



# DOE/OE Transmission Reliability Program

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## Powerline Conductor Accelerated Testing (PCAT)

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**Washington, DC**

**Current Vendor: General Cable/CTC with E3X coating**



# Topics to Address

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- Overall project objective
- Looking Back:
  - Major accomplishments during the past year (July 2015/project start-June 2017)
  - Deliverables and remaining schedule for activities to be completed under FY16 funding
  - List accepted publications/presentations
- Looking Forward:
  - Outline planned activities and schedule





# Recap - History: Powerline Conductor Accelerated Testing Facility – Why is it here?

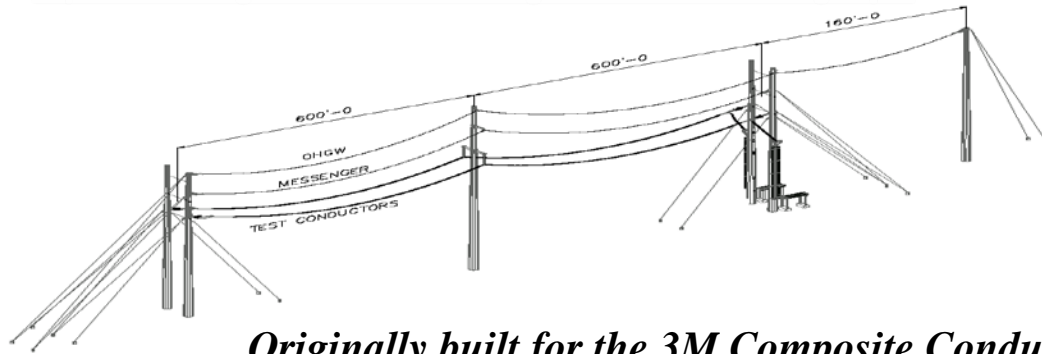
## 2002 - National Transmission Grid Study

- One of the 51 Recommendations -

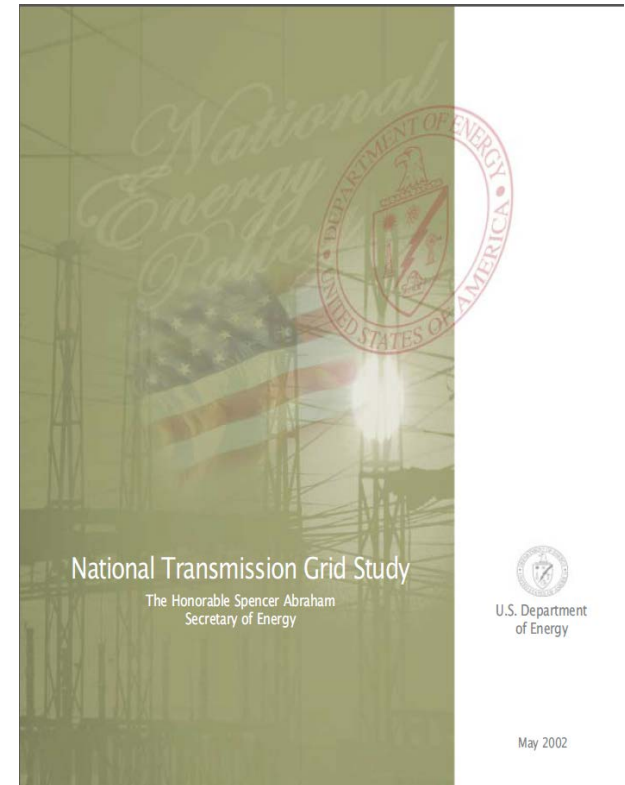
***“DOE will develop national transmission-technology testing facilities that encourage partnering with industry to demonstrate advanced technologies in controlled environments.***

***Working with TVA, DOE will create an industry cost-shared transmission line testing center at DOE 's Oak Ridge National Laboratory (with at least a 50 percent industry cost share).”***

