Transforming the Electric Grid

- ORNL's role in supporting DOE's mission

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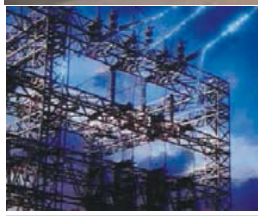
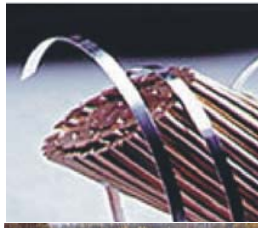
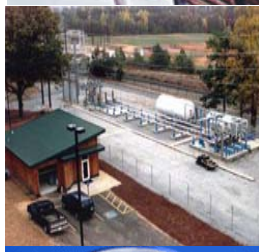
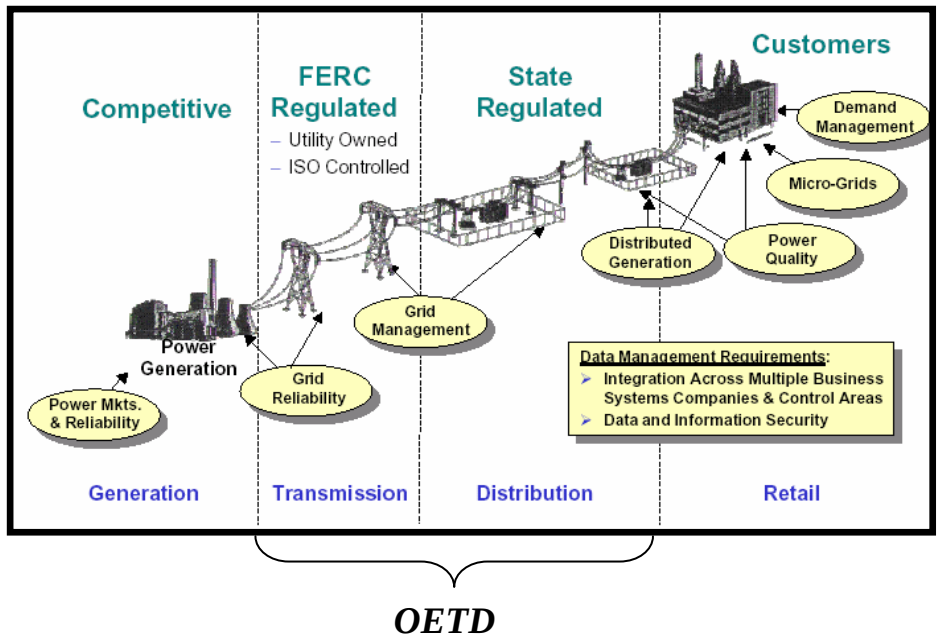




Office of Electric Transmission and Distribution

Mission

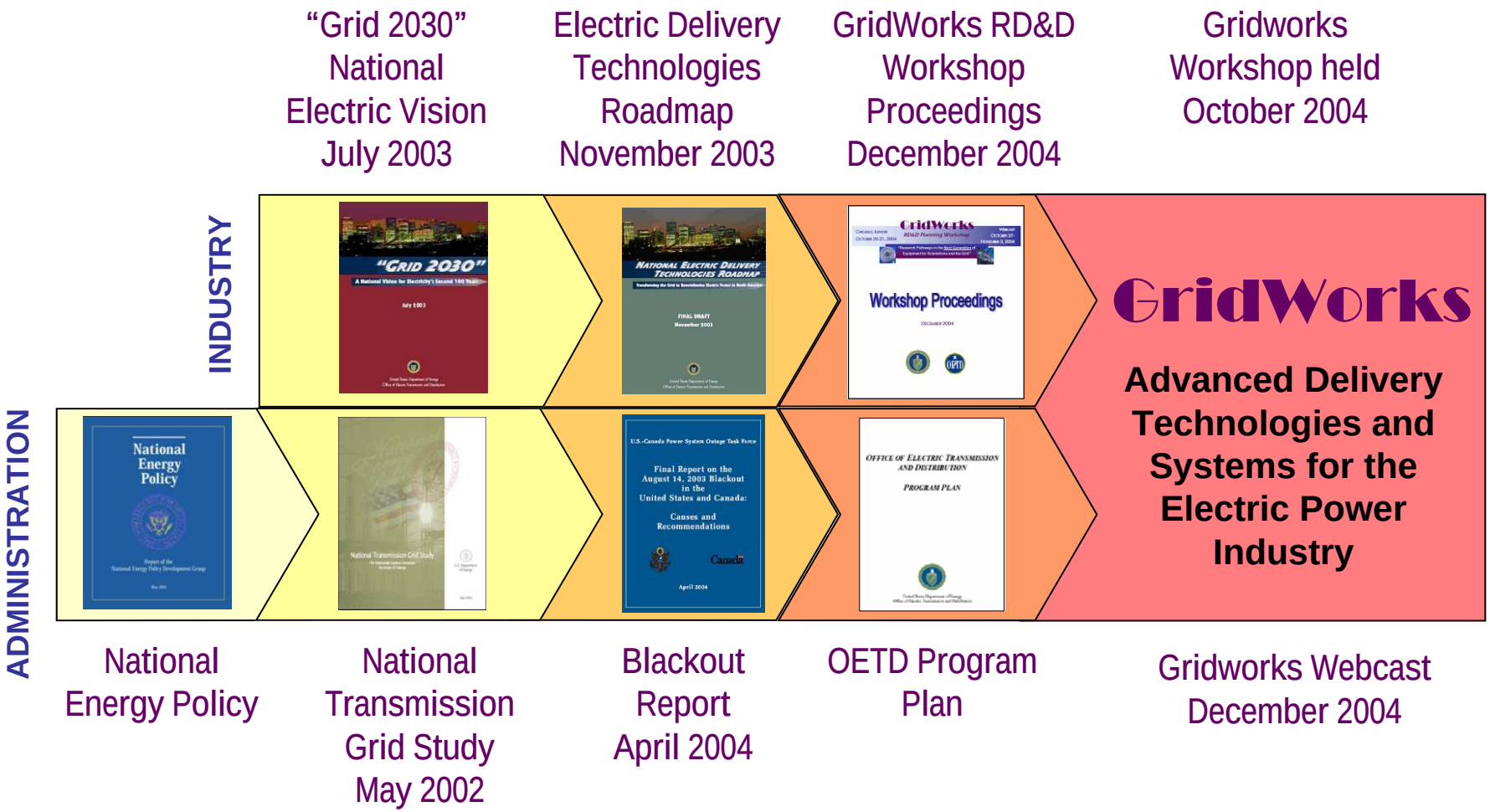
"To lead a national effort to help modernize and expand America's electric delivery system to ensure a more reliable and robust electricity supply, as well as economic and national security"



