SAND2014-4340C

Sandia National Laboratories Photovoltaic and Related Research Facilities

Opportunities for Partnered Research in a World-Class Setting

Charles Hanley, Actg. Sr. Mgr.
Grid Modernization and Military Energy Systems

5/29/2014

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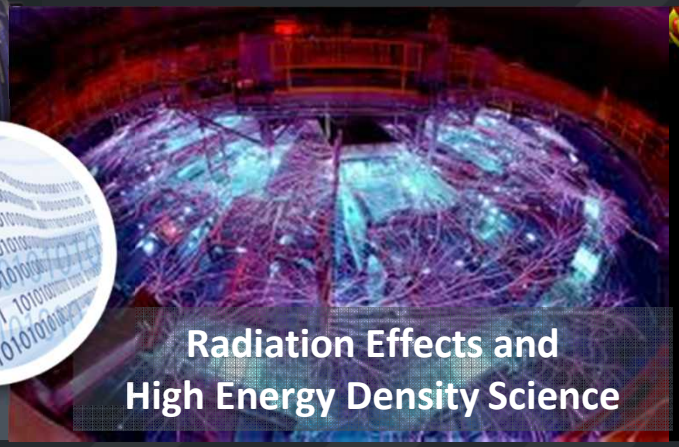
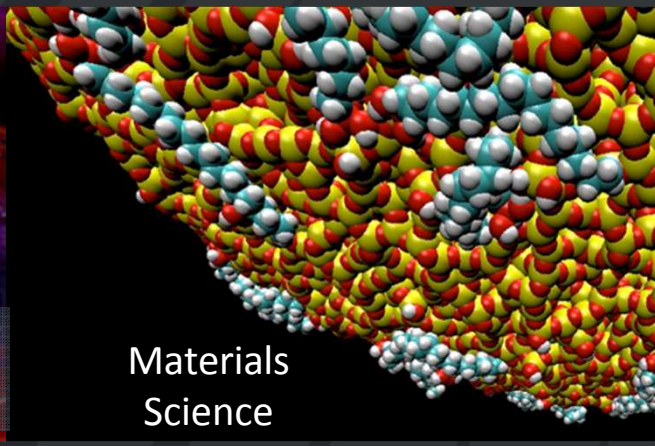
Sandia's Research Foundations Enable Mission Performance

