than real-time**
  - **Hardware in the loop operation with analytical models**

Technology Development Needs

- **Automation and Controls**
  - **Autonomous Controls**
    - **Economic negotiation of load demand**
    - **Management of distributed energy resources**
    - **Power network management**
    - **Fault detection and recovery**
    - **Coordination with the larger power grid**
  - **Adaptive control algorithms for changes in plant and input parameters**
  - **Prognostics to identify faulty sources and loads**
- **Intelligent Distribution / Interface Hardware**
  - **Power Electronics for bi-directional power flow techniques for real and reactive power**
  - **Bi-directional fault control**
  - **Intelligent switching centers to enable distributed hierarchical control**

Technology Development Needs

- **Communication**
  - **Wireless data transmission**
  - **Secure data interchange**
- **Decision support tools**
  - **Data Fusion**
  - **Autonomous and human-agent operations in high information density environments for advanced data integration and presentation**
- **Sensors**
  - **Intelligent Sensors with integrated data transmission and energy harvesting**
- **Intelligent Interface Standards – Data**
- **Intelligent Interface Standards – Power**

Wrap-up

- **The key to Smart Grid implementation is successful system integration of the new underlying component and control technologies**
    - **Integration of "Micro-Grids" or "Micro Energy Islands" with large power grids**
    - **Incorporation of a high degree of automation and fault tolerance for reliable / secure operation**
    - **Stable and reliable operation issues with power grids having a high percentage of renewable generation and energy storage**
    - **Ability to utilize large amounts of data to optimize grid operation**
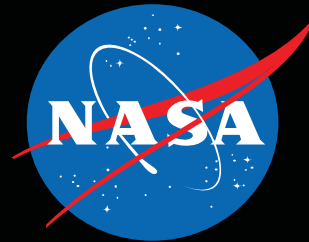
Terrestrial Micro Grids

Islanded micro-grids have very similar needs to space vehicle power systems

   - Both need to function autonomously for extended periods of time

   - Both need to manage distributed energy resources

   - Both need to manage loads over constrained capacity and time horizons

   - Both need to guarantee that the network is safely managed

   - Both need to detect, isolate, reconfigure and accommodate faults