Photovoltaic Systems: Power Technology Status and Needs

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ARPA-E workshop on "Power Technologies"

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Introduction

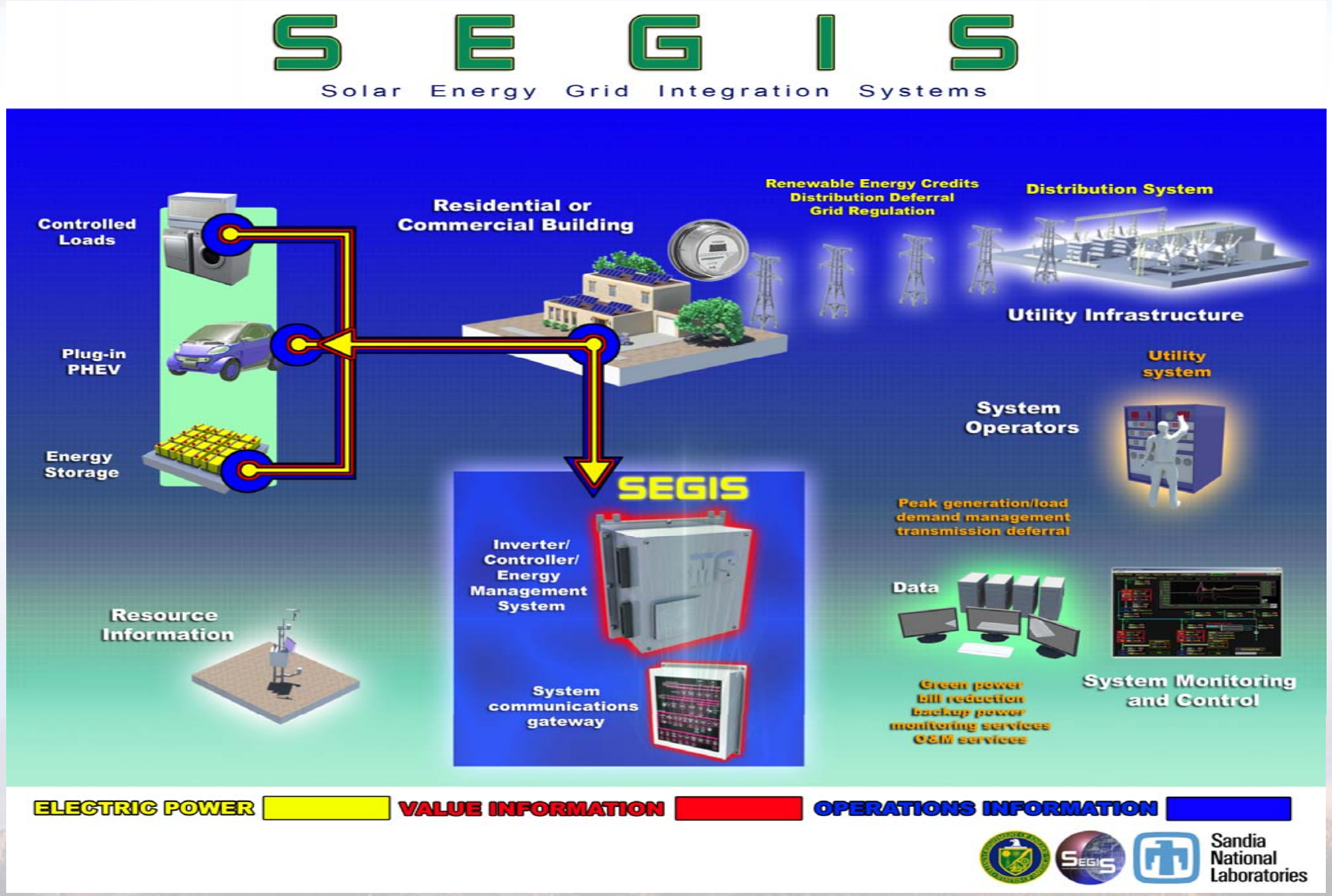
- **Power Electronic Needs for Advancements**
- **The DOE Solar Program SEGIS Overview**
- **Discuss Advance Component Applications**
  - Power Electronics/ICs/Devices/Technology
  - Compatibilities with logistical needs
  - New Short-term needs
- **Device and Technology Discussion**
- **Smart Grid and Micro-grid**