Sandia National Laboratories

Computing and Information Sciences

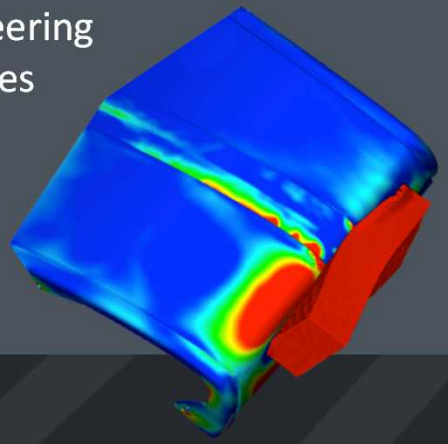


Radiation Effects and High Energy Density Science

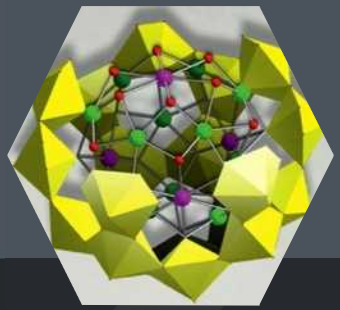


Materials Science

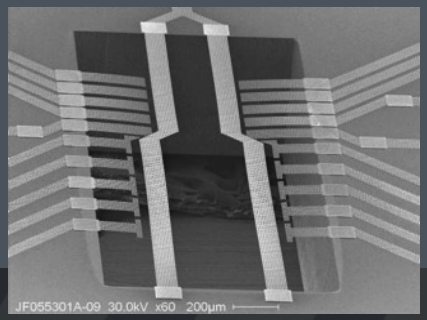
Engineering Sciences

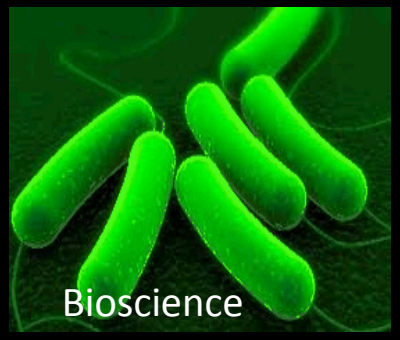


Geoscience



Nanodevices and Microsystems





Bioscience

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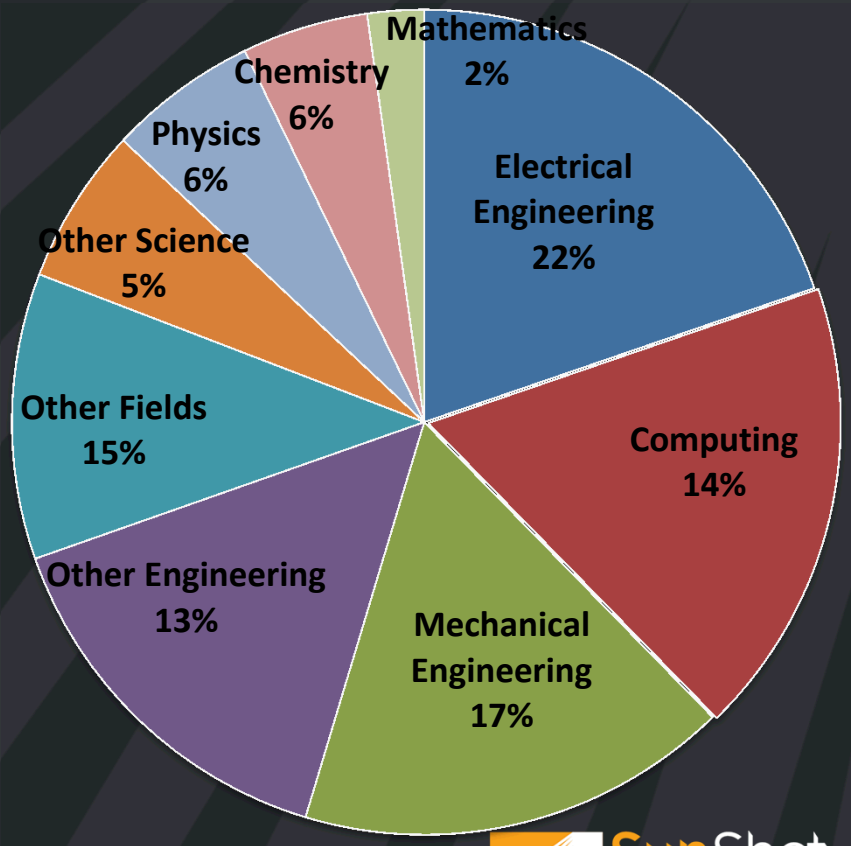
Our Workforce

- On-site workforce: 11,711
- Regular employees: 9,494
- Gross payroll: ~$1.046 billion

Data as of April 12, 2013

R&D staff (4,799) by discipline



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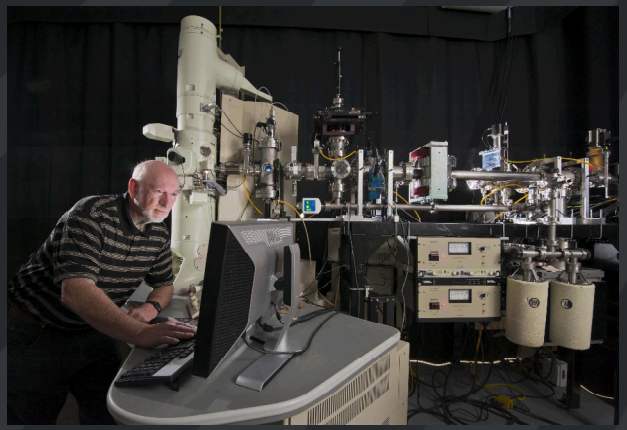
SNL World-Class Research Facilities Support our Mission