Department of Energy - Office of Electric Transmission & Distribution

Superconductivity	*High temperature superconducting (HTS) materials for electric power systems.*
Transmission Reliability	*Information technologies, software programs, and reliability/analysis tools to support grid reliability and efficient markets.*
Electric Distribution Transformation	*Interconnection standards and communications and controls to integrate distributed energy with the electric power distribution system.*
Energy Storage	*Energy storage technologies and systems, including batteries, flywheels, and ultracapacitors.*
GridWorks	*Cables and conductors, substation and auxiliary equipment, and power electronics.*
GridWise	*Communications, information, and control technologies to create a smart automatic electric power network.*

Strategic Guidance



GridWorks Initiative

GridWorks takes an <u>integrated perspective of the entire electric system</u>. It is organized to create a cohesive, comprehensive portfolio of equipment that will be introduced into the electric system in a manner that will ensure safe, reliable, and efficient operation.

Cables and Conductors

Advanced Conductors

Next-Generation Cables

Cable Diagnostics

High-Voltage Testing

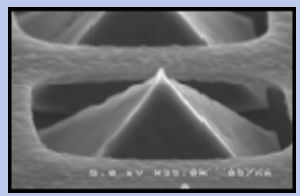
Power Electronics
(Advanced Materials)

Sensors

Solid-State Devices

SiC

Diamond



Substations and Protective Systems

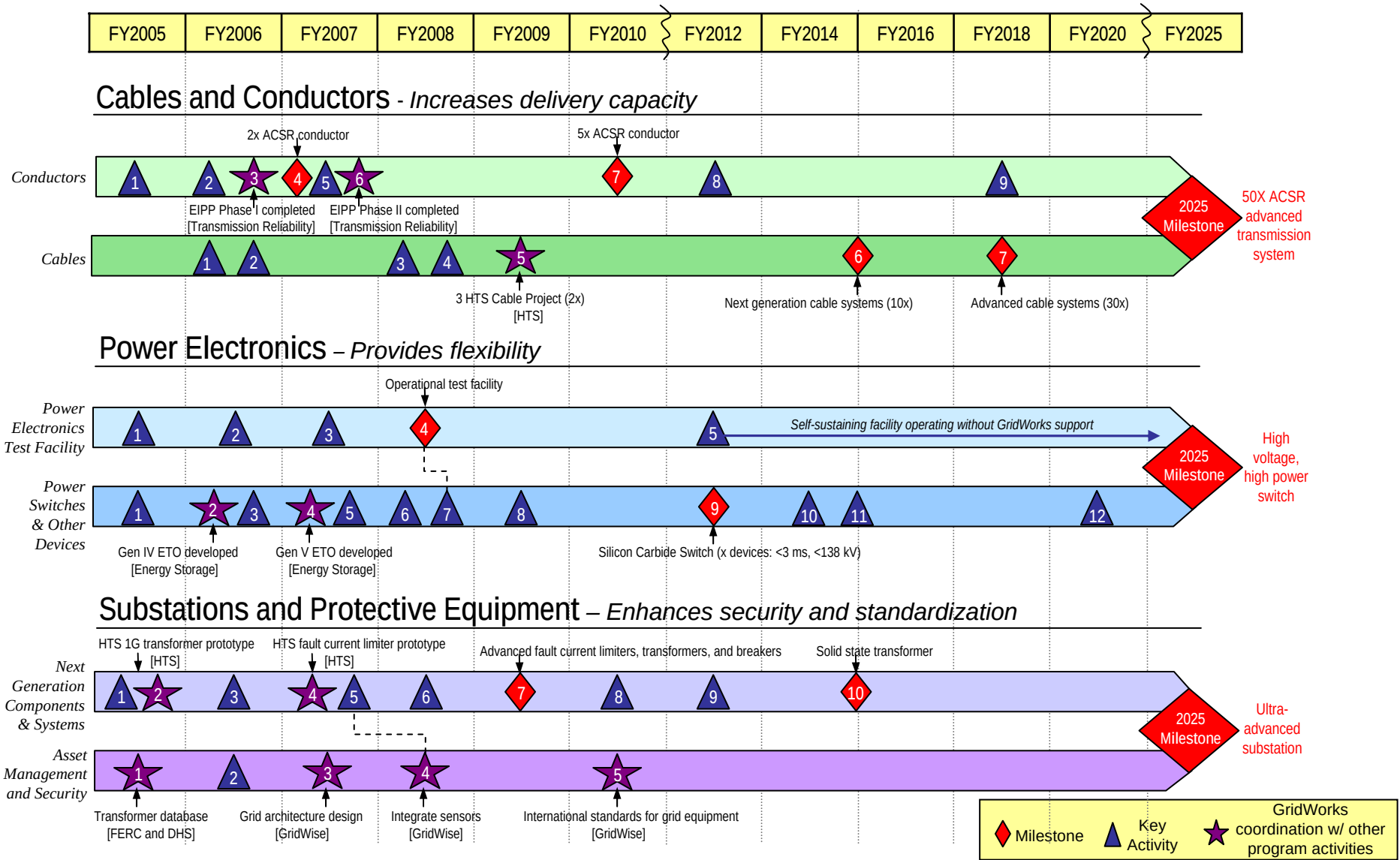
Transformers

Circuit Breakers

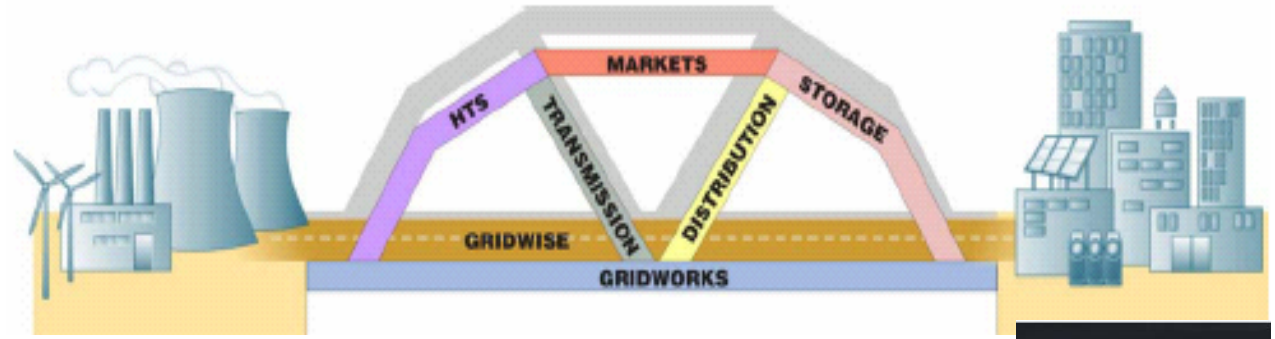
Switchgear

Fault Current Limiters

GridWorks
Milestones and Schedule



Gridworks – A bridge to advancing T&D technologies



- FY 05 - $5.5 Million
- Demonstration and research based program:
  - Cables and conductors – improved core materials
  - Substation and protective equipment – transformer cores, dielectrics, fault current limiters, surge arresters
  - Power electronics – high voltage and current devices, power electronics testbed, SiC-based materials, thermal management
- Planning meeting held in October to establish technical priorities
  - Next meeting – December 15th to lay out program plan