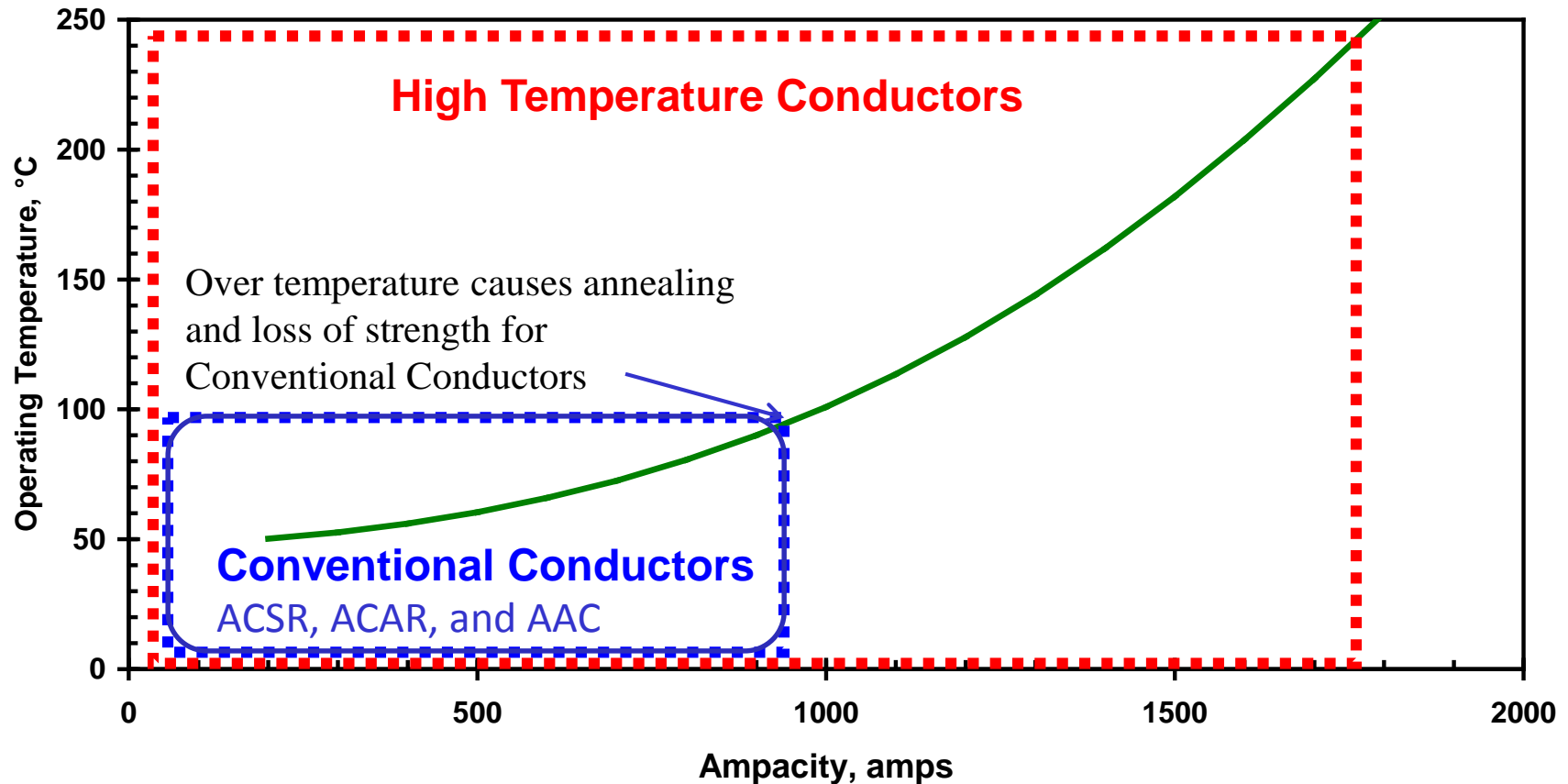
<http://www.ferc.gov/industries/electric/gen-info/transmission-grid.pdf>



***Originally built for the 3M Composite Conductor development, now available for any manufacturer to validate their product.***



# Recap: Driver of higher operating temperatures is higher current ratings



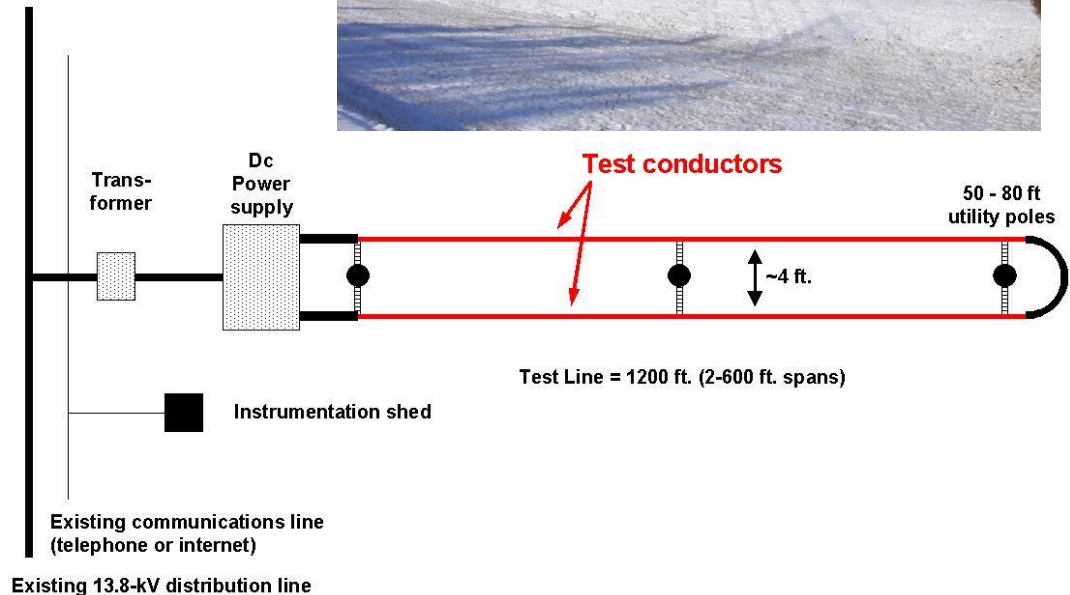
***Need to test / verify new conductors over entire operating range***