Microsystems and Engineering Sciences Applications

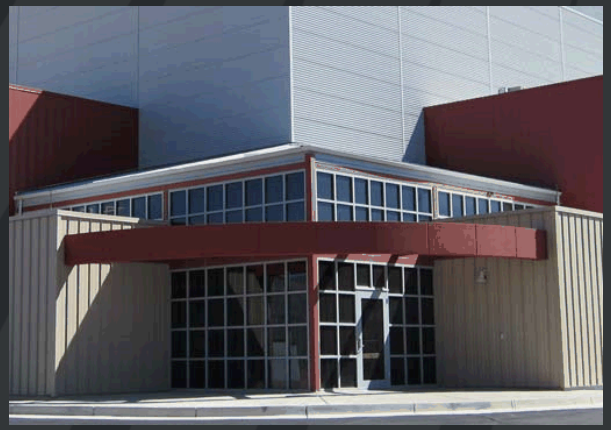
Cyber Engineering Research Laboratory

The Center for Integrated Nanotechnology

Combustion Research Facility



Ion Beam Analysis (IBA)



Gamma Irradiation Facility

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MESA provides a Strategic National Security Advantage

Sandia National Laboratories

Silicon Fabrication

- Strategically Radiation Hardened Silicon CMOS Process Technology for ASIC, MEMS, and Special National Security Component Fabrication

Compound Semiconductor Fabrication

- III-V Compound Semiconductor Process Technology for HBT Fabrication, Energy Research, Special National Security Component Fabrication

- Co-located Component Design & Integration

MESA provides a research enabled production environment closely integrated with national security aspects of design and engineering. > 300 Patents; >40 R&D100 Awards

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Microsystems Enabled Photovoltaic Cells (MEPV)

