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- Expertise: Carbon Nanotube Fiber (CNTF) conductor technology, characterization and system modeling; Synthesis of raw CNTs and conversion to CNTF in high speed roll to roll processing

- Expectations:
  - Understand System Level design opportunities for CNTF to simplify Underground T&D power conductors installation – how may this **ENABLE?**
  - Reduce Total Cost of Ownership (install, upgrading capacity, repairs) and failure modes
  - Evaluate Degrees of Freedom increase for equipment and system design with new material set

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How may a new Power Conductor Material with highly different properties and improvement ongoing impact Underground T&D Design, Installation and Equipment Systems?

- Will tremendous weight difference enable longer cable runs with CNTF? Significantly REDUCE number of splices….Enable improved pulling machines….
- CNTF is **very strong and rugged** – how does a rethought system design and equipment use this effectively? Ultimate tensile strength (Pulling strength) is **order of magnitude beyond** current tech – Stronger pulls with LIGHTER cables
- CNTF Thermal conductivity is higher with potential to be multiples of Al or Cu – Improved ampacity, more resistant to overheating, temp spikes
- CNTF Processed like a textile – **HOW** do we **re-think** splicing processes and equipment to simplify, remove human error, decrease failures
- **Highly impervious to most chemicals including water – its all Carbon**
- Carbon surface may lend to unique chemistries for insulation methods

Comparison of Conductors for Undergrounding T&D

Performance Metric	Al Aloy 1350	Cu Alloy	CNTF (current)	CNTF (potential)
Density	2.7	8.9	1.9	1.5
Tensile Strength (Gpa)	0.115	0.21	4	20
Electrical Conductivity (MS/m) 25°C	35	58	11	75
Thermal Conductivity (W/m-K)	234	350	450	1000
CTE x 10^{-6} / °C	24	16.6	1	1
Linear Density @ 2000 A	4.6	10.6	6.8	1
Susceptibility to Chemicals/Corrosion/Oxidation	mid - high	mid - high	Little to none	Little to none
Young's Modulus (GPa)	62	110	260	500

Potential significant Manufacturing/installation Advantages in UG

Multiple form Factors to enable New conductor and Neutral wire designs

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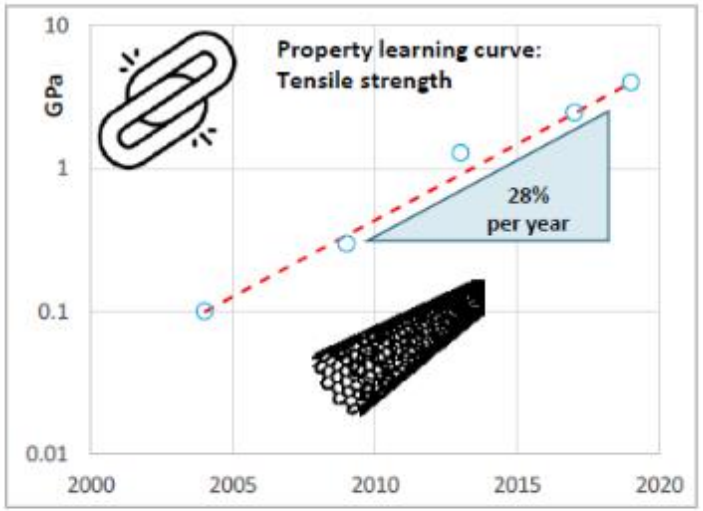
- How do We Translate New Properties to Improved Install and Performance?

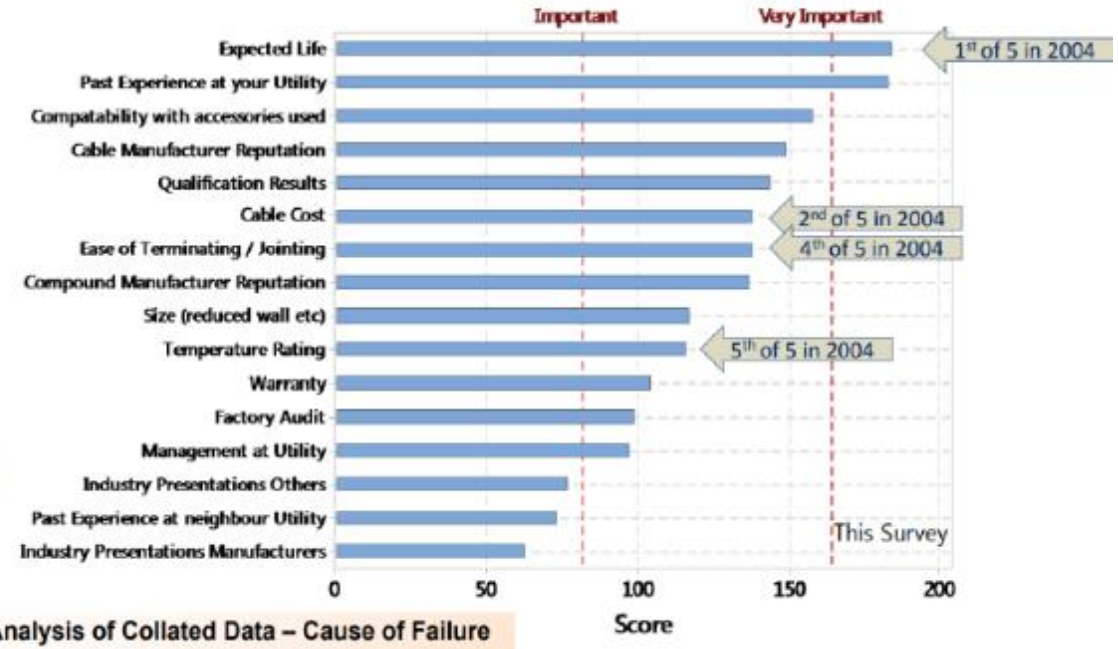


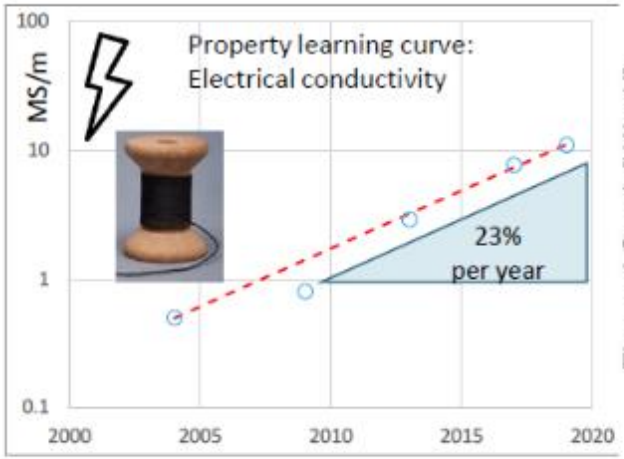
In 2004, Flexibility Was a Major Choice

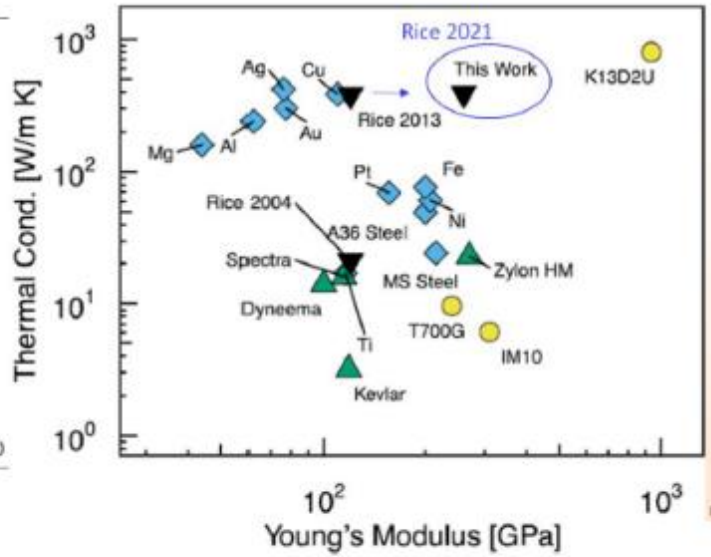
What is relationships Between Conductor Material Properties and Total Cost of Ownership?

Do we have a Pareto Analysis Of Install Cost Factors, Complexity To Conductor Material?

* Factors for Cable Choice - 2014

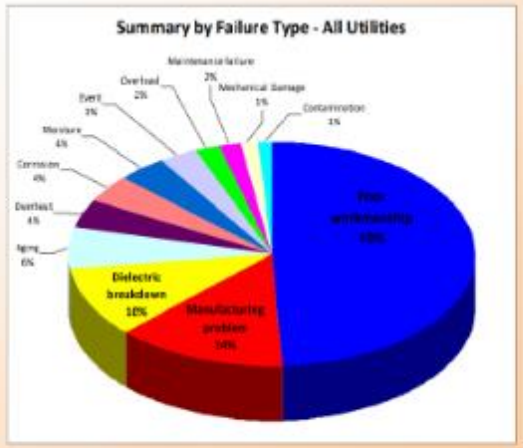




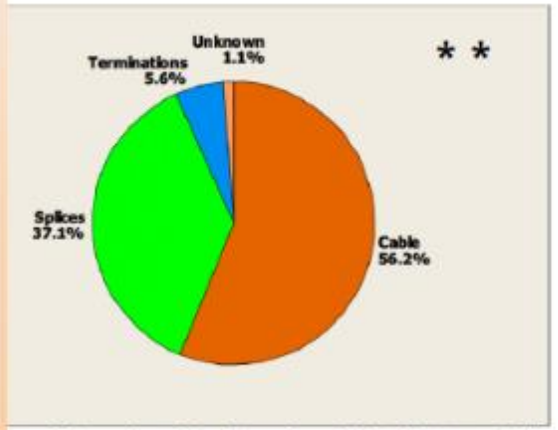


L. W. Taylor, O. S. Dewey, M. Pasquali, et al., *Carbon*, 2021

Analysis of Collated Data – Cause of Failure



Fall 2010 ICC Education Session



**uated Dispersion of North American MV Cable System Failures by Equipment Type as Reported by Utilities

***Evolution of MV Cable Designs from 1993 to 2014**
Essay Wen Shu and Nigel Hampton, 2018 NEETRAC

****Medium Voltage Cable System Issues, NEETRAC, 2016**
Cable Diagnostic Focused Initiative Phase II