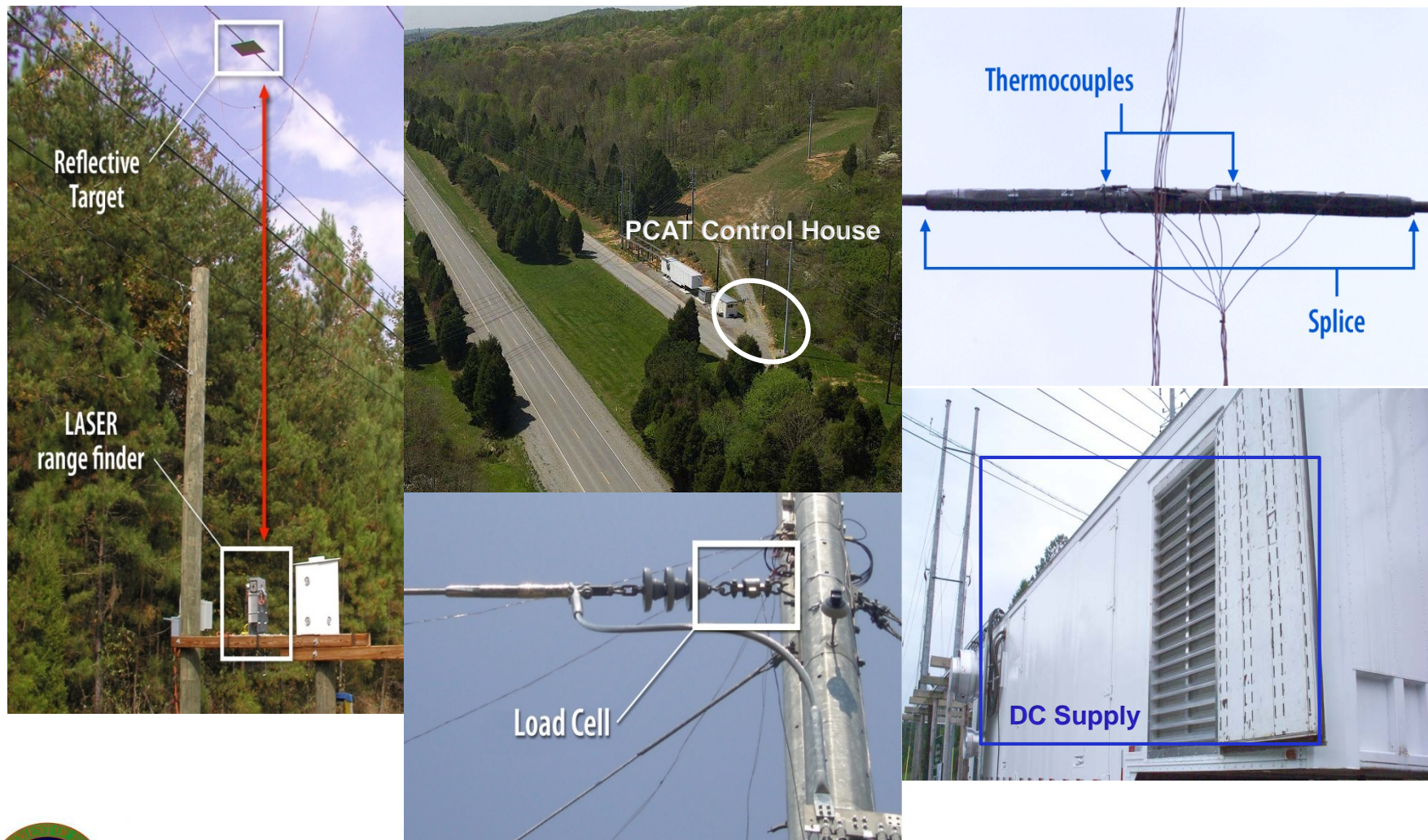
# Recap - Capabilities: Powerline Conductor Accelerated Testing Facility

- Testing Capabilities
  - Thermal / Mechanical Cycling
  - Current / Temperature Ramp
  - Current / Temperature Steps and Hold
  - Controlled current testing
  - Controlled temperature testing
- Facility
  - 2400 feet of conductor
    - two 600 foot spans
    - 3 towers
  - 0 to 400 Vdc
  - 0 to 5,000 Adc
  - Conductor and accessories
  - Tested up to 300°C
    - can go higher if needed