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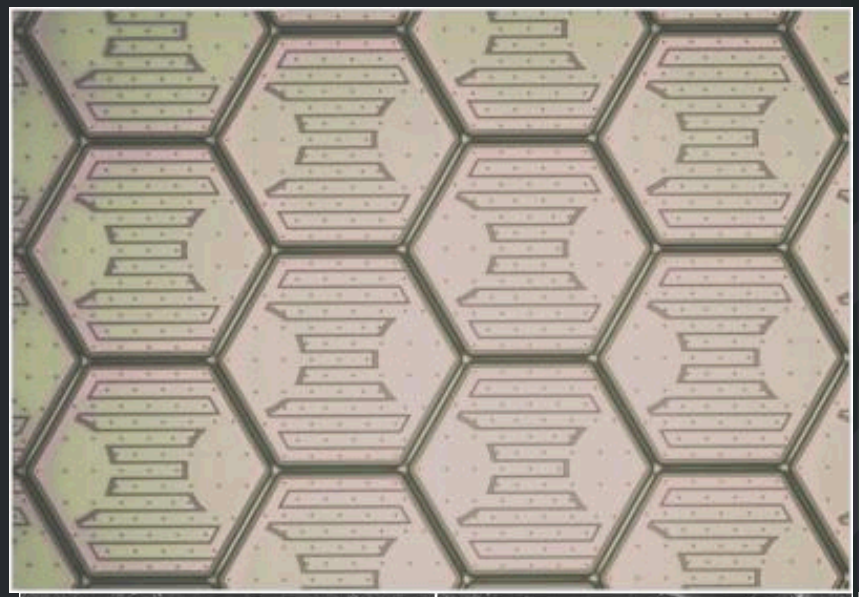
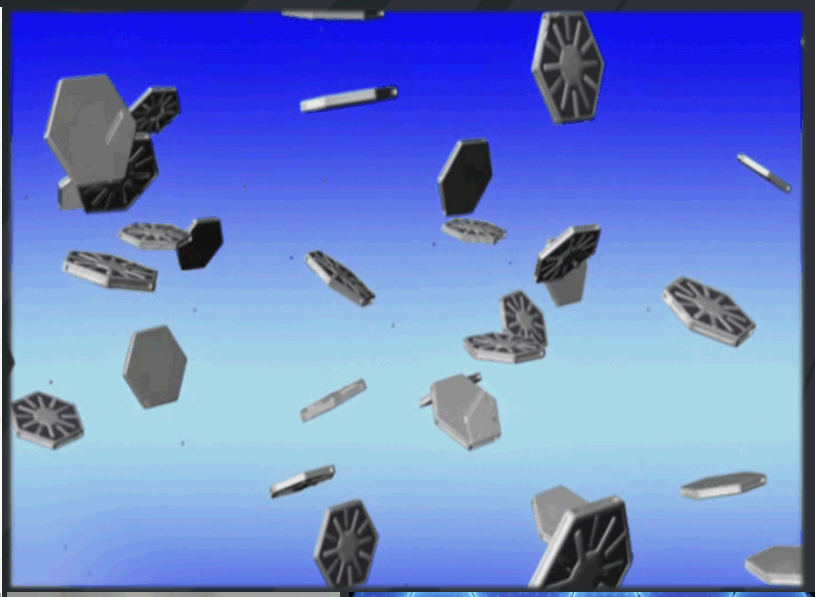
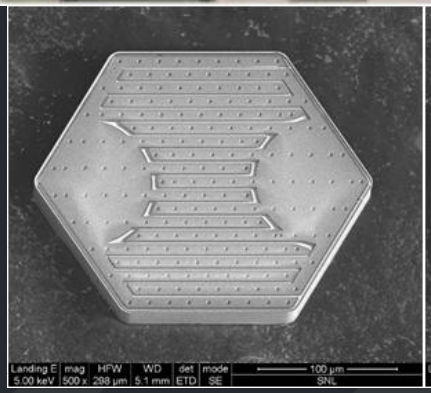
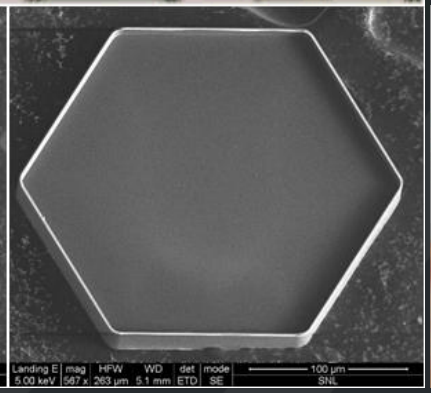
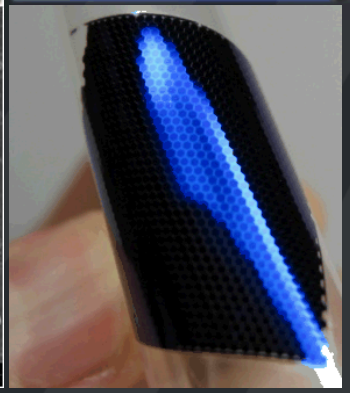
Microsystems technologies are creating disruptive change in PV











R&D 100

CINT is a Nanoscale Science Research Center (DOE/SC National User Facility)

Sandia National Laboratories

The DOE/SC nanoscience centers are different from traditional user facilities

- Defined by a scientific field, not specific instrumentation.
- NSRC staff support user projects and conduct original research.
- Capabilities involve hardware plus research expertise.

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The CINT Vision: Nanomaterials Integration

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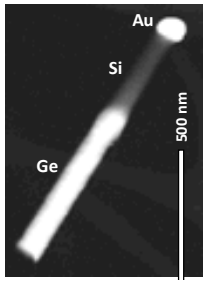
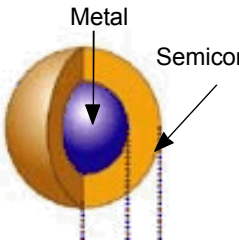
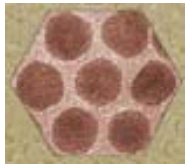
Nanoscale building blocks



Vapor & liquid phase synthesis

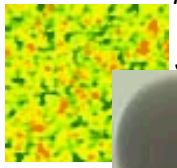




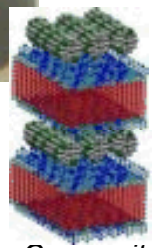
Heterostructuring & interface modification