The Power Electronics Applicabilities for PV and DG

- Prepare for high-penetration of PV/DG in the context of the future “Smart” utility grid
  - Integrated and Advanced Inverter/Controller/BOS
  - Integrated Energy Management and Storage Control/Isolation
  - Advanced Communication and Sensors
- Improve BOS Power Electronic Reliability and Lifetimes
- Develop “Advanced Concepts” such as micro-inverters, micro-grids, electrical grid support, electrical grid reliability
- Support the advanced technology and applications areas (Smart Grids, Energy Storage, Distributed Generation, Energy Management, Communications, Safety)

The DOE Solar Program

First Steps



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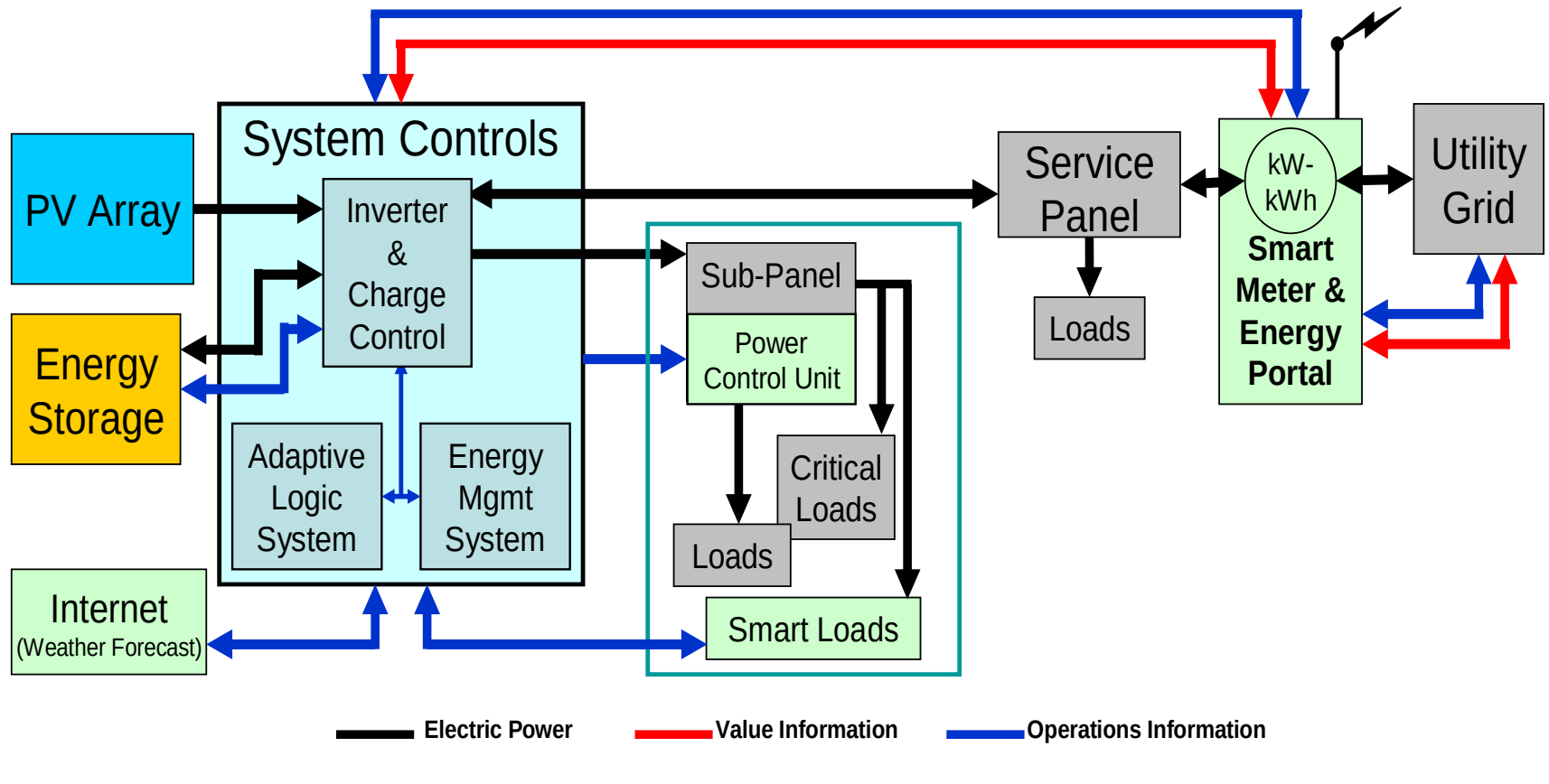
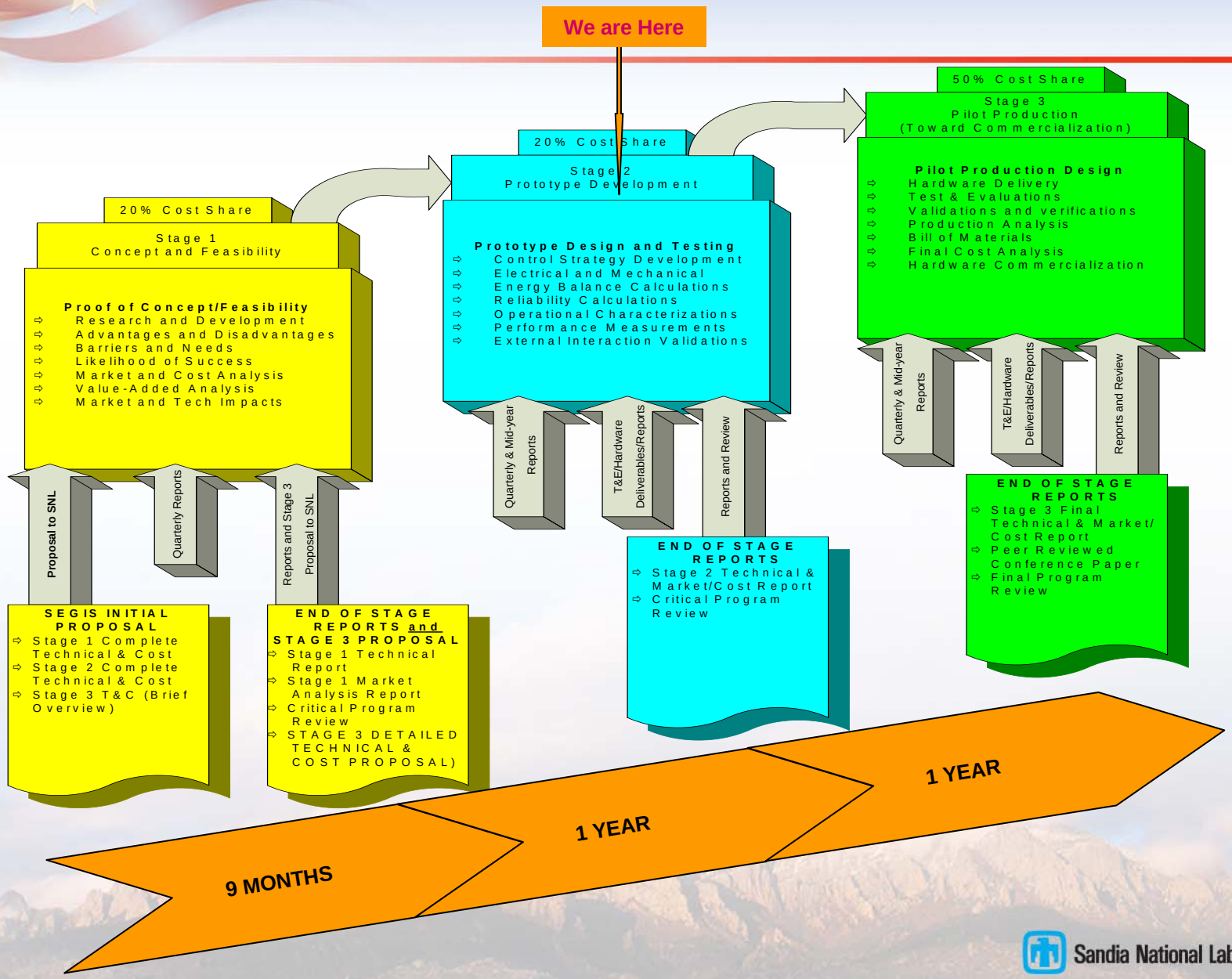
One Future Conceptual Intelligent Utility Interconnection