Conductors & Cables

Conductors

- Conduct materials research to increase the transmission corridor power density. Achieve power densities of 50x ACSR by 2025
- Develop overhead conductor to increase capacity by at least 2x with same ACSR characteristics (sag, temp). Achieve power densities 5x ACSR at current costs by 2010
- Demonstrate/showcase installation of high-temperature, low-sag conductors (include value proposition)
- Develop qualification standards for high-temperature, low-sag conductors. Address reliability, environmental concerns
- Install real-time monitoring on transmission to determine real-time ratings and sag to improve capacities and reliability and prevent exceeding clearances – on long lines (100-200 miles)

Cables

- Develop methodology (diagnostics) to assess in-situ condition of underground cable
- Develop less expensive (trenchless) directional boring technologies for new and replacement installations and reduce O&M cost of underground cables

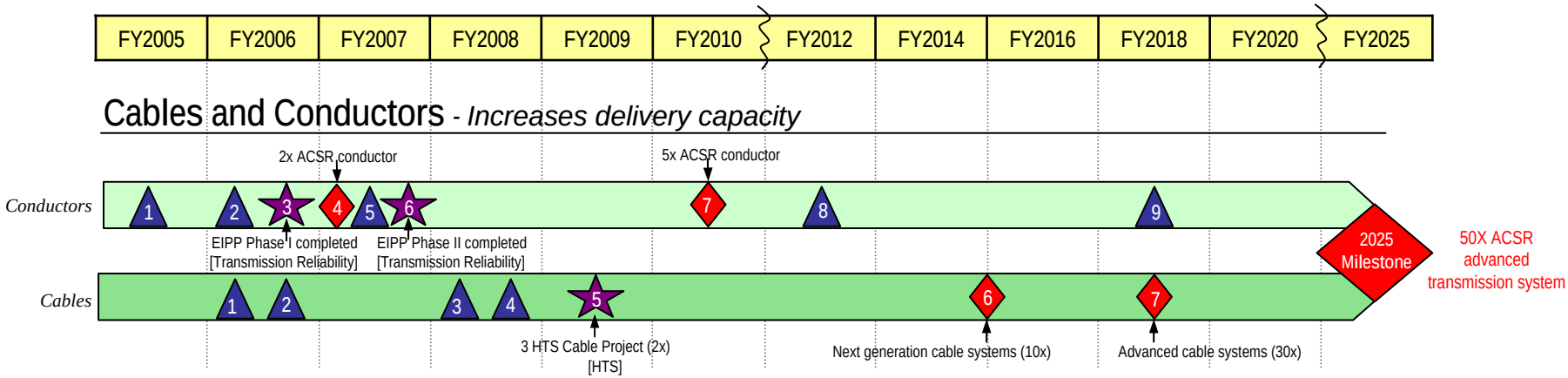
Power Electronic Needs

- **Integrating PE with Power System Operations**
  - Getting devices working in real world environments
  - Better understanding value proposition
  - Significant reduction in costs and improvement in reliability
- **PE Test Facility and Beta Projects**
  - Location, ownership, design, capabilities, and funding
  - Host utilities for field demonstrations
- **Power switches with high voltage, high frequency, high current and power densities, with minimum or no cooling**
  - Better materials
  - Competitive cost-to-value relationship
- **Building Block Converter Units**
  - Easily put in series or parallel – building blocks
  - Controllability
  - Standardization and redundancy = reliability and affordability
  - Easy grid interface
- **Solid State Transformers with Added Functions/Capabilities**

Substations and Protective Equipment Needs

- Develop operational and diagnostics decision support tools for asset management
- Develop inexpensive fault current limiters
- Develop cost-effective, flexible, standard transformers that have a longer life expectancy
- Standards for products, modularity, international protocol for devices, and state-of-the-art substation designs
- Develop low-cost sensors for diagnostic use of substation equipment
- Develop a standard cyber-security method/equipment to allow secure and reliable supervisory control

Cables and Conductors Timeline



OETD Objectives

- *Reliability - Increases delivery capacity*
- *Affordability* - Reduces the needs for new ROW
- *Efficiency* - Reduces energy losses from the transmission system