Fabrication & assembly

Nanocomposite



SWNT aerogel

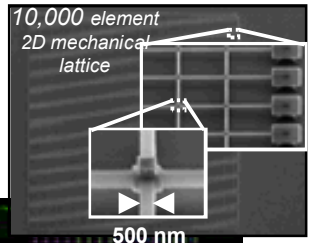


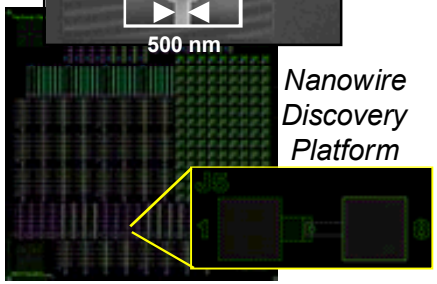
Composite membranes

Switchable metamaterials

Functional composites & systems

Nanomechanical arrays





Nanowire Discovery Platform

Length scale

Nano

Micro

One scientific community
focused on the science of nanomaterials integration

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Who can be a CINT user?

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Pre-competitive User Project
- Must publish results
- No fee to use CINT
- New IP is shared

Individual...team...organization...consortium

Undergraduate & graduate students, post-docs, faculty, National Lab staff, industries, DOD research organizations, small businesses…

Proprietary User Project
- No publication requirement
- Must pay to use CINT
- IP is owned by users

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Impactful science is our product!

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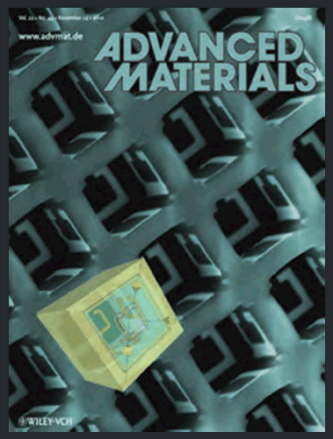
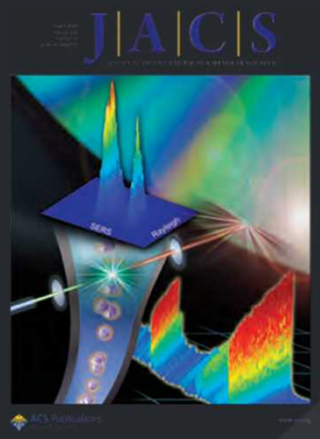
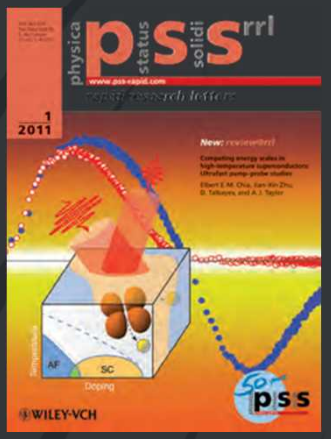


Novel SSR Designs
Burckel et al., 2010



Plasmonic Nanoparticles
Goddard et al., 2010

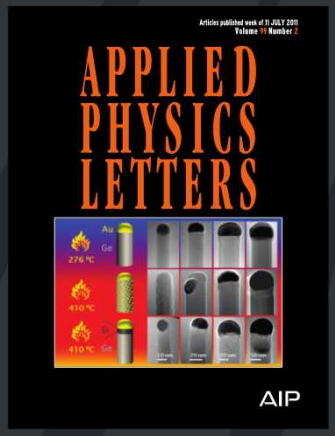
Semiconductor Nanostructures
Wong et al., 2010



Ultrafast Dynamics in HTS
Chia et al. 2011

Functionalized Nanoparticle Behavior
Lane and Grest, 2010

Ordered Nanowire Arrays
Neal, 2010



Nanowire Heterostructures
Dayeh et al., 2011

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PV Systems Capabilities & Facilities

Regional Test Centers (RTC)

PV deployment areas available for RTC systems designed to leverage Sandia expertise in PV testing, research, performance modeling, and reliability.