The "SEGIS" Timetable



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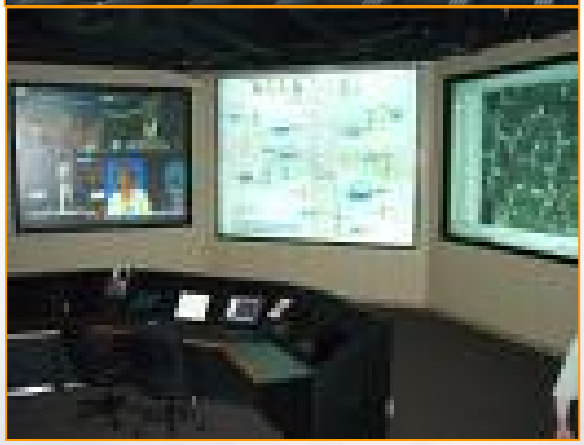
Advanced Component Applications

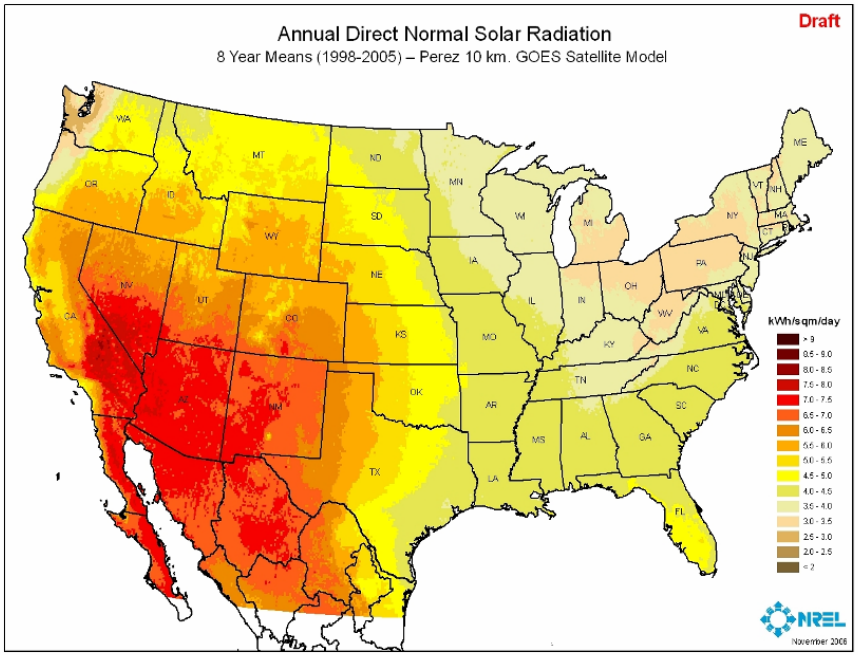
- Integrated Communications
- Micro-grid Controls & AMI
- MEMs & SiC Applications
- Diagnostics/Gateways
- Interactive Monitoring/Control
- Innovative Packaging
- Thermal Stress Management
- Internal Protection/Longevity
- Predictive/Adaptive Operation