# Recap: Existing Infrastructure





# Recap: Conductors are installed by TVA using conventional industry practices

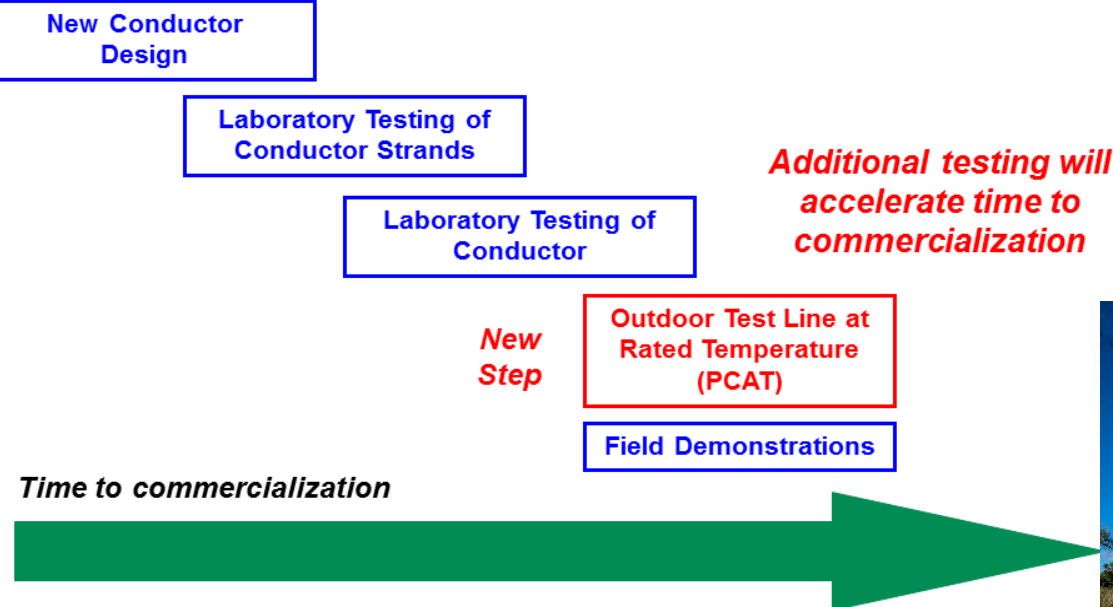


Typical installation is ~ 3-4 days



# Where PCAT fits?

- PCAT provides a unique transmission conductor testing facility to augment utility field tests and demonstrations
- Each conductor test undertaken in collaboration with industrial partner