Photovoltaic Systems Evaluation Laboratory (PSEL)

2-axis outdoor tracker capable of testing multiple modules at a high level of precision

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PSEL Mission

- Supports Sandia's DOE Program Areas
  - Emerging Technologies
  - Modeling and Analysis
  - Derates
  - Reliability
  - Regional Test Center
- Outdoor and Indoor Module Characterization Facilities
- Outdoor Small Systems Characterization
- Focus on DC measurements

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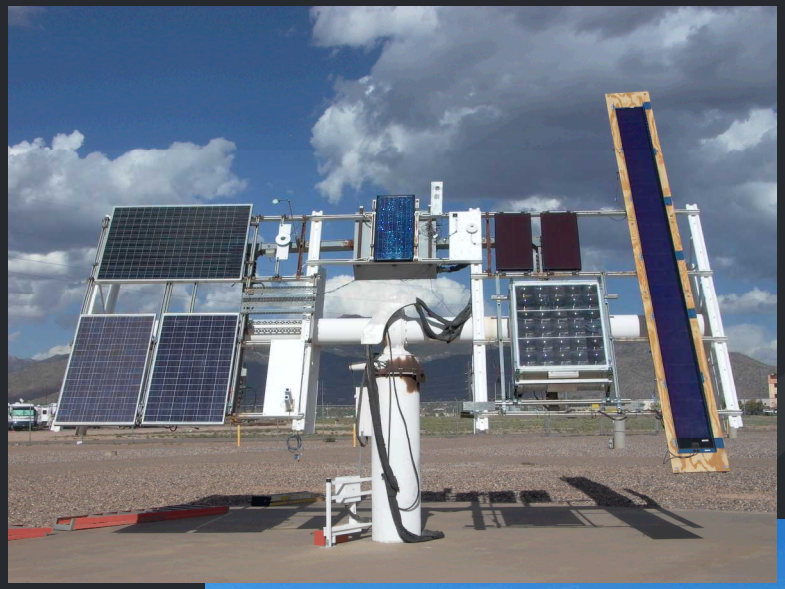
Outdoor Module Characterization

Sandia National Laboratories



Capabilities

- Two fully programmable Two-Axis trackers
- 8 Data Channels (split between two trackers)
- 3m x 3m mounting area (per arm)

Range of Technologies

- Flat plate (c-Si, CIGS, CdTe)
- Concentrating Photovoltaics (High and Low-X)
- BIPV
- Bifacial
- Single cells

Types of Characterization

- I-V Curves
- Thermal Performance
- Angle of Incidence
- Specialized tracker simulations (e.g. Horizontal Single-Axis)

Instrumentation

- Calibrated Silicon Reference Cell
- Calibrated Precision Spectral Pyranometer
- Tracking Error Monitors

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Small Systems Characterization

Sandia National Laboratories

Purpose

- Focus on Emerging Technologies
- Minimum 1-year installations
- Data used to validate energy yield calculations
- Evaluate system reliability and degradation rates

Configuration and Capacity

- Up to eight 1-5 kW systems (~ 35kW total)
- Flat plate (c-Si, CIGS, CdTe)
- Grid-Tied
- Fixed Latitude Tilt
- CPV Tracking Systems

System Monitoring

- DC Voltage and Current (string and combiner)
- AC Voltage, Current and Power Factor
- Module Temperature
- Local Irradiance Sensors
- Other temperatures (e.g. inverter) as desired

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Other Environmental Characterization

Connector Reliability Study

Purpose

- Focus on Component Reliability Studies
- 1-month to 1-year installations
- Data used to evaluate materials and component reliability and degradation rates

Configuration

- Flexible, stand-alone platforms at any orientation
- Tracker-mounted for maximum sun exposure

Monitoring

- Can be set up to be completely autonomous
- Configured per experimental needs
- Remote access via cell modem

Weather Platform

Parameters Measured

- Irradiance
  - Direct Normal
  - Global Normal
  - Global Horizontal
  - Global Latitude Tilt
  - Diffuse Horizontal
- Spectrum
- Ambient Temperature
- Relative Humidity
- Wind Speed and Direction at 10m
- Barometric Pressure
- Precipitation
- Electric Field Strength

Calibrations

- Pyranometers
- Reference Cells

Weather Data is synchronized and merged with I-V Curve data for later analysis

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Indoor Module Characterization