2025 Milestone
Demonstration of 50x ACSR advanced transmission system

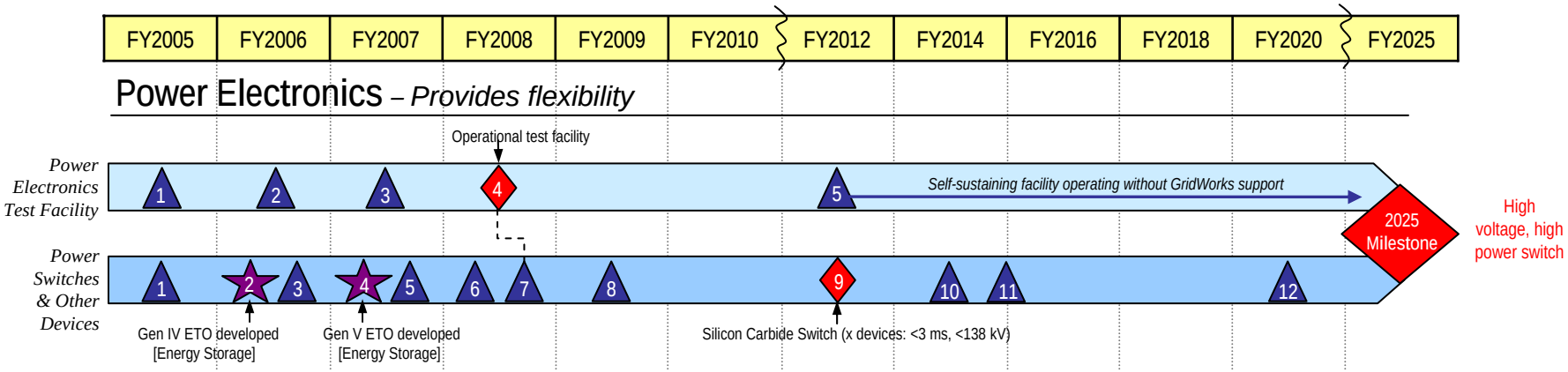
Conductors

2005: Small business innovative research project on sensors
2006: Determine qualification standards for high temperature, low sag conductors
Develop monitoring devices to determine real-time ratings of transmission lines
Initiate advanced materials for insulators
2006: Complete Eastern Interconnection Phasor Project Phase I [Transmission Reliability]
2007: Demonstration of advanced composite conductor that has 2x the power density of ACSR
2007: Initiate advanced materials research for integrated systems that have 50x the power density of ACSR
2007: *Complete Eastern Interconnection Phasor Project Phase II [Transmission Reliability]*
2010: Demonstrate advanced composite conductor that has 5x the power density of ACSR
2012: New materials developed for 50x advanced conductor system
2018: Conduct lab demo or field test of 50x advanced conductor system

Cables

2006: Develop accurate real-time diagnostics for underground cables
2006: Develop cost-effective directional (trenchless) boring for underground cables
2008: Conduct materials research for next generation cables
2008: Develop methodology for in situ cable assessment
2009: Complete demonstrations of 3 HTS Cable Project (2x) [HTS]
2015: Demonstration of next generation cable systems (10x)
2018: Demonstration of advanced cable systems (30x)

Power Electronics Timeline



OETD Objectives

- *Reliability –Provides flexibility*
- *Affordability* - Increases functionality and lowers operations and management costs
- *Efficiency* – Reduces the footprint, while increasing functionality

2025 Milestone

Complete high voltage, high power switch (solid state "breakers")
(x/4 devices: <1 ms, >138 kV)

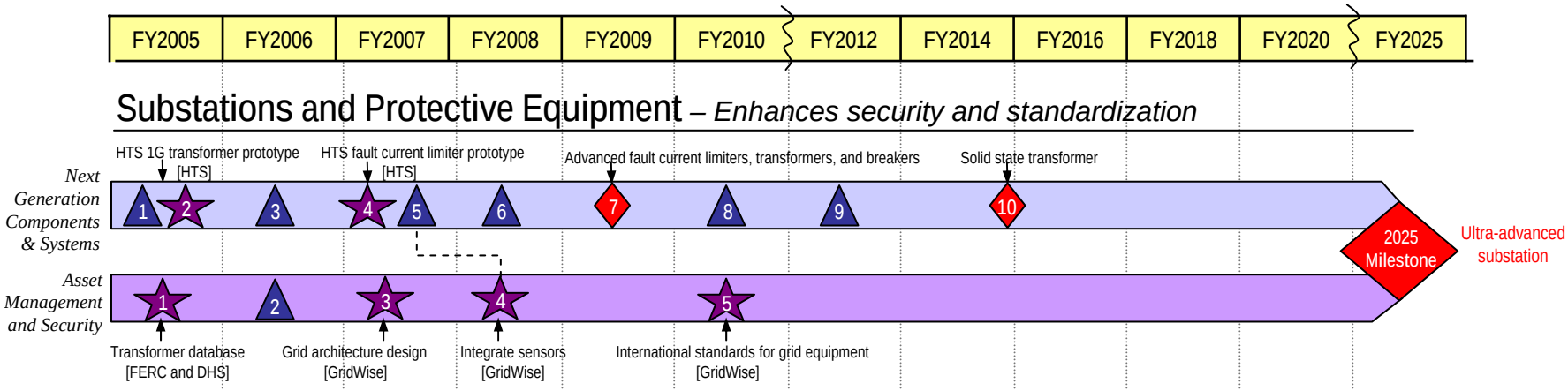
Power Electronics Test Facility

2005: Request for Information (RFI) on power electronics test capabilities
2006: Design power electronics test facility
2007: Begin construction of power electronics test facility
2008: Fully operational power electronics test facility
2012-2025: Self-sustaining facility operating without GridWorks support

