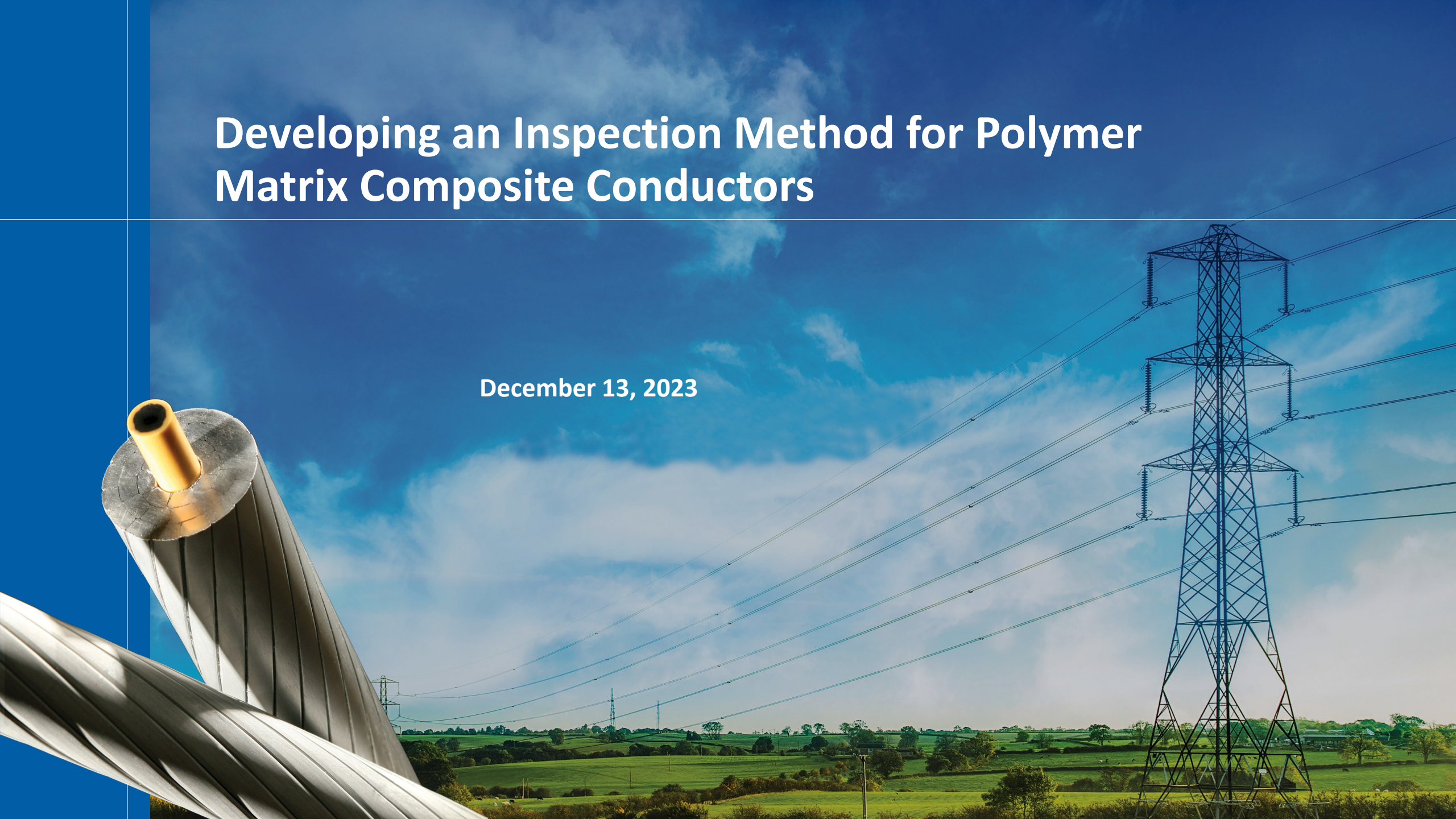
Developing an Inspection Method for Polymer Matrix Composite Conductors

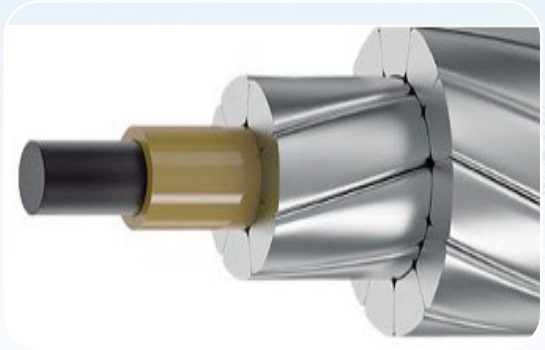
December 13, 2023



Polymer Matrix Composite (PMC) Conductors

- PMC Conductors are installed and used in the grid for 20+ years.
- Industry Concern: There are sources of installation errors that can damage the PMC strength member resulting in a latent defect.
- Managing the Install: knowledge, training and proper installation methods are well documented and deployed.