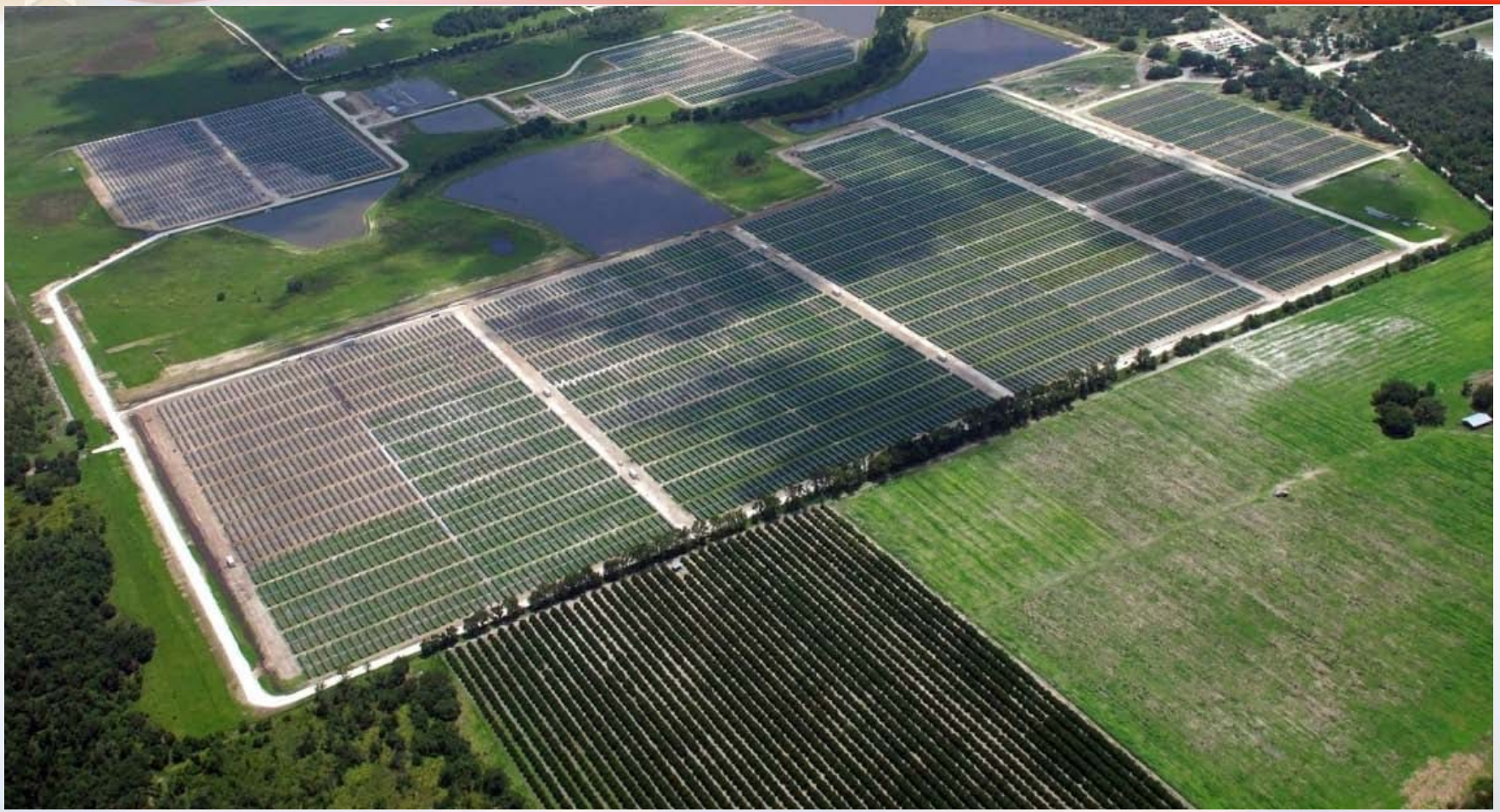
Thermal Stress Management 101

Resource and Performance Predictions

- Resource forecasting over various time steps, (Minutes, 1-3 hour, day ahead, seasonal, annual)
- Reliable, sub-hourly data sets
- Improve the spatial resolution of data sets
- Develop a user-interactive data portals.
- Focus new solar radiation products to support requirements
- Develop utility grade hardware for automated and utility-controlled functionality



Maximum Power Point Tracking
Intermittent Power Production



Potential Issues for Intermittency, String Combiners, MPPT, System Stability
25MW DeSoto PV Pland, Arcadia, FL

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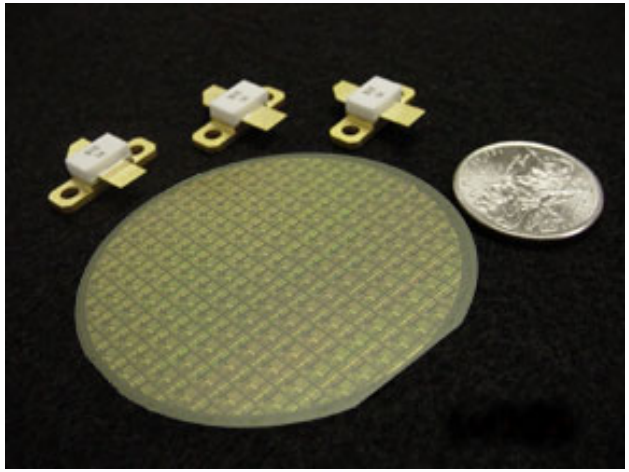
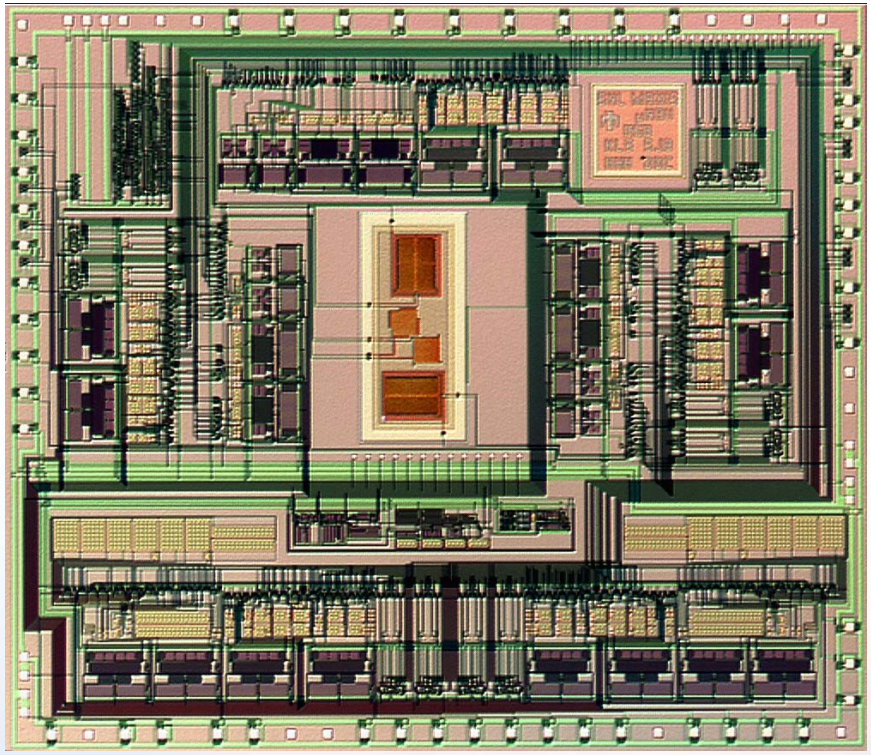
Advanced Component Applications for Future Advanced Hardware