Power Switches & Other Devices

2005: Small business innovative research on advanced power electronics and real-time sensors
2006: Gen IV ETO developed [Energy Storage]
2006: Begin diamond research for advanced power switches
2007: Gen V ETO developed [Energy Storage]
2007: Lab development of a silicon carbide switch
2008: Develop power switch "building block" design *
2008: Design "grid shock absorber" devices and field test at host utilities
2009: Field test silicon carbide
2012: Complete silicon carbide switch (x devices: <3 ms, <138 kV)
2014: Aggregation of silicon carbide switches (138 kV)
2015: Demonstrate functionality of building blocks
2020: Field test of power switch

Substations and Protective Equipment Timeline



OETD Objectives

- *Reliability – Enhances security and standardization of system and components*
- *Affordability* - Increases asset management (aging infrastructure)
- *Efficiency* – Increases asset utilization (load factor)

2025 Milestone

Demonstration of ultra-advanced substation utilizing next generation components and sophisticated communication architecture

Next Generation Components and Systems

2005: Initiate materials research
2005: Develop HTS 1G transformer prototype [HTS]
2006: Begin fundamental transformer R&D
2007: Develop HTS fault current limiter prototype [HTS]
2007: Develop add-on sensors to measure critical performance characteristics
2008: Develop embedded sensors for substation components
2009: Demonstration of advanced fault current limiters, advanced transformers, and advanced breakers
2010: Design solid state transformer prototype
2012: Develop a solid state transformer prototype
2015: Complete solid state transformer