# Why Industry comes to PCAT

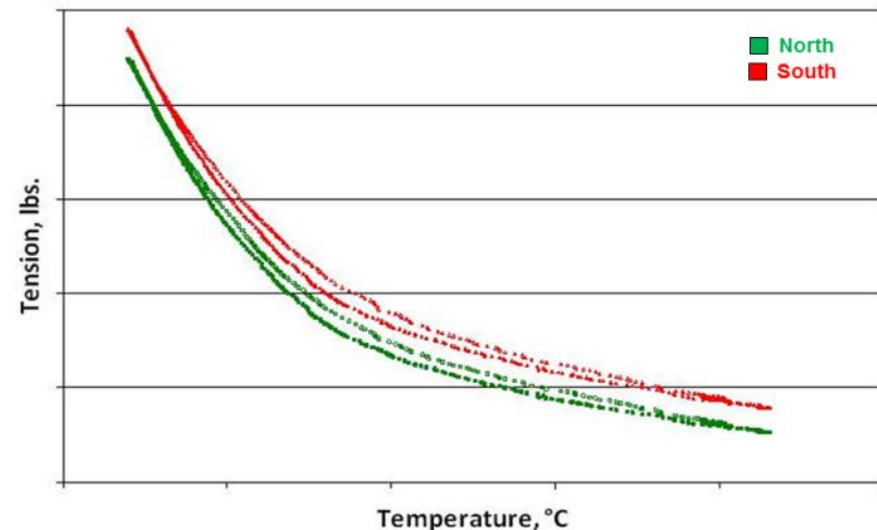
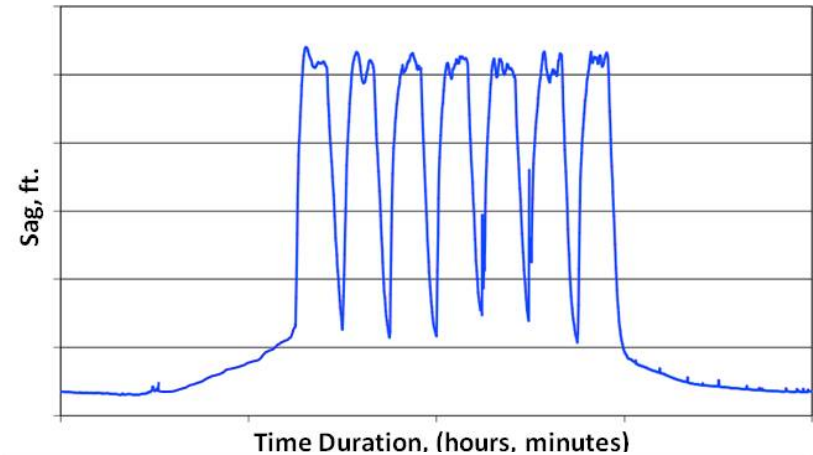
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- Information provided from Underground Systems Incorporated:
  - USi has repeatedly called upon ORNL to utilize the PCAT line over the last 13 years, specifically due to its:
    1. **Uniqueness:** PCAT is the **only** outdoor overhead transmission line test laboratory in North America where line sensor instrumentation can be tested and validated very close to real-world conditions.
    2. **Value:** USi has attempted to utilize other facilities, as well as considering building their own facilities. All of those options were extremely cost prohibitive. The cost of testing at PCAT is more **cost-effective, and provides good value for the services provided.**
    3. **Capabilities:**
      - a. It has the ability to energize the test conductors to extreme temperatures, thereby manipulating the conductor position (i.e. sag) to a high degree. This is very important to successfully validate line sensors.
      - b. It has the ability to instrument the conductor with a large number of temperature sensors to accurately measure the conductor temperature, and therefore the clearance/sag of the conductor, thereby allowing a validation of the USi instrumentation measurements.
      - c. PCAT has a variety of other test, measurement and data logging capabilities which allow testing to be executed in short- and long-term durations lasting anywhere between minutes and years.
    4. **Staff:** ORNL has a **highly experienced staff** fluent in the operation and maintenance of overhead transmission lines, as well as an engineering staff fluent in sensor instrumentation and data acquisition.



# Recap: Past Accomplishments

- PCAT has been in operation for over 10 years
- The PCAT facility has been used to test many different conductors and sensors:
  - 3M 477 kcmil ACCR
  - 3M 675 kcmil ACCR
  - Southwire 1113 kcmil ACSR FO
  - Power Donut2
  - 3M 1272 kcmil ACCR
  - 3M 795 kcmil ACCR
  - Southwire C7 Overhead Conductor
  - General Cable E3X Coated Conductor





# Accomplishments

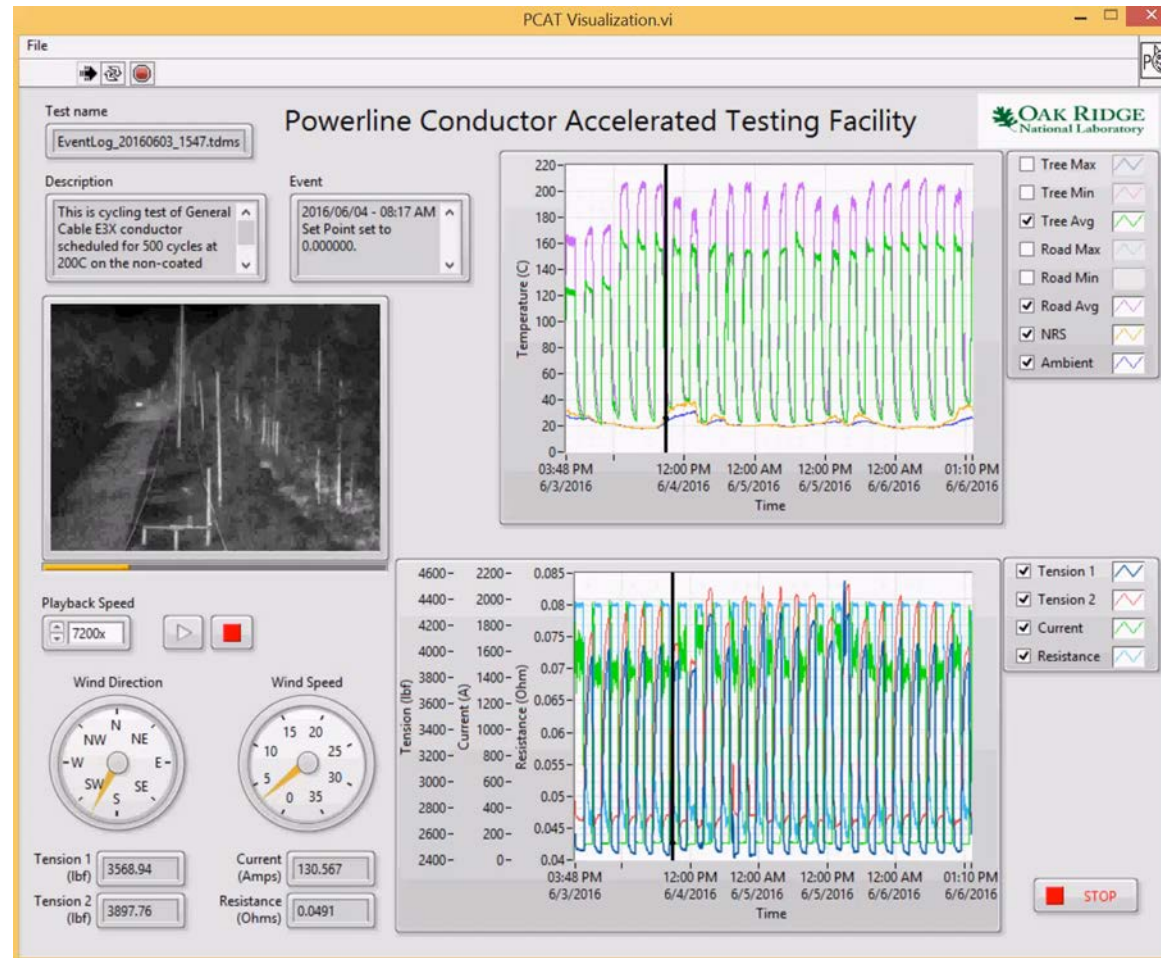
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- Testing and expansion at PCAT
  - Completed testing of General Cable ACSS Drake 795 Conductor
  - Tested USi's Power Donut at end of General Cable ACSS Test
    - Worked with General Cable to support testing before transition to
  - Began testing of General Cable/CTC ACCC E3X Conductor
  - Code created to combine all .tdms data into 1 file for easier analysis of full test





