CABLE Conductor Manufacturing Prize

Prize Voucher Capabilities Menu

The Conductivity-enhanced materials for Affordable, Breakthrough Leapfrog Electric and thermal applications (CABLE) Conductor Manufacturing Prize will identify, verify, and reward affordable breakthroughs in conductivity that will enable U.S. manufacturers to leapfrog to next-generation materials.

July 2022

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1. Introduction

You are now competing in the Stage 2 Contest for the chance to win cash prizes and a $100,000 voucher to be used during Stage 3 for services at a U.S. Department of Energy (DOE) national laboratory or approved facility in the American-Made Network. Voucher-supported work provides you with the opportunity to develop, test, and validate your innovation at national lab and/or private facilities. Voucher-supported services allow your team access to experts, new networks, and third-party validation, which may support and augment your broader funding efforts (public and/or private). To complete your Stage 2 submission package, you must identify the lab(s) you would like to use your voucher to work with, should you win one.

Why now?

The process of developing relationships, scoping potential work, and finalizing contracts to conduct work can be lengthy, which is why you must begin the process in advance, even before you know whether you are a Stage 2 contest winner.

If you become a finalist, you will only have a limited time (anticipated 7 months) in Stage 3 to get your final material sample ready for Stage 3 testing and your submission materials finalized, so the requirement to coordinate use of the voucher ahead of time is to your benefit.

2. Voucher Opportunities

If you are a finalist Stage 2 Winner, you will receive:

- $100,000 to be redeemed at national lab and/or private facilities in the American-Made Network (not to be split more than three ways, minimum $10,000 at a single VSP).
- Access to national lab expertise, testing, and validation, and other resources to advance your solution.
- Sustained partnership and resources beyond the prize competition (subject to funds and contractual partnership with the lab and/or private facility).

If you have any general questions or would like help with the voucher process, please reach out to the CABLE Conductor Manufacturing Prize email.

Do I have to accept a voucher if I am a Stage 2 winner—what if I don't need any services?

Although a small part of your score is based on your voucher slide submission, you are allowed to refuse the voucher award if you have concerns about working with a third party on your CABLE Conductor Manufacturing Prize material. If intellectual property (IP) is your primary concern, we encourage you to review the cooperative and development research agreements (CRADA) in the Voucher Guidelines (which can be requested from the Prize Administrator at CABLEprize@nrel.gov). The CRADA agreement addresses how IP is handled for each national laboratory. For higher technology readiness level CABLE Conductor Manufacturing Prize materials, we encourage you to consider the marketing benefits of having a well-known lab characterize your Stage 3 sample using advanced technologies. If you still have concerns about using your voucher in Stage 3 or would like to explore how you can best use vouchers to your advantage, please reach out to the CABLE Conductor Manufacturing Prize email.

Please note: Competitors must submit a completed Voucher Statement of Work for Prize Administrator review within 30 days of the announcement of the Stage 2 Contest winners. Failure to do so may result in forfeiture of voucher funds. Vouchers will expire 1 year after the winners of the Stage 2 Contest are announced. Vouchers cannot be redeemed for cash and may not be transferred to other parties.

3. Voucher Process

Your team is responsible for identifying your technical needs and coordinating those needs with the network to redeem your voucher. In particular, **it is your responsibility to ensure you submit a voucher slide** (see Appendix A) **as part of your Stage 2 submission package that outlines: (i) your choice of national lab or facility and a point of contact for each; and (ii) the activities that will advance your prototype, which is due on Dec. 1, 2022, by 5 p.m. ET.**

Step 1. Identify your technical needs to advance your prototype.

Step 2. Review offerings and capabilities provided by the American-Made Network. While only some national labs and Connectors have provided capabilities we deem to be relevant to the CABLE Conductor Manufacturing Prize (detailed in Appendix B of this document), you are free to choose any lab or network member. Additionally, you should review the Voucher Guidelines, which answers questions related to the voucher redemption process. If you have additional questions, please reach out to the CABLE Conductor Manufacturing Prize email.

Step 3. Depending on your needs, determine if you would like to work with a national lab and/or a private facility in the American-Made Network. Follow the respective steps noted below.

Step 4. Discuss your needs with a national lab and/or private facility in our network. We suggest allowing at least 1 month to explore each facilities' capabilities and discuss potential voucher-supported work, especially if you are working with a national lab. This means that, by late October/early November 2022, you should be starting or in a conversation with a lab and/or facility to determine best fit; earlier is better!

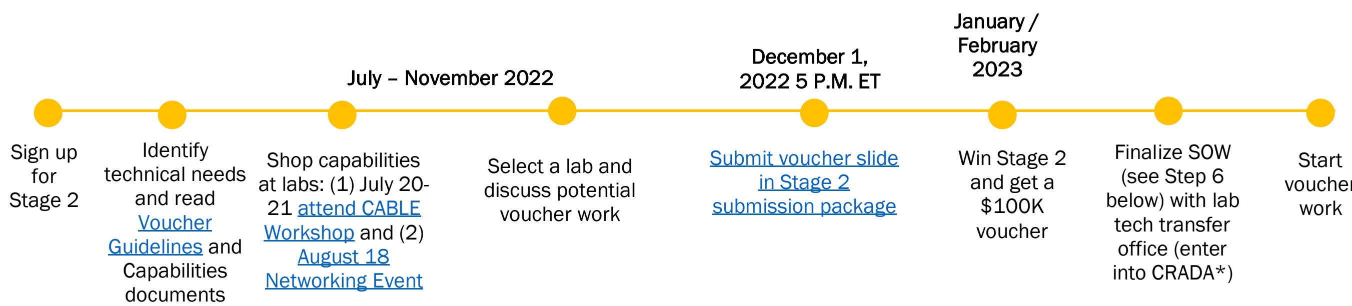
To help with voucher matchmaking, the CABLE Conductor Manufacturing Prize Administration team is hosting two events:

- The CABLE Big Idea Workshop: Attend the CABLE Conductor Manufacturing Prize Workshop July 20–21, 2022, in person at Argonne National Laboratory near Chicago, Illinois, or virtually to learn more about national lab capabilities and engage with the broader CABLE Innovation Ecosystem. *Note: if viewing this document after July 21, 2022, a recording of the CABLE Workshop will be available at the link above.*

- The CABLE Prize Virtual Voucher Networking Event: On Aug. 18, 2022, 12:30–2:30 p.m. ET, we will have representatives from national labs and the American-Made Network in attendance to discuss your innovations and begin making connections for your team's voucher-supported work.