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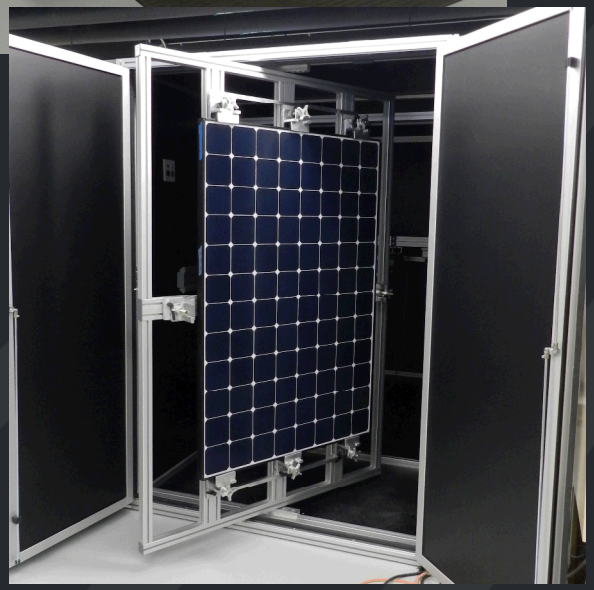

1-Sun Flash Tester

- Spire 4600SLP
- Characterize IV behavior of modules as a function of irradiance
- Class AAA flash lamps
- 2m x 1.37m test plane
- 200-1100 W/m^2
- room temperature operation only

Electroluminescence

- Reltron PV Electroluminescence Inspection System
- Cell and Module defect mapping via reverse-bias photon emission
- 16MP camera, NIR optimized optics
- Custom enclosure and module mounting
- Max size: 2.1m x 1.4m module

Dark I-V

- Sandia Constructed (~1990's)
- Reverse bias IV mapping isolated from light
- Characterize series and shunt resistance
- Max size: 1.6m x 1.4m x 0.25m
- Heated chamber, r.t. through 60°C

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Indoor Cell Characterization

Sandia National Laboratories

1-Sun Cell Tester

- SpectroLab XT-10
- Characterize IV behavior of cells at various irradiance and temperature levels
- Wide range of cell sizes (up to 160mm)
- 0-1.0 Suns
- Temperature controlled vacuum chuck (-10-90°C)

Solar Cell Spectral Response

- PV Measurements QEX10
- Characterize electrical response of cells as a function of wavelength
- 300 - 1700 nm (0.5nm steps)
- Motorized X-Y table for spatial mapping
- 160 mm wafer handling

Reflectance and Transmission

- Cary 5000/DRA 2500
- Characterize optical behavior (reflection and transmission) of cells, glass and optics as a function of wavelength
- 250nm – 2500nm (1nm steps)
- Diffuse or specular reflection
- Small sample handling (~25mm x 75mm)

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REGIONAL TEST CENTERS

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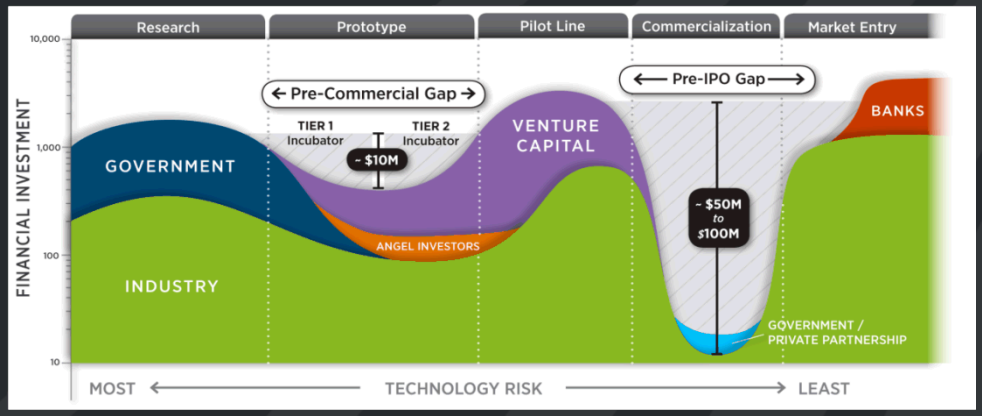
RTC History