# General Cable ACSS E3X cycling testing



# USi's Power Donut Testing

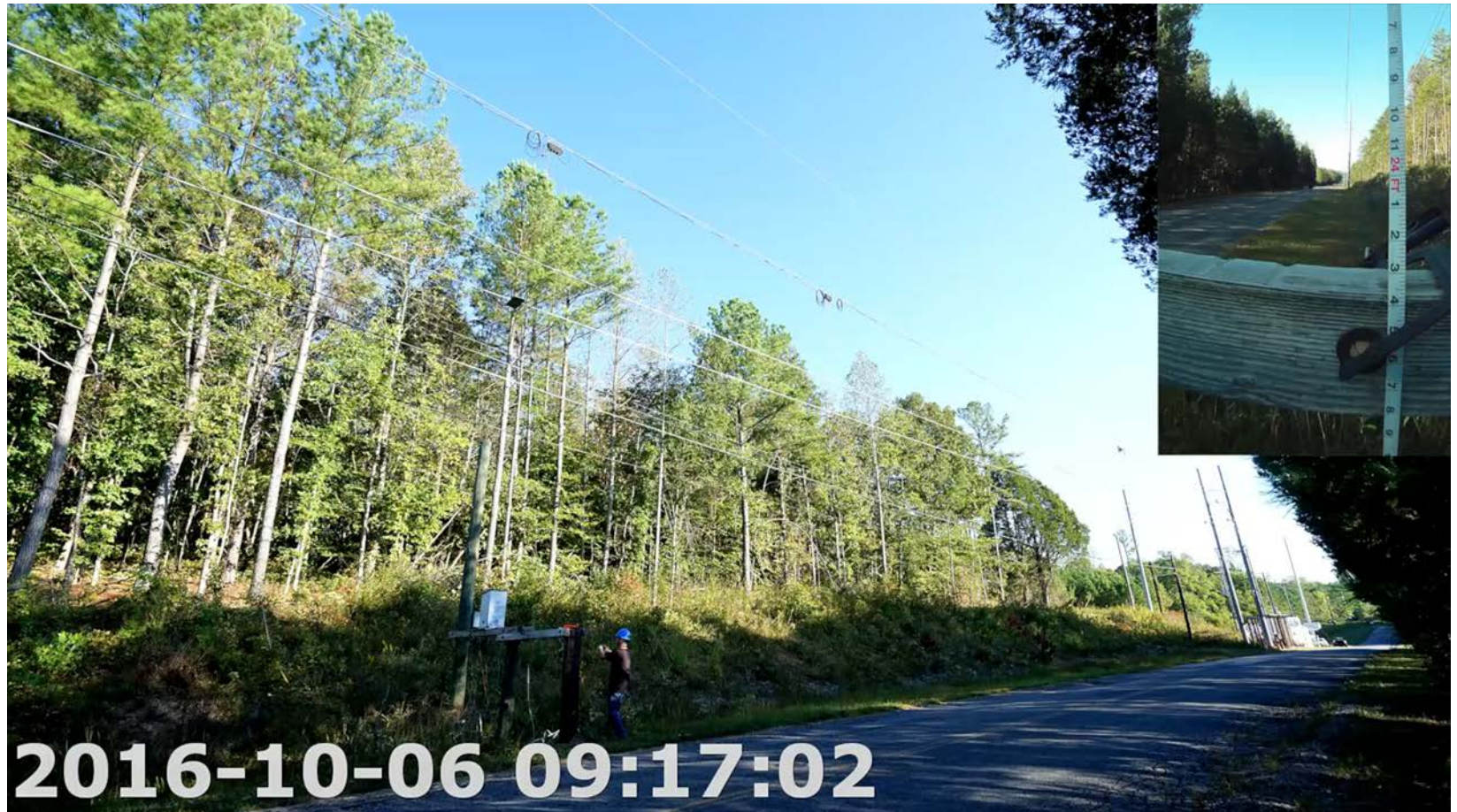
- ORNL successfully ran through a series of tests including:
  - Constant temperature
  - Constant Current
  - Rapid cycling of the conductor
  - Extreme temperatures (250 C on the Power Donut)







# USi's Power Donut Testing





# General Cable/CTC ACCC Installation

- Installation completed successfully
  - 10/2016
  - Included removal of existing General Cable ACSS Conductor



# System Failure – What Happened

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- A failure in the overall control system caused a continuous high current which caused the conductor to burn through.
- When the conductor failed, it resulted in a fire at the test-site



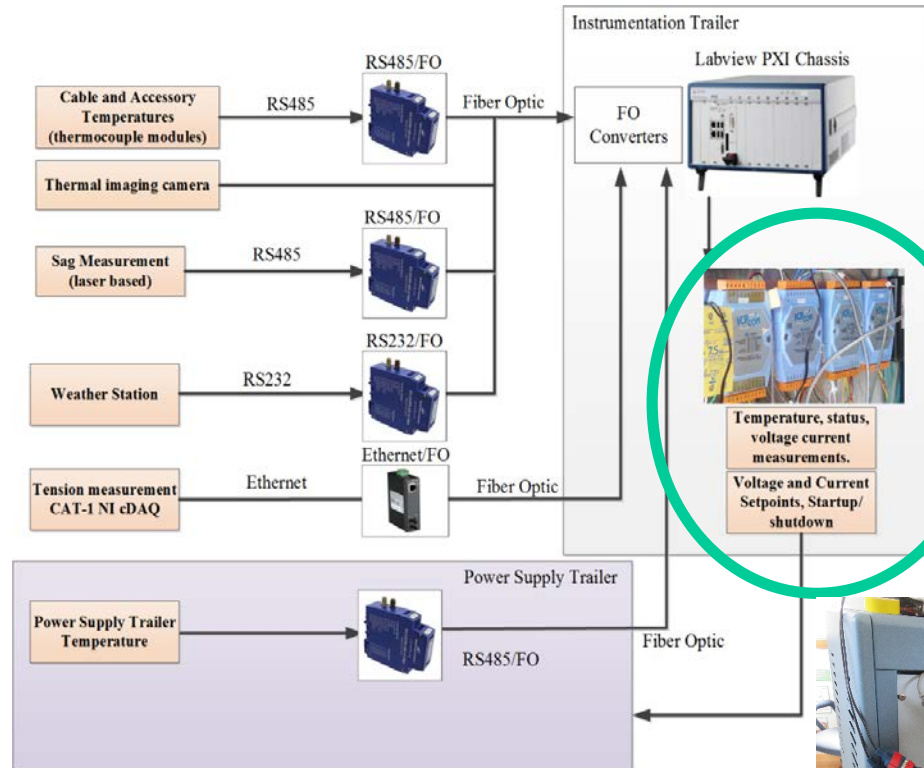
Note: The conductor was not the cause of the failure





# System Failure – Why this happened

- Analog Output module (+/- 10V output) failed in an unusual way (-7Vdc).
  - Results in 5000Amp setpoint
- 12Vdc supply for control modules decreased from 12Vdc down to 7Vdc
  - Below the power-on value for the control modules which shut them all down disabling their watchdog feature and ability to open the relays for the DC supply.



Note: This sequence of failures was highly unforeseeable







# System Failure – Mitigated failure modes

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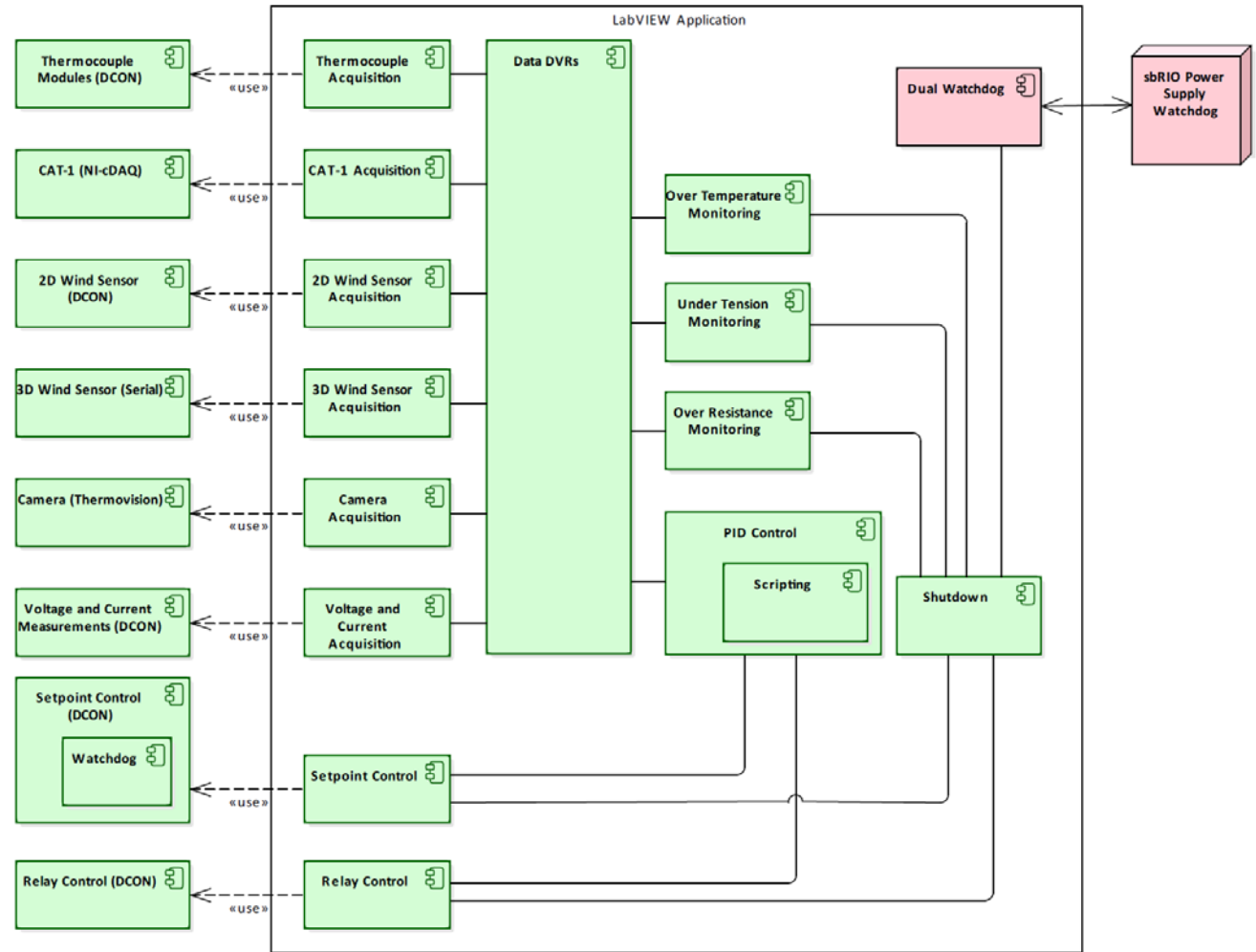
1. Module fails without pulling down the 12Vdc supply
  - Software would've detected communication failure to the one module and opened the relay.
2. Module failed in a 0V mode instead of -7Vdc
  - This would be a 0 current set-point
3. Module failed in a +7Vdc mode instead of -7Vdc
  - This would also be a 0 current set-point
4. 12Vdc supply fails completely
  - Analog output would've been a 0 current set-point
5. Main application exits in a bad state
  - Modules have built-in watchdogs that would've opened the relay
6. Failure occurred 3 minutes later
  - We would've been in an off cycle

Note: Software attempted to open all relays, but with no power was unable to.



# System Failure – Future Mitigation Plan

Complete  
isolated system  
with Normally  
Open relay



# FY17 Plans

- Develop and perform troubleshooting plan
  - COMPLETE
- Develop Mitigation Strategy
  - 6/30/2017
- Implement mitigation plan and perform test procedure
  - 7/31/2017
- Distribute Lessons Learned
  - 7/31/2017
- Re-install General Cable/CTC conductor
  - This is planned for end of July currently
  - General Cable and CTC are confident in the mitigation plans and ready to re-install
- Completion of General Cable/CTC conductor
  - 12/31/2017







# Additional features

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- Integrate 3D wind speed sensor
- Integration of weather forecast
- Integrate rain gauge measurement
- Enhance Real-time controls
- Addition of cloud camera feed
- Addition of end tower voltage
- Additional sensors at end tower
- Conversion of older data to .tdms for comparison



# Q&A

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