Still, how do we know an install is flawless?



What's the Problem?

- Conductors prove to be challenging to inspect in the field post installation.

- Expressed Need: Utilities want a method to know the conductor's structural integrity is intact and confirmed after an installation.

- Why?
  - Installation errors can have adverse impact to PMC Conductors.
  - Damage can occur at different stages of the conductor life
  - Current conductor inspection methods do not address all products available and may have limits in efficacy

The Challenge: Market Expressed Need ⟹ Product Addressing the Need

- Can we develop a practical check and ‘know’ the conductor integrity status?
- What does it take to ‘prove’ it?
- Good Ideas VS Commercialized Solutions – Product Development Process*

Engaged Cross-Functional Organization

* Product Development References:
- The PDMA Handbook of New Product Development, Rosenau
- Four Practical Revolutions in Management, Shiba
- Design for Six Sigma: A Roadmap for Product Development, Yang

Stand-up the Right Solution – Ideation through Business Case

Ideation | Business Case

- New products require significant company investment – limited resources
  - Require a commercial responsive solution at the end of the process

- Investigated Signal Sensor Technologies to Inspect Composite Strength Members
  - Researched and Developed four different feasibility prototypes; test cases, efficacy, cost, ease of deployment, supportability…..
  - Intense Focus on inspectable PMC. R&D to get to a Technology Readiness Level (TRL) Stage 4. Validated the use case, primary function and performance of system with prototypes.

- Know what Excellent Outcomes look like – Work Backwards and Define ‘It’
  - Marketing Requirements – define the expressed market needs
  - Engineering Requirements – define the product capabilities
  - Does the product capabilities address enough of the marketing requirements to be viable?

Cross Functional Engagement and Commitment

Ideation

Business Case

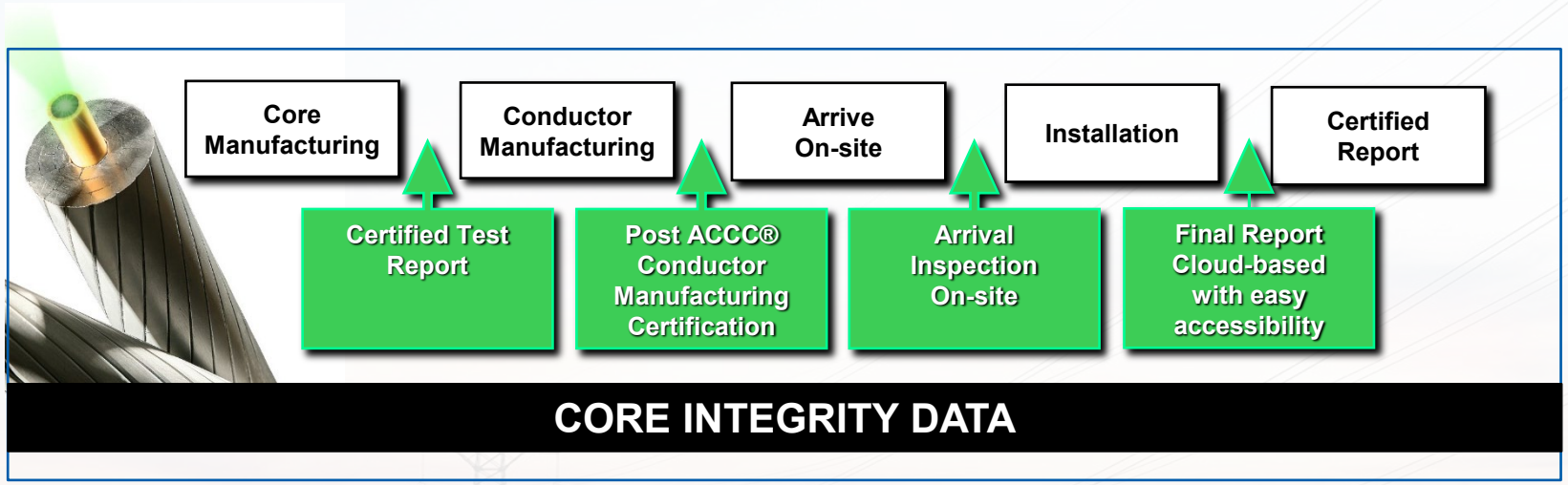
Requirements

Inspection System

Industry Standards and Functional Requirements

Company Competencies and Processes to Execute

Confirmation Data Tracking



Design/Development

- Heavy Analysis
  - Hypothesis of Function
  - Analytical Proof of Function
- Design and Develop – Physically Demonstrate Proof of Function to Requirements.

Design, Development, Manufacture and Test Verification

Manufacture

Design, Development, Manufacture and Test Verification

- Design the Manufacture Process Method
- Confirm Consistent Manufacture Outcomes - Attributes about the Sensor and Core
- Scalability – Build Inspectable core strength member at any factory, globally
- Re-Tool Factories for new product
- New Quality Requirements about core and equipment – Processes, Methods and Checks

Test Verification – Significant Effort

Design, Development, Manufacture and Test Verification

Two Year Test Program: Core, Manufacture Process, Inspection Capability, Data Base Reporting / Governance

- Inspectable PMC the same as incumbent PMC
  - ASTM B987
  - IEC 62818
- Damage Detection Capability from Factory to Field Conditions
- Large Body of Reports documenting the testing, results and conclusions
- Manufacture Method Verification
- Inspection Equipment
- Data Cloud Verification

Field Tests – Pilot Lines

Design, Development, Manufacture and Test Verification

Performed Two Field Pilot programs

- Instruction / Service Manual
- Operator Training
- Time required to perform confirmations
- Field Condition Realities
- First Attempt Test Results
- Timely Decision Process in the Field

Field test realities informed us on improvements needed for commercial deployment.

- Customer Transparency
- Improvement Action list
- Do the work and Implement the Improvements (and prove them out)

Pre-Launch

Pre-Launch

- Is the Company Ready?
  - Sales
  - Commercial
  - Operation
  - Quality
  - Services
  - Engineering
- Each group has deliverables to coordinate a proper product launch

Launch, Feedback and Improve

Launch, Production, Support

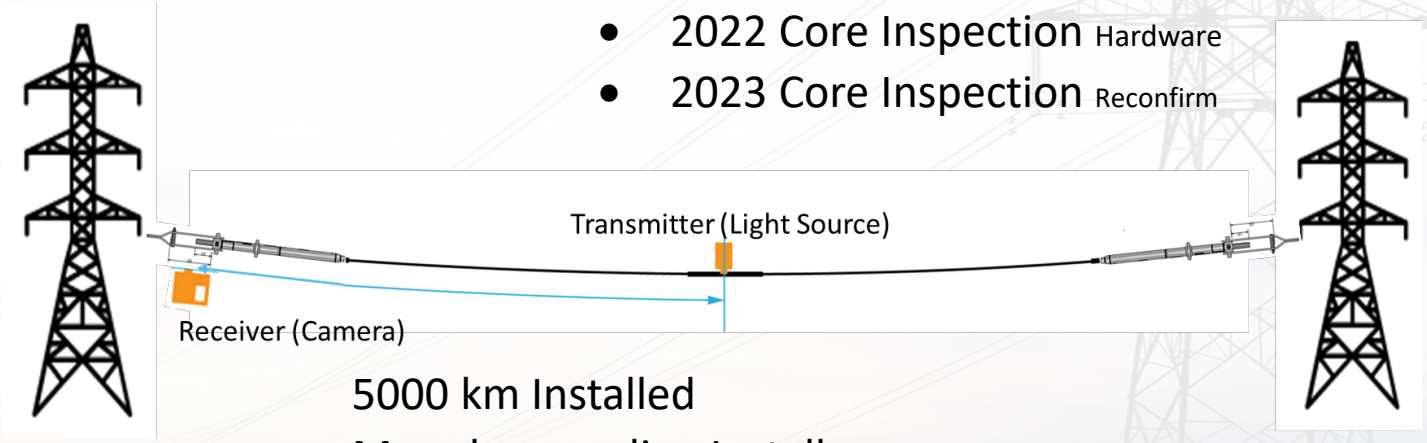
Field Trials led to specific improvements for our first official installation

- Equipment
- Manufacture Process
- Getting Data to the Cloud and Reporting
- New feature requests

System capable of Inspection:

- Installed to Line Pull
- Post Install after Dead-ending
- Inspection when outages are available
  - Following storms
  - Tree or debris strike
  - Planned maintenance

- 2020 Core Inspection System
- 2022 Core Inspection Hardware
- 2023 Core Inspection Reconfirm



5000 km Installed

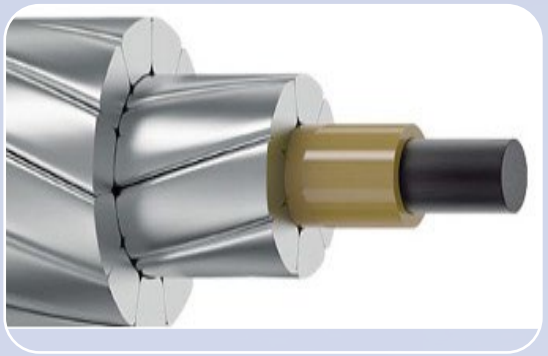
More km pending Install

Greater Adoption Occurring

Lessons Learned

- Executive buy-off on requirements and scope critical.
- Product Development is not an Engineering Function. It is a Company Function.
- Leading the team to engage in quality development work through formulation of hypotheses and proving/disproving rather than Hyperbole.
- Have the team united in their approach to problem solving – improves communication and focus on the right topics (recommend Kepner Trego method).
- Transparency with key customer stakeholders

About CTC Global



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>13,000km Europe
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Questions?