- **Highly-integrated Custom ICs**
  - Micro-inverter on a Chip (Set)
  - Universal Control Chip Sets
- **MEMs (MicroElectroMechanical systems)**
- **High Temperature Semiconductor Components (SiC, SOI,)**
- **Magnetic Materials**
  - Lower cost, higher performing
  - Planar & integrated devices
  - Nano-crystalline materials
- **Advanced Surge Suppression**
- **Integrated Cooling/Packages**
- **Advanced (Long Lived, Self Healling) Capacitors**
- **Innovative Energy Storage**



MEMs Can Be Integrated into ICs



MEMs 3-axis Accelerometer

MEMs Possibilities	
Electrical switches	Solar cells
RF Switches	Fluidic Components
Actuators	Detectors
Pressure sensors	Filters

Arc-Fault Detection and Interruption

690.11 Arc-Fault Circuit Protection (DC).

PV systems with dc source and/or output circuits on or penetrating a building operating at a PV system maximum system voltage of 80 volts or greater shall be protected by a listed (DC) arc fault circuit interrupter, PV type, or other system components listed to provide equivalent protection.

The PV arc-fault protection means shall comply with the following requirements:

(1)The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the dc PV source and output circuits.

(2)The system shall disable or disconnect one of the following:

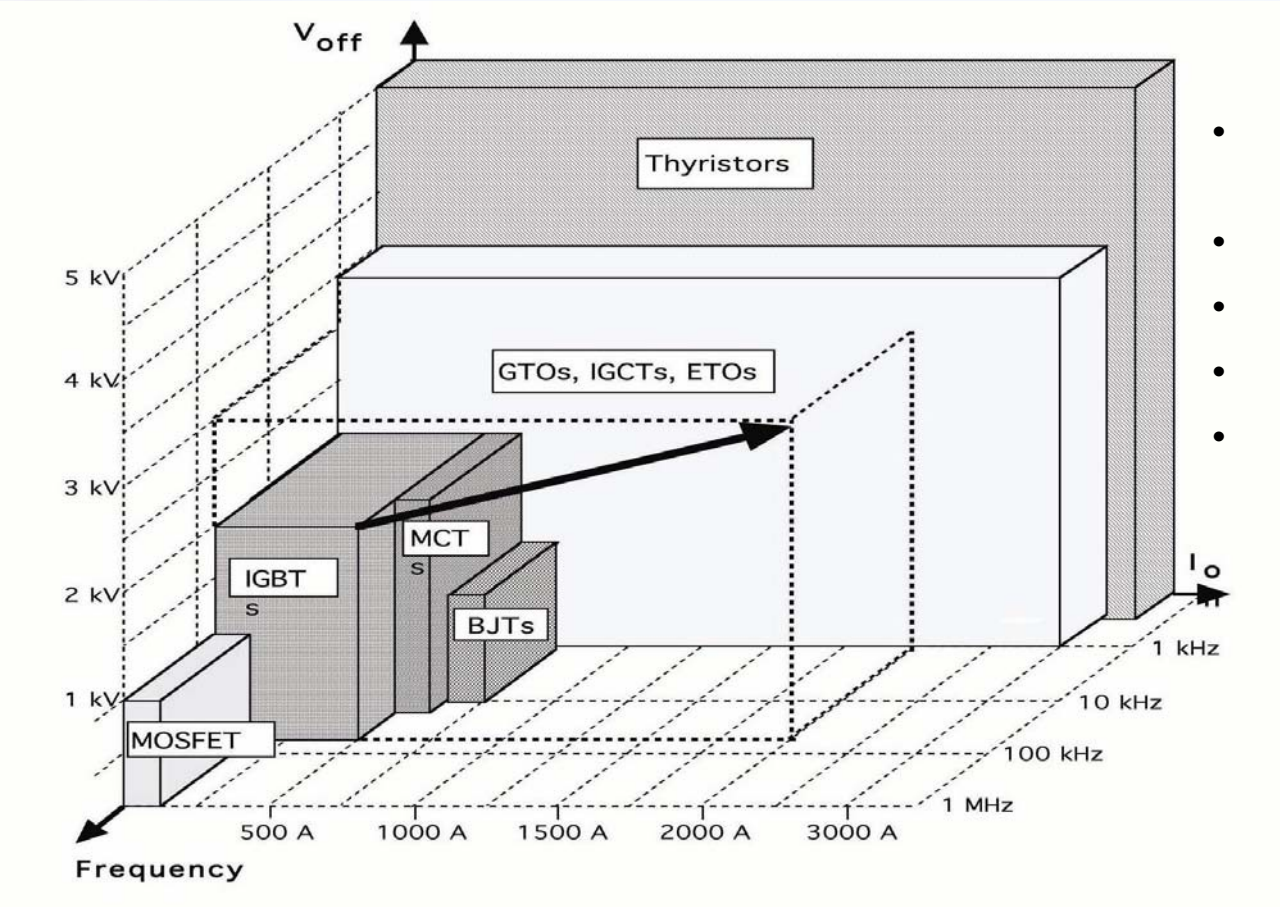
a. Inverters or charge controllers connected to the fault circuit when the fault is detected

b. The system components within the arcing circuit

(3) The system shall require that the disabled or disconnected equipment be manually restarted.

(4) The system shall have an annunciator that must be manually disabled.

Silicon Power Device Advances

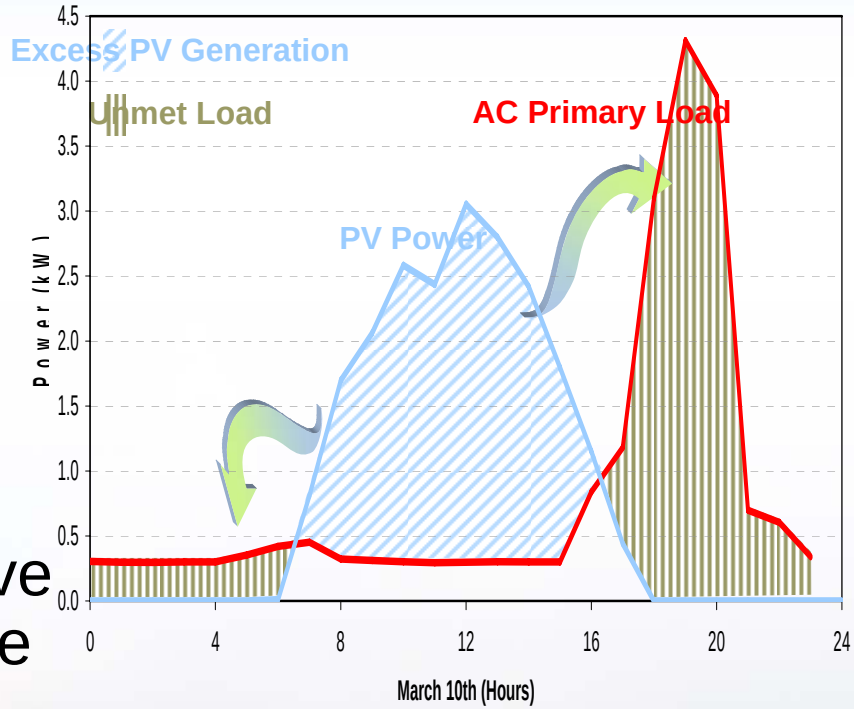


Trends:

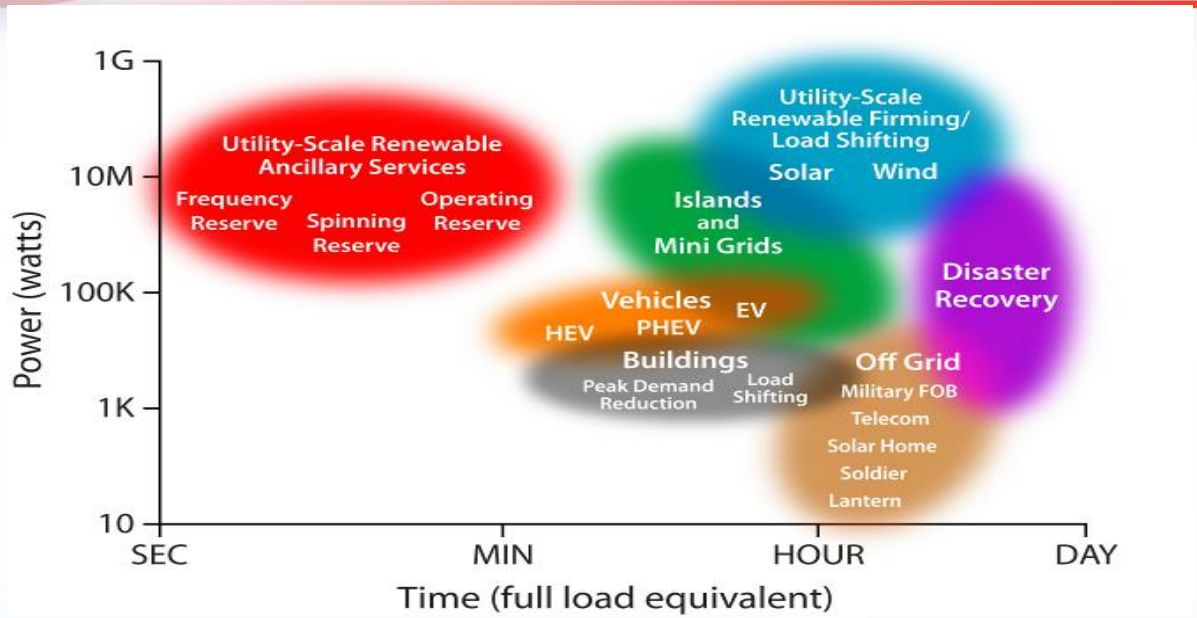
- **Increase Voltage/Current Ratings**
- **Increase Switching Frequency**
- **Improved Thermal Rejection**
- **Lower Switching Losses**
- **More Integration**
  - **Self Protection & Diagnostics**
  - **Lower Inductance**
  - **Packaged Bridges**
  - **Hybrid Chip Sets**

Advanced Methodology Applications

- **Energy Management and Communications Methods**
  - Integration with energy storage & other generation
    - Protocol, Wireless/PLC/Ethernet
    - Safe switching, isolation
  - Value-added, integrated Sensors/Detection to improve reliability & utility acceptance
  - Advanced communications devices, sensors and methods



Objectives for Distributed PV System Technology Development

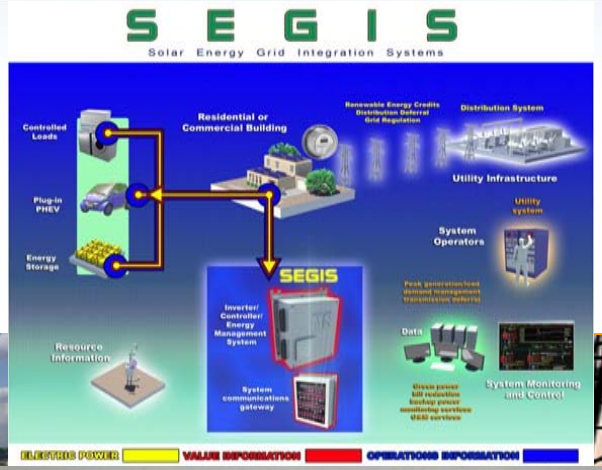


- Inverter-tied storage systems to use dc bus, allow intentional islanding (microgrids) and system optimization (demand control).
- Energy system controllers to monitor solar resource, utility pricing, building loads, occupant data and then provide safe switching.
- Embed voltage regulation in inverters, controllers, voltage conditioners.
- Integrate communications and control concepts with *SEGIS*.
- Communications protocols to prevent unauthorized tampering.

Inverter/Controller/BOS/EMS Next-Generation Logistics Needs

- **Device & System Self-protection/Reliability**
  - Hardware and software advances to protect the inverter and components for higher reliability/longer lifetimes
  - Advanced systems to “Predict System” Status, health and remaining lifetime
- **Improved Inverter <u>AND</u> System Modeling to Facilitate Advanced Power Electronic Hardware and Adaptive Controls**
- **Customer Friendly Products**

THANK YOU!



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http://www.sandia.gov/solar/

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