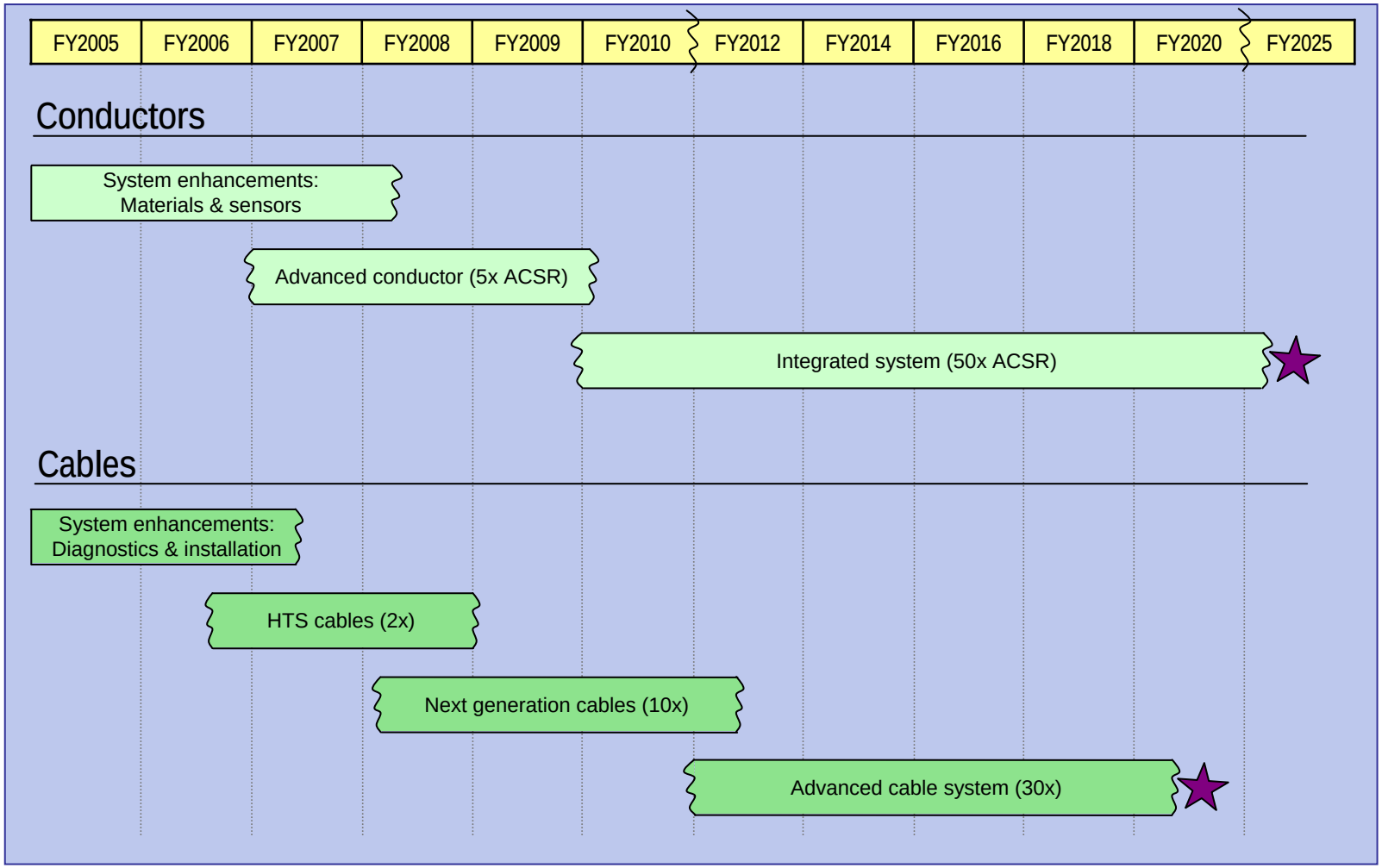
Asset Management and Security

2005: Completion of transformer database [FERC and DHS]
2006: Develop real-time diagnostic tools that can be coupled with programs and algorithms for asset managers
2007: Complete grid architecture design [GridWise]
2008: Integrate sensors with communication/software tools [GridWise]
2010: Develop international standards for grid equipment [GridWise]