- Established by U. S. Department of Energy (DOE) to independently validate performance and reliability of photovoltaic (PV) systems
- Intended to supplement SunShot program to help advance DOE's production goals and build stakeholder confidence in new/existing PV technologies
- Sunshot Initiative's Goal – total installed system cost = $1/W of capacity
- Intent - help US PV manufacturers overcome commercialization "Valley of Death"



- Utilized to validate performance of PV systems, verify and validate models used to predict performance, collect detailed operations and maintenance (O&M) data, and investigate the role of various environmental (climatic) factors on reliability, durability, and safety of PV technologies.

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Regional Test Centers for Photovoltaic Technologies

Regional Test Centers
Differentiating PV Quality

Powered by SunShot
U.S. Department of Energy

www.pvrtc.org

The five DOE Regional Test Centers conduct extensive field-testing to:

- Assess and validate the performance and reliability of new PV technologies and increase the confidence of manufacturers, integrators and the financial community in the bankability of those technologies.
- Better understand validation standards
- Support the DOE SunShot Initiative goals by helping accelerate innovation in the solar sector.

Develop predictive performance models, collect detailed operations and maintenance data, and quantify performance in four areas:

- Design Evaluation and Baseline Testing
- Performance and System Monitoring
- Analysis and Modeling
- Reliability and Safety Key

Williston, Vermont
This site is located at an IBM facility outside Burlington and will provide important data on PV performance under harsh, winter conditions.

Green Mountain Power · IBM · The University of Vermont

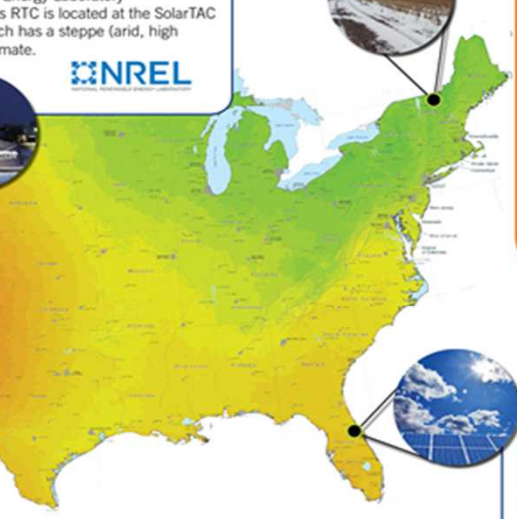
Vermont Photovoltaic Regional Test Center

Denver, Colorado
Managed by the National Renewable Energy Laboratory (NREL), this RTC is located at the SolarTAC facility, which has a steppe (arid, high altitude) climate.

NREL

Las Vegas, Nevada
Located at a site managed by Southern Nevada Water Authority this site represents a hot, arid climate.

UNLV · Southern Nevada Water Authority



Albuquerque, New Mexico
Located at the National Solar Thermal Test Facility on Kirtland Airforce Base in Albuquerque and managed by Sandia National Laboratories, this site represents a hot, arid climate.

Sandia National Laboratories

Orlando, Florida
Managed by the Florida Solar Energy Center and located at the University of Central Florida, this RTC will test PV performance in a hot tropical environment.

FSEC

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Regional Test Center Capabilities

National Solar Thermal Test Facility Site

- Intended for larger sized systems (>50kW)
- Flexible plan site allowing the RTC Team to combine or split lots to accommodate testing criteria
- Supports 1.2 MW of PV plus baseline test equipment, labor and data analysis.
- Expansion into sites B-F will accommodate additional partners

Photovoltaic Systems Evaluation Laboratory Site

- Intended for smaller PV systems (5-50kW)
- Available in the Fall of 2014
- Colocated with Sandia's indoor and outdoor PV module and system laboratories

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Regional Test Center Partnership Opportunities

The RTCs invite manufacturers and integrators of PV and CPV modules, power electronics and other system components, to apply for technical support from the RTC to conduct a validation study for their product or service

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