Step 5. Finalize your voucher slide and include this in your Stage 2 submission package, due on **Dec. 1, 2022**, by 5 p.m. ET for evaluation by the reviewer panel. Remember 6 points of your competition score is based on the quality of your voucher slide.

4. Process To Work with a National Lab



*CRADA required for voucher work at NREL.

Step 1. Sign up as a Stage 2 competitor in the CABLE Conductor Manufacturing Prize and identify your technical needs for the next phase of competition and beyond.

Step 2. Read the CABLE Conductor Manufacturing Prize Voucher Guidelines as well as the information presented in this Voucher Capabilities document.

Step 3. Familiarize yourself with national lab capabilities in the following ways:

- Start the process early. We suggest being in contact with national labs by **late October 2022** at the latest. Review your technical needs and peruse lab and/or private facility capabilities provided in Appendix B to determine which lab(s) has the capabilities that meet your technical needs.
- Reach out directly to your candidate lab(s) by contacting the respective lab's Voucher Representative(s) (*see Appendix B*). These people will help route you to an appropriate lab researcher. After the Voucher Representative introduces you to the appropriate lab researcher(s), set up an initial substantive phone call (e.g. 30–45 minutes) to include the following:
  - Your explanation of the conductor material, manufacturing, or marketing problem you are attempting to solve and your ideas for a solution
  - Why their capability is helpful in advancing your proposed solution
  - Anticipated tasks/deliverables for associated voucher-supported work
  - Your intended budget for allocating voucher funding (include additional prize or team cash, if desired).
- Participate in the CABLE Conductor Manufacturing Prize Workshop (July 20–21, 2022) and the CABLE Prize Virtual Voucher Networking Event (Aug. 18, 2022).

Step 4. Narrow down your Voucher Service Provider (VSP) choices to what can reasonably be accomplished with $100,000 at the lab(s) you would most like to work with. While you are free to pay for additional services, such arrangements need not be made at the time of your Stage 2 application. Coordinate potential voucher-supported work and anticipated tasks. Transfer tasks and costs to a voucher slide. An example slide is in Appendix B and a template can be found on HeroX. Ensure that you specify the lab/facility researcher or principal investigator (PI) you intend to work with and provide contact information.

Step 5. Include your voucher slide in your Stage 2 submission package, due on **Dec. 1, 2022, by 5 p.m. ET.**

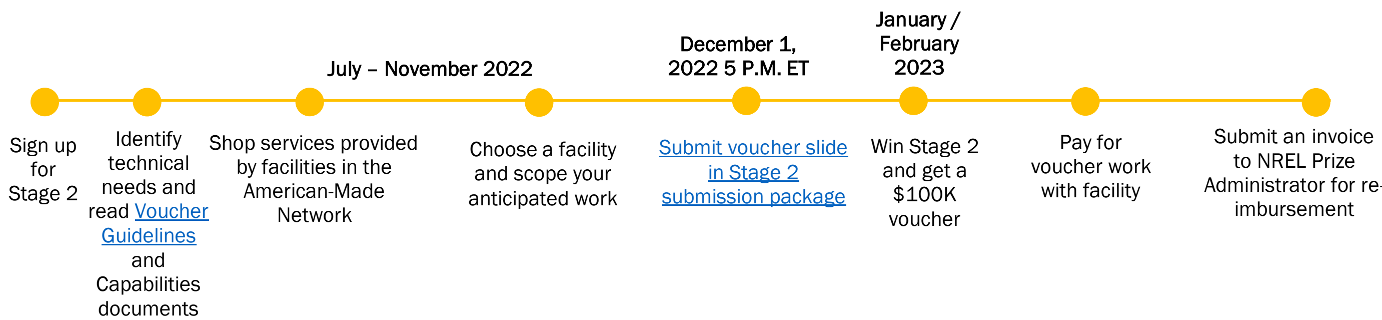
Step 6. If you are a winner, your lab(s) of choice will immediately provide the required CRADA, statement of work (SOW), and any other required documents to your team upon winning the Stage 2 Contest by your selected national lab and/or private facility (see appendices of Voucher Guidelines). Once you receive this, immediately set up another meeting with your lab/facility PI to fill out the complete required documentation.

For voucher work with the National Renewable Energy Laboratory (NREL), you have 1 month to finalize your Joint Statement of Work (JSW) after winning Stage 2. Please submit your finalized JSW to the CABLE Conductor Manufacturing Prize email, which will be forwarded to the NREL technology transfer office. From there, you will enter into a CRADA so that work can commence.

For voucher-supported work with other national labs, send your SOW to the lab's Voucher Representative (see below lab capabilities on pages 11-30). They will work directly with you to put an agreement in place between your team and lab of choice.

Step 7. After the agreement and/or CRADA has been signed, begin voucher-supported work.

5. Process To Work with a Non-DOE Laboratory Facility in the American-Made Network



Step 1. Sign-up as a Stage 2 Competitor in the CABLE Conductor Manufacturing Prize and identify your technical needs for the next phase of competition and beyond.

Step 2. Familiarize yourself with services provided by facilities in the American-Made Network in the following ways:

- Go to the American-Made Network webpage.
- Identify facilities you'd like to work with by region or capability. Create an account on the Networking Matching Tool and reach out via the "message" button to start conversations.
- Reach out to the American-Made Network team for additional assistance.
- Alternatively, you may seek out new providers and have them join the American-Made Network as a new Connector and CABLE Prize VSP Service Provider (see Voucher Guidelines for additional information on this process).