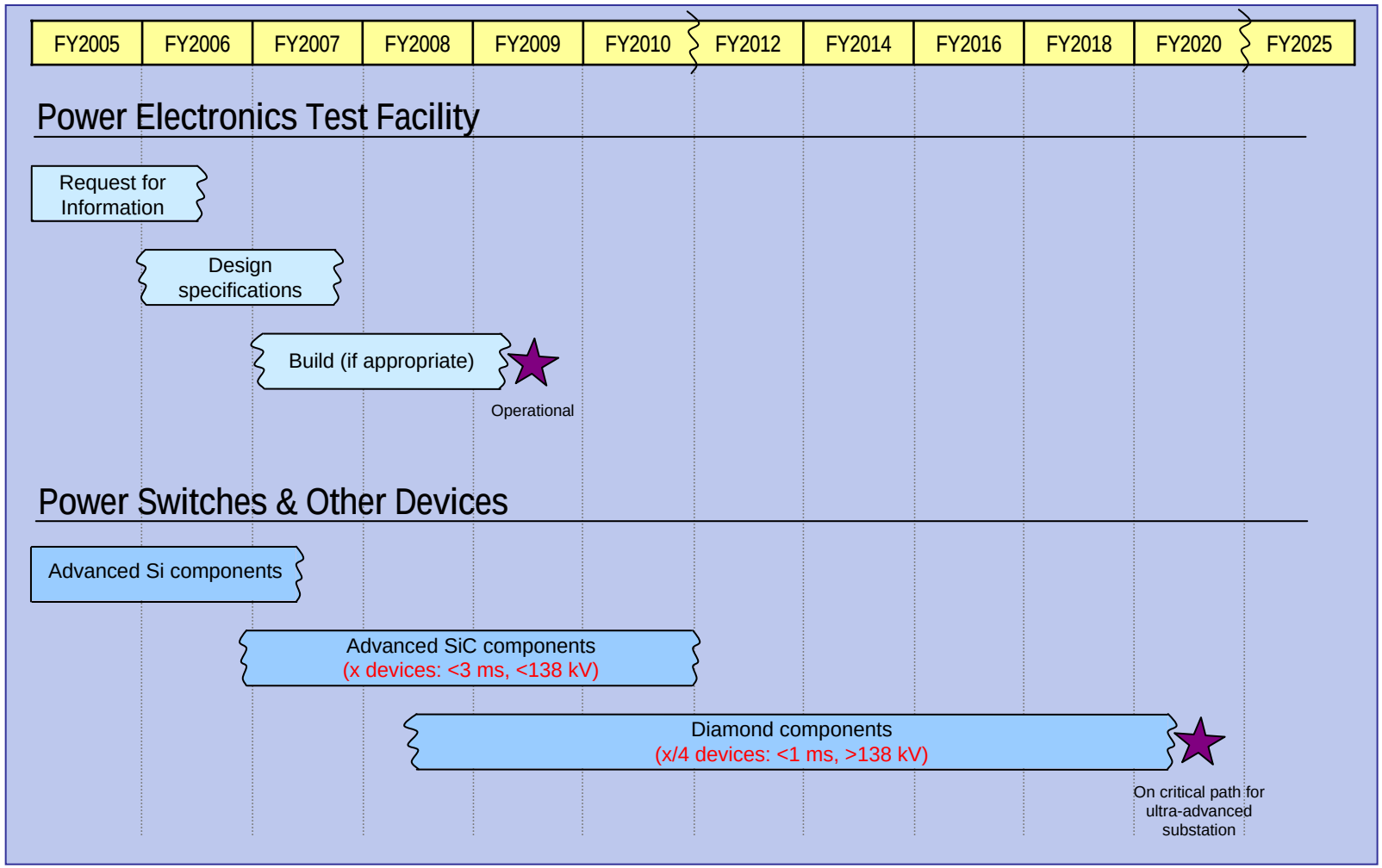
Next Steps

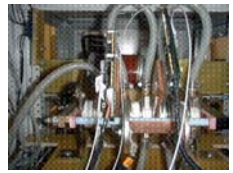
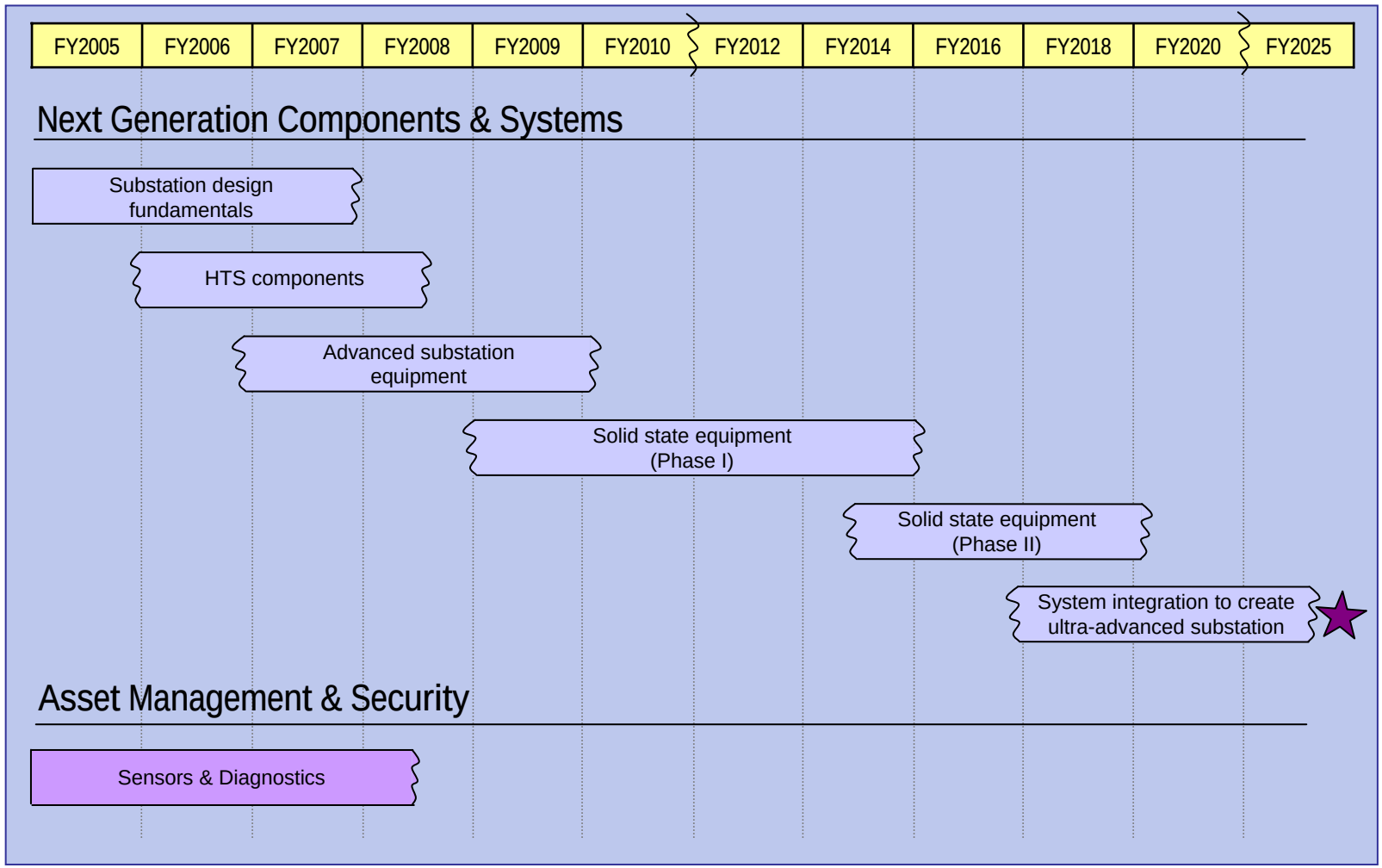
- Project identification
  - Gaps in Dielectrics, Materials for Power Electronics
- Identify partners
  - Utilities – TVA, Navigant consortium
  - Universities – UT Battelle consortium
    - UT, Ga Tech, NC State, Virginia Tech
  - National Laboratories – PNNL, INL, Sandia
  - Industry – EPRI-Solutions, Southwire, AK Steel,etc
- Obtain support from them
  - Letter of support, MOU, CRADA, etc.
- Prepare for Lab Call

Cables and Conductors Detailed Timeline



Power Electronics Detailed Timeline





Substations and Protective Equipment Detailed Timeline