Step 3. Narrow down a choice facility with which you would like to work. Coordinate potential voucher-supported work, anticipated tasks, and associated costs. Transfer tasks and costs to a drafted SOW.

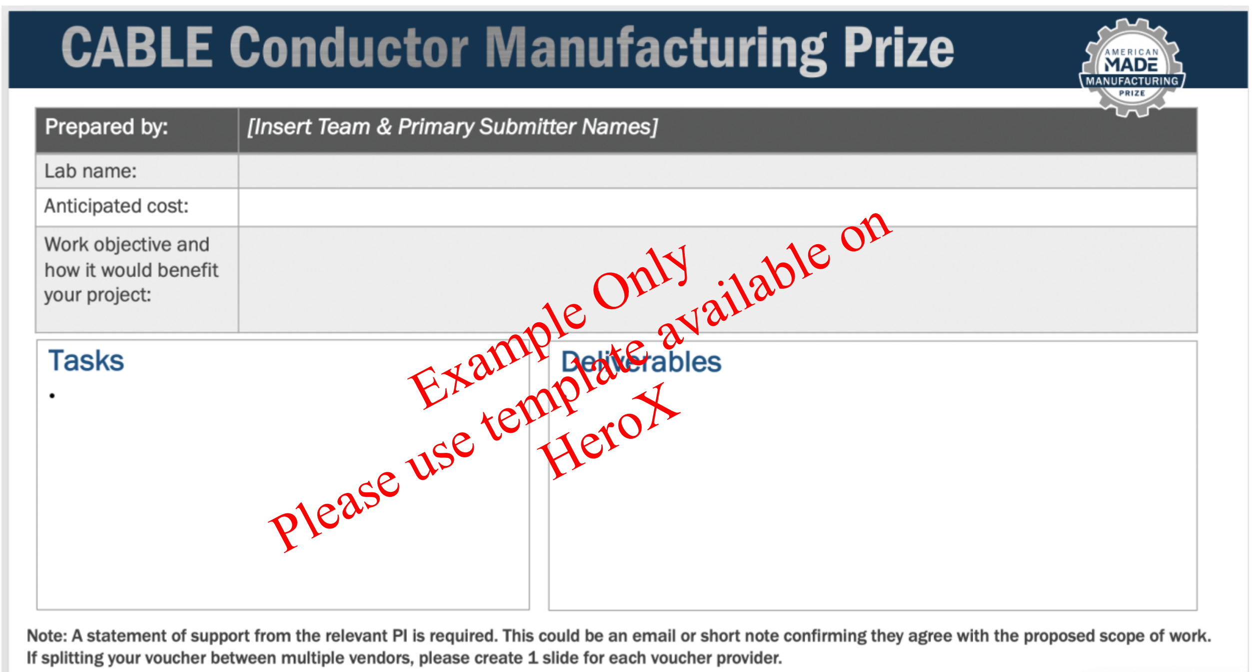
Step 4. Include your anticipated scope of work in your Stage 2 submission in your Voucher Work Slide, due on Dec. 1, 2022, by 5 p.m. ET.

Step 5. Should you win Stage 2, finalize your SOW with your choice facility. Fund and conduct the work using prize money or any other money you have available. See the Voucher Guidelines for more details.

Step 6. After work has been completed, submit an invoice to the Prize Administrator for reimbursement.

Appendix A. Voucher Slide

Include a complete voucher slide in your Conductivity-enhanced materials for Affordable, Breakthrough Leapfrog Electric and thermal applications (CABLE) Conductor Manufacturing Prize Stage 2 submission package, due on Dec. 1, 2022, by 5 p.m. ET, with the below information. A template for the Voucher Work Slide is available on HeroX.



Appendix B. Select Lab Capabilities

This appendix provides overviews of select U.S. Department of Energy (DOE) national lab and other American-Made Network member capabilities, categorized by topic areas considered to be highly relevant to the Conductivity-enhanced materials for Affordable, Breakthrough Leapfrog Electric and thermal applications (CABLE) Conductor Manufacturing Prize. Additional information and specific applicability of national lab capabilities to individual projects can be discussed with the Technical Representative(s) identified for each lab. The table below provides an "at-a-glance" summary of lab capabilities.

If you win a Stage 2 voucher, you will be required to coordinate with the Technical Representative(s) at your selected national lab(s) to complete a detailed Statement of Work (SOW) for the voucher work as well as any other requirements (such as a cooperative and development research agreements [CRADA] or statement of work [SOW]). Once the SOW is completed, submit it to the Prize Administrator (CABLEprize@nrel.gov) with indications of approval by both the competitor and the national lab.

At-a-Glance Lab Capabilities

Capability	National Laboratory						AMN Network
	Ames	Argonne	PNNL	NETL	NREL	SNL	Prysmian
Electrical Characterization	X	X	X			X	X
Imaging		X	X		X	X	
Mechanical Characterization	X	X	X	X	X	X	X
Metallurgical Characterization	X	X	X	X	X	X	
Metallurgical Processing	X	X	X	X		X	
Structure Characterization	X	X	X		X	X	
Superconductivity-specific Measurement		X				X	
Thermal Characterization	X	X	X		X	X	X
Theory, Modelling, Simulation		X	X		X	X	
Other		X				X	X

Ames National Laboratory Capabilities

Voucher Technical Representative: Dr. Nicolas Argibay (nargibay@ameslab.gov)

Location: Ames, Iowa

About the Lab

Ames National Laboratory is a government-owned, contractor-operated national laboratory of the U.S. Department of Energy (DOE), operated by and located on the campus of Iowa State University in Ames, Iowa. For more than 70 years, the Ames Laboratory has successfully partnered with Iowa State University and is unique among the 17 DOE laboratories in that it is physically located on the campus of a major research university. Many of the scientists and administrators at the Laboratory also hold faculty positions at the University and the Laboratory has access to both undergraduate and graduate student talent.

Ames National Laboratory is a global leader in the discovery, synthesis, analysis and application of new materials, novel chemistries and transformational analytical tools. They conduct fundamental and applied research that helps the world to better understand the nature of the building blocks that make up our universe, and translate that knowledge into new and unique materials, processes, and technologies that advance the nation's economic competitiveness and enhance national security. Through multi-institutional collaborations, industry partnerships, and technology licensing, Ames Laboratory has a proven track record of transitioning basic energy science through early-stage research to commercialization

Facilities

- Materials Preparation Center (MPC)
- Sensitive Instrument Facility (SIF)

CABLE-Specific Capabilities Overview

Ames Laboratory has expertise in the development of materials and process solutions for a broad range of problems, including electrical, magnetic, and structural alloys and composites. The Materials Processing Center has wire drawing and other extensive processing capability, and there is extensive microscopy, mechanical, thermal, and electrical property testing at the coupon level.

Capability	Available
Electrical Characterization	X
Mechanical Characterization	X
Metallurgical Characterization	X
Metallurgical Processing	X
Structure Characterization	X
Thermal Characterization	X

Additional Information on Capabilities

Electrical characterization: Coupon-level electrical resistivity measurements via 4-wire system

Mechanical characterization: Micro and nanoindentation, tensile testing (including wire specimens), scratch testing, friction and wear testing

Metallurgical characterization: Extensive microscopy capabilities, including the SIF's SEM, AC/STEM, and FIB, x-ray diffractometer

Metallurgical processing: MPC offers a wide range of services for those involved in metallurgical, materials science and engineering, materials chemistry, and materials physics involving the use high purity rare earth metals, high purity alloys and intermetallic compounds, and single crystals. With capabilities ranging from small-scale arc casting and single crystal preparation to ingot casting with vacuum induction melting (VIM), casting and plasma melting (PAM), this breadth of capabilities positions MPC to assist research groups in many areas. MPC is not a production facility; we specialize in preparing lab scale alloys and can cast ingots up to 5" in diameter by 17" long. Post alloying MPC can fabricate samples to specific forms with rolling, swaging, wire drawing, and EDM cutting. With metallography, analytical, and characterization resources to complement our fabrication capabilities, MPC is capable of addressing projects from many directions. All services are provided on a cost recovery basis.

Structure Characterization: EDS (Energy Dispersive X-Ray Spectroscopy), EBSD (Electron backscatter diffraction), EELS (Electron Energy Loss Spectroscopy), SAXS (small angle x-ray scattering), Raman Spectroscope, other X-ray based tools (e.g., XPS-ESCA XRD, XPS)

Thermal properties: Differential scanning calorimeter with up to 1500°C range.

Argonne National Laboratory Capabilities

Voucher Technical Representative: Aaron Fluitt (afluitt@anl.gov)
Location: Lemont, IL

About the Lab

Argonne is a multidisciplinary science and engineering research center, where talented scientists and engineers work together to answer the biggest questions facing humanity, from how to obtain affordable clean energy to protecting ourselves and our environment. Ever since the lab was born out of the University of Chicago's work on the Manhattan Project in the 1940s, Argonne's goal has been to make an impact — from the atomic to the human to the global scale.

The laboratory works in concert with universities, industry, and other national laboratories on questions and experiments too large for any one institution to do by itself. Through collaborations here and around the world, Argonne strives to discover new ways to develop energy innovations through science, create novel materials molecule-by-molecule, and gain a deeper understanding of our planet, our climate, and the cosmos.

Argonne congratulates the CABLE Prize Competitors and looks forward to working with them to advance their discoveries toward commercialization.

Facilities

- Advanced Photon Source (APS)
- Argonne Leadership Computing Facility (ALCF)
- Center for Nanoscale Materials (CNM)
- Materials Engineering Research Facility (MERF)

CABLE-Specific Capabilities Overview

Argonne offers a comprehensive set of capabilities to CABLE Prize Competitors, covering both superconductors and non-superconductors, conductivity and non-conductivity property measurement, and applications of new materials.

Capability	Available
Electrical Characterization	X
Imaging	X
Mechanical Characterization	X
Metallurgical Characterization	X
Metallurgical Processing	X
Structure Characterization	X
Superconductivity-specific Measurement	X
Thermal Characterization	X
Theory, Modelling, Simulation	X
Other	X

Additional Information on Capabilities

Electrical characterization: Capabilities in conductivity, resistivity, ampacity, dielectric strength, and operational voltage/current range. Specific tools include an electrical probe station, I-V, C-V, precision current source, nanovoltmeter system, signatone probe station, source meter. Experts include Jeff Elam, Balu Balachandran, Jeff Eastman, and Matt Highland.

Imaging: Capabilities include SEM, TEM, HR-STEM, STM, AFM, APT. Specific facilities include the Advanced Photon Source. Experts include Andrew Chuang, Jeff Elam, and Dileep Singh.

Mechanical characterization: Capabilities include tensile and yield strength, fracture toughness, and creep resistance. Experts include Dileep Singh.

Metallurgical characterization: Capabilities in microstructural analysis (size, shape, alignment), secondary phase contamination, compositional analysis, and chemical surface probes. Specific tools include an optical microscope, two XRD systems, XPS, and XRF. Experts include Jeff Elam, Balu Balachandran, and Dileep Singh.

Metallurgical processing: Capabilities in thermo-mechanical processing (e.g. cold-working), annealing, and powder atomization. Specific tools include sputter deposition of Cu, C, and other species, furnaces, and a vacuum chamber for processing and annealing of samples. Experts include Balu Balachandran, Jeff Eastman, and Matt Highland.

Structure characterization: Capabilities include EDS, EBSD, EELS, SAXS, Raman spectroscopy, and other X-ray based tools (e.g., XPS-ESCA XRD, XPS). Many of these are housed at the Advanced Photon Source. Experts include Andrew Chuang, Ganesh Sivaraman, Jeff Eastman, Matt Highland, Jeff Elam, and Dileep Singh.

Superconductivity-specific measurement: Capabilities include measurement of critical temperature (Tc), critical current density (Jc), critical field (Bc). One lab (Kwok) performs measurements on superconducting samples 5 mm x 5 mm. Another lab (Balachandran) measures Tc and Jc down to 77 K. Experts include Wai-Kwong Kwok and Balu Balachandran.

Thermal characterization: Capabilities include operational temperature range, thermal conductivity, resistivity, thermal diffusivity, and specific heat capacity. Specific tools include NETZSCH STA 449 F3 Jupiter system and NETZSCH LFA 467 HyperFlash system for measuring thermal diffusivity (thermal conductivity) and heat capacity from room temperature to 500 C. Experts include Jie Li, Balu Balachandran, and Dileep Singh.

Theory/modeling/simulation: Capabilities include physics-based atomistic modeling including ab initio calculations, multiphysics, mesoscale phenomenological models, integrated computational materials engineering (ICME) for conductivity enhancement, physics-informed machine learning (PIML) for materials and microstructure design and process modeling, non-equilibrium Green's function approaches for electrical conductivity estimation, and design and materials performance modeling. Resources include the Argonne Leadership Computing Facility. Experts include Subramanian Sankaranarayanan, Ganesh Sivaraman, and Jeff Elam.

Other: Capabilities include light-based imaging, e.g. UV/VIS/NIR, and electrochemical testing. Experts include Jeff Elam.

Pacific Northwest National Laboratory Capabilities

Voucher Technical Representative: David Gotthold (david.gotthold@pnnl.gov)

Location: Richland, WA

About the Lab

Pacific Northwest National Laboratory advances the frontiers of knowledge, taking on some of the world's greatest science and technology challenges. Distinctive strengths in chemistry, Earth sciences, biology, and data science are central to PNNL's scientific discovery mission. The lab's research lays a foundation for innovations that advance sustainable energy through decarbonization and energy storage and enhance national security through nuclear materials and threat analyses. PNNL collaborates with academia in fundamental research and with industry to transition technologies to market.

Facilities

- Environmental and Molecular Sciences Laboratory (EMSL)
- Energy Sciences Center (ESC)
- Materials Testing Lab (3410)
- Applied Process Engineering Laboratory (APEL).

CABLE-Specific Capabilities Overview

PNNL has extensive characterization facilities at the Environmental and Molecular Sciences Laboratory (EMSL) and Energy Sciences Center (ESC) to determine elemental composition, second phase morphology and topology, and microstructural features in metals, polymers, ceramics and composites using SEM/EDS/EBSD, TEM, HR-STM, EELS, XPA, SAXS, AFM and APT. Recently, PNNL developed the CABLE electrical performance measurement that can accurately measure the geometry of conductors and determine their electrical conductivity, temperature coefficient of resistance, current density, and operational current/voltage of high conductivity materials. PNNL houses facilities in the 3410 Materials Testing Lab for determining tensile and yield strength, fracture toughness, creep resistance, wear resistance, corrosion resistance and rheological properties through equipment such as MTS load frames coupled with DIC and high temperature furnaces, DSC/TGA and DMA as well as micro/nanoindenters. The solid phase processing technologies housed at the Applied Process Engineering Laboratory (APEL) at PNNL are capable of thermomechanically manipulating materials to achieve bulk scale, homogeneous components in an energy-efficient manner. In the last 3 years, PNNL has developed multi-physics modeling capabilities for atomistic, mesoscopic, and phenomenological performance of metal- and polymer-composites using phase field, crystal plasticity, smooth particle hydrodynamics, finite element, molecular dynamics and density function theory models. PNNL also has developed physics based and purely data driven deep learning (artificial intelligence) and machine learning tools that can provide trustworthy, interpretable, transparent predictions for accelerating technology deployment, particularly through experimental design, uncertainty quantification, performance modeling and ICME integration, for developing materials with multifunctional performance.

Capability	Available
Electrical Characterization	X
Imaging	X
Mechanical Characterization	X
Metallurgical Characterization	X
Metallurgical Processing	X
Structure Characterization	X
Thermal Characterization	X
Theory, Modelling, Simulation	X

Additional Information on Capabilities

<u>Electrical characterization:</u> PNNL developed the CABLE electrical performance measurement that can accurately measure the geometry of conductors and determine their electrical conductivity, temperature coefficient of resistance, current density, and operational current/voltage of high conductivity materials. The system is capable of performing measurements for wires, bars, rods and strips among other final forms.

<u>Imaging:</u> PNNL has extensive characterization facilities at the Environmental and Molecular Sciences Laboratory (EMSL) and Energy Sciences Center (ESC) to determine elemental composition, second phase morphology and topology, and microstructural features in metals, polymers, ceramics and composites using SEM, TEM, HR-STM, EELS, WDS, AFM and APT.

<u>Mechanical characterization:</u> PNNL houses facilities in the 3410 Materials Testing Lab for determining tensile and yield strength, fracture toughness, creep resistance, wear resistance, corrosion resistance and rheological properties through equipment such as MTS load frames coupled with DIC and high temperature furnaces, DSC/TGA and DMA as well as micro/nanoindenters.

Metallurgical characterization: PNNL can determine features in material microstructures (such as grain size distribution in metals/alloys, morphology and alignment of additives, secondary phases contamination concentration, and compositional analysis using large area SEM combined with EBSD, TEM and WDS systems housed at APEL, EMSL and ESC.

Metallurgical processing: The solid phase processing technologies at PNNL are capable of thermomechanically manipulating materials to achieve bulk scale, homogeneous components in an energy-efficient manner. Additionally, PNNL can perform material processing using traditional casting and forming approaches such as stamping and rolling with the capabilities in the APEL facility.

Structure characterization: PNNL can perform EDS (Energy Dispersive X-Ray Spectroscopy), EBSD (electron backscatter diffraction), EELS (electron Energy Loss Spectroscopy), SAXS (small angle x-ray scattering), Raman spectroscopy at the nano-to-mesoscales, X-ray diffraction (XRD), liquid and solid phase NMR (nuclear magnetic resonance) spectroscopy to determine the structure of additives, second phases and matrix materials.

Thermal Characterization: Operational temperature range, Thermal conductivity, resistivity, Thermal diffusivity, Specific heat capacity

Theory/modeling/simulation: In the last 3 years, PNNL has developed multi-physics modeling capabilities for atomistic, mesoscopic, and phenomenological performance of metal- and polymer-composites using phase field, crystal plasticity, smooth particle hydrodynamics, finite element, molecular dynamics and density function theory models. In particular, PNNL's models can predict electrical conductivity, temperature coefficient of resistance and current density in a composite (metal/polymer based) as a function of microstructural features and additive composition/structure.

PNNL also has developed physics based and purely data driven deep learning (artificial intelligence) and machine learning tools that can provide trustworthy, interpretable, transparent predictions for accelerating technology deployment, particularly through experimental design, uncertainty quantification, performance modeling and ICME integration, for developing materials with multifunctional performance.

National Energy Technology Laboratory Capabilities

Voucher Technical Representative: Martin Detrois (martin.detrois@netl.doe.gov)

Location: Albany, OR, Morgantown, WV, and Pittsburgh, PA

About the Lab

The National Energy Technology Laboratory (NETL), part of the U.S. Department of Energy (DOE) national laboratory system, is owned and operated by the DOE. NETL supports the DOE mission by driving innovation and delivering solutions for an environmentally sustainable and prosperous energy future.

NETL implements a broad spectrum of energy and environmental research and development (R&D) programs that will return benefits for generations to come. These include:

- Ensuring affordable, abundant, and reliable energy that drives a robust economy and national security
- Developing technologies to manage carbon across the full life cycle
- Enabling environmental sustainability for all Americans.

NETL is organized to provide flexible, dynamic expertise and capabilities to its public and private sector customers throughout the Nation, prioritizing science, global climate change mitigation, social equity, environmental justice and economic revitalization. NETL's Research and Innovation Center exercises core technical competencies associated with Computational Engineering, Energy Conversion Engineering, Geological and Environmental Systems, Materials and Manufacturing Engineering, and Systems Analysis & Engineering, to deliver knowledge and technologies that enable affordable and environmentally sustainable energy solutions.

CABLE-Specific Capabilities Overview

NETL's alloy development capabilities are anchored by NETL's alloy ingot metallurgy (melting) and thermo-mechanical processing (forging and rolling) capabilities that are unique in scale within the DOE complex. This capability allows researchers to efficiently and cost effectively prototype alloy concepts at scales that readily translate to industrial practices (at a scale between the laboratory and production scales). This manufacturing capability, coupled with NETL's capabilities in computational materials design and performance evaluation under real conditions, allows NETL to provide affordable alloy solutions to enable technologies needed to meet our Nation's clean energy goals. Various capabilities are available to CABLE range across mechanical characterization, metallurgical processes, and analysis. The MEM capability includes scale-up processes utilizing vacuum induction furnaces with crucible sizes ranging from 10 to 500 lb.

Capability	Available
Mechanical Characterization	X
Metallurgical Characterization	X
Metallurgical Processing	X

Additional Information on Capabilities

Mechanical characterization: NETL mechanical testing capabilities include tension testing from room temperature up to 1000°C (3150 MPa max.) to determine yield stress, ultimate tensile strength, and elongation to failure. High-cycle and low-cycle fatigue testing up to 1100°C. Multiple creep frames for testing up to 1000°C including constant load and constant stress fames.

Metallurgical characterization: Chemistry analysis using X-ray fluorescence (XRF). Combustion analysis on LECO systems is used to determine C, N, O, S and H.

Metallurgical processing: NETL's unique melt processing laboratory that includes capabilities for research and up-scaling activities. These include vacuum induction melting (VIM) furnaces (20 lb, 50 lb and 500lb based on crucible size) and air induction melting furnaces (50 and 100lb crucible sizes), as well as vacuum arc remelting (VAR) and electroslag remelting (ESR) capabilities (VAR and ESR furnaces can melt 440 lbs and have 4-, 6-, and 8-inch diameter crucibles). The air melting furnaces can be equipped with electrodes which can be submerged into the melt. Heat-treatment and thermomechanical processing capabilities include vacuum heat treatment furnaces with forced Ar gas fan cooling, air heat treatment furnaces with temperature capabilities up to 1700°C of various sizes to accommodate research samples and large ingots and plates, a 500-ton press forge and hot/cold rolling (2 high and 4 high configurations) mills.

Additional information on the MEM capabilities is available at: https://netl.doe.gov/onsite-research/materials.

National Renewable Energy Laboratory Capabilities

Voucher Technical Representative: Emily Evans (Emily.Evans@nrel.gov)

Location: Golden, CO

About the Lab

At the National Renewable Energy Laboratory (NREL), we focus on creative answers to today's energy challenges.

From breakthroughs in fundamental science to new clean technologies to integrated energy systems that power our lives, NREL researchers are transforming the way the nation and the world use energy. NREL advances the science and engineering of energy efficiency, sustainable transportation, and renewable power technologies and provides the knowledge to integrate and optimize energy systems.

NREL has decades of focused leadership in clean energy research, development, and deployment. No other institution has the long-standing expertise and breadth of knowledge that will form the foundation of the clean energy transition. The Material Sciences Center is a recognized leader in creating new knowledge and accelerating the industrial impact of materials science research to support the nation's energy and environmental goals.

From NREL's work in basic sciences to systems engineering and analysis, all NREL researchers are focused on solving market-relevant problems that result in deployable solutions. NREL's partnerships ensure our work is relevant and applicable to the energy problems that people are trying to solve.

Facilities

- Materials, Chemical, and Computational Science Center
- Science and Technology Facility
- Energy Systems Integration Facility (high-performance computing)
- High-Performance Computing and Data Visualization

CABLE-Specific Capabilities Overview

NREL's Materials, Chemical, and Computational Science (MCCS) directorate spans across foundational scientific understanding and state-of-the-art modeling and simulation to industry-relevant applied R&D for renewable energy and energy efficiency. Within MCCS, NREL provides fundamental and applied materials science discovery and problem-solving for current and next-generation renewable energy and energy-efficient technologies. Within the MCCS, the Material Science Research group includes the following core competencies: Materials Physics, Electronic Structure Theory, Analytical Microscopy and Imaging Science, Interfacial and Surface Science.

Capability	Available
Imaging	X
Mechanical Characterization	X
Metallurgical Characterization	X
Structure Characterization	X
Thermal Characterization	X
Theory, Modelling, Simulation	X

Additional Information on Capabilities

Metallurgical Characterization: NREL specific capabilities: NREL maintains a broad range of characterization tools for identifying phases and compositions of novel materials. Additional information on capabilities and resources can be found at:

- NREL Analytical Microscopy and Imaging Science
- NREL Interfacial and Surface Science
- NREL X-Ray and Related Capabilities

NREL researchers: Steven Hayden and Helio Moutinho (SEM/EDS/EBSD), Glenn Teeter (XPS, SEM/SAM)

Metallurgical Characterization Facilities Available:

- High-resolution SEM/EDS/EBSD: Thermo Fisher SEM Nova 630 equipped with Oxford EBSD Symmetry system, to detect grain orientation and sizes. Secondary phases can be identified with EDS to determine changes in composition. Very high resolution EBSD maps are available.
- Small-spot XPS: Physical Electronics Phi VersaProbe III: 10 micron mapping capability, surface composition and chemical states, depth profiling
- Scanning electron/auger microscopies (SEM/SAM): Physical Electronics Phi 710: nanoscale chemical imaging, surface composition, depth profiling, EBSD

Imaging: NREL has tools for SEM imaging, and cross-sectional imaging in a focused ion beam. HR-TEM is currently available, and a new Spectra 200 HR-STEM will be installed in December 2022 with sub-angstrom resolution. NREL has both STM and AFM, with many advanced features in AFM including operation in an Ar-filled glovebox.

NREL researchers: Andrew Norman (TEM), Harvey Guthrey (SEM), and C.S. Jiang (STM/AFM)

Imaging Facilities Available:

- A recently acquired HR-STEM (available beginning early 2023) will provide advanced capabilities for in-situ characterization and strain mapping.
- The AFM capabilities are state-of-the-art providing custom high-sensitivity measurements and various electrical and mechanical characterization.

Additional detailed information on capabilities and resources can be found at:

- NREL Analytical Microscopy and Imaging Science

Structure Characterization: The Materials Science Center at NREL stewards a broad range of x-ray- and electron-based diffraction and spectroscopy tools that can be applied in correlative studies of material crystal structure and composition. Additional information on capabilities and resources can be found at

- NREL Analytical Microscopy and Imaging Science
- NREL Interfacial and Surface Science
- NREL X-Ray and Related Capabilities

NREL researchers: Helio Moutinho (SEM/EDS/EBSD), Andrew Norman (TEM), Glenn Teeter (XPS), Phil Parilla (XRD)

Facilities Available: Coupled to imaging, we can provide chemical and grain orientation maps, using EDS (either SEM or STEM) and EBSD. A newly acquired HR-STEM (available beginning 2023) will have high detection efficiency for EDS, and the EBSD detector provides very high-resolution maps.

- Aberration-corrected TEM: Spectra 200 HR-STEM sub-angstrom spatial resolution system equipped with high detection efficiency for EDS.
- High-resolution SEM/EDS/EBSD: Thermo Fisher SEM Nova 630 equipped with Oxford EBSD Symmetry system, to detect grain orientation and sizes. Secondary phases can be identified with EDS to determine changes in composition. Very high resolution EBSD maps are available.
- Small-spot XPS: Physical Electronics Phi VersaProbe III: 10-micron mapping capability, surface composition and chemical states, depth profiling.

Mechanical Characterization: NREL has characterization capabilities to completely characterize the thermomechanical properties (dynamic mechanical analysis, rheological profile, tensile properties, compressive properties, thermal transitions, etc.) and structure (e.g. FTIR, NMR, molecular weight distribution via GPC, crosslink density, additive content, etc.) of all polymers in use today, polymers post deconstruction, and emergent new polymers.

Thermal Characterization: Thermal Interface Materials Research Stand, Infrared Imaging, Transient Thermoreflectance Technique, Differential Scanning Calorimeter, Transient Thermal Tester (Mentor Simcenter POWERTESTER 2400A 16C 12V), Large Calorimeter, Particle Image Velocimetry. More information can be found here.

Facilities Available:

- Transient Plane Source Technique: Testing the thermal transport properties of monolithic and powder samples from 60K to >400K. Measures the transport of heat from a source out through the sample being tested, and by fitting well defined heat transport equations we directly fit thermal conductivity, thermal diffusivity, and volumetric heat capacity simultaneously.

Theory/modelling/simulation: NREL's computational science, high-performance computing, applied mathematics, and advanced computer science, visualization, and data drive advancements in energy efficiency, sustainable transportation, renewable power, and energy systems integration research. NREL researchers use industry-standard software for modeling and simulation analysis, including ANSYS Mechanical Enterprise and ANSYS Fluent. Customized tools written in MathWorks MATLAB extend the functionality of ANSYS for design exploration and optimization. Computational hardware includes state-of-the-art workstations and NREL's flagship high-performance computing system, Eagle, operating at 8 PetaFLOPS. More information can be found here.

Sandia National Laboratories Capabilities

Voucher Technical Representative: Irene Trujillo (itrujil@sandia.gov)
Location: Albuquerque, NM and Livermore, CA

About the Lab

Sandia National Laboratories is operated and managed by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc. National Technology and Engineering Solutions of Sandia operates Sandia National Laboratories as a contractor for the U.S. Department of Energy's National Nuclear Security Administration (NNSA) and supports numerous federal, state, and local government agencies, companies, and organizations.

A strong science, technology, and engineering foundation enables Sandia's mission through a capable research staff working at the forefront of innovation, collaborative research with universities and companies, and discretionary research projects with significant potential impact.

In keeping with Sandia's vision to be the nation's premier science and engineering laboratory for national security and technology innovation, Sandia recruits the best and the brightest, equip them with world-class research tools and facilities, and provide opportunities to collaborate with technical experts from many different scientific disciplines.

Facilities

- Center for Integrated Nanotechnologies (CINT): CINT's facilities provide laboratory and office space for researchers to synthesize and characterize nanostructured materials, theoretically model and simulate their performance, and integrate nanoscale materials into larger-scale systems in a flexible, clean-room environment. Capabilities include materials synthesis; characterization; nano-micro integration; theory and simulation; and modular micro-laboratories for integrating nano and micro length scales and for studying the physical and chemical properties of nanoscale materials and devices.
- Microsystems Engineering, Science, and Applications (MESA): MESA includes fabrication, testing, and validation capabilities. The MESAFab complex develops and maintains core semiconductor processing capabilities and capacity that enable our customers to build differentiating Microsystems products.

CABLE-Specific Capabilities Overview

Sandia has the technical capabilities needed to support the prize's entrepreneurial teams and a history of supporting small businesses with R&D and technology transfer. Our expertise and capabilities include advanced materials modeling, a suite of materials characterization techniques (electron microscopy, various relevant spectroscopies), mechanical testing, thermal testing, electrical and magnetic testing, carbon nanotube and superconducting materials expertise, and advanced annealing techniques.

Capability	Available
Electrical Characterization	X
Imaging	X
Mechanical Characterization	X
Metallurgical Characterization	X
Metallurgical Processing	X
Structure Characterization	X
Superconductivity-specific Measurement	X
Thermal Characterization	X
Theory, Modelling, Simulation	X
Other	X

Detailed Overview of Capabilities

Electrical characterization: Electrical characterization techniques are employed to determine the electrical properties and/or behavior of a device to diagnose internal fault locations. Often used in failure validation/verification. External chip data such as scan-based diagnostics, fault dictionaries, schmoo plots, IDDQ versus pattern, timing, voltage, temp, and memory bit-fail maps are a few tools available for failure verification. Other less complicated techniques such as curve tracing, I-V and C-V profiling, 2 and 4-point probing can be used to determine resistivity, carrier concentration, mobility, contact resistance, depletion width and more. At Sandia, many tools are used to electrically stimulate or measure the response of a semiconductor device for root cause failure analysis. Equipment such as parametric analyzers, waveform generators, curve tracers, automated test equipment, etc., have been used for root cause failure analysis.

Imaging: Failure analysis techniques performed using a Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM) or Focused Ion Beam (FIB) use signals generated from an electron or ion beam source to produce an image. These signals such as secondary or backscattered electrons and characteristic x-rays are used to examine the structure or electrical activity of a device. Tools and techniques employed at Sandia include: Scanning Electron Microscopy, Voltage Contrast, Resistive Contrast Imaging, Charge-Induced Voltage, Alteration, Electron Beam Induced Current, Nanoprobing, Transmission Electron Microscopy, Focused Ion Beam, FIB Circuit Edit, Energy Dispersive X-ray Spectroscopy, and Thermal Imagining.

Mechanical characterization: Sandia is heavily active in developing novel and emerging processing and characterization techniques. Current activities include the development of high-throughput and in-situ methods for mechanically testing additively-manufactured (AM) metals; highly customized tribological testing; digital image correlation; failure and deformation under complex loading; stress mapping using photo-luminescence; tribology of nanocrystalline materials; and 3D characterization of microstructure and components. Sandia also manages several multi-million-dollar programs which currently include the Brittle Material Assurance Prediction Program (BritMAPP) and Materials Margins Assurance (MMA).

Metallurgical characterization & Metallurgical processing: By applying a breadth of techniques, including spectroscopic and diffraction techniques, light and electron microscopy, metallography, surface analysis, chemical analysis, and contaminant analysis, we provide materials understanding and solutions for: engineering components and structures, failure analysis of all types of materials, materials aging and compatibility, and research projects across a wide customer base. We take pride in owning, maintaining, and utilizing—to the fullest extent—the best instrumentation available anywhere. When required, we develop new instrumentation and advance what's possible in materials characterization.

Structure characterization: Capabilities include Energy Dispersive X-ray Spectroscopy, CSAM (C-mode scanning acoustic microscopy), real-time x-ray imaging, 3D X-Ray Tomography, and light emission microscopy.

Superconductivity-specific measurement: The MESAFab complex develops and maintains core semiconductor processing capabilities and capacity that enable our customers to build differentiating Microsystems products. Two unique facilities are co-located within the 65,000 square foot MESAfab complex including: (1) a 34,500 square foot Silicon Fab for 6-inch silicon wafer processing with Class 1 bays and (2) a 30,400 square foot MicroFab with Class 10 and Class 100 bays for compound semiconductor material processing and silicon wafer post-processing.

Thermal characterization: Sandia researches the fundamental thermal properties and decomposition products and pathways of a wide variety of materials experiencing an expansive range of environments. This work entails both state-of-the-art diagnostics as well as developing custom diagnostics and techniques to provide information on the underlying science of thermal behaviors of materials.

Theory/modeling/simulation: Sandia performs research and development in physics-based materials modeling and high-performance computing. Our team brings together experts in density functional theory, molecular dynamics, direct simulation Monte Carlo, microstructure modeling, continuum mechanics, equations of state, and peridynamics. We lead a number of software development efforts, including the

LAMMPS molecular dynamics code, and strive to advance the state of the art in materials modeling through a broad range of collaborations across the laboratories. Capabilities of CINT include MEsoscale Multi-physics PHase fIeld Simulator (MEMPHIS) and simulations using atomistic or coarse-grained models for studying nanoparticles, biomolecules, and polymers.

Other: Density, geometry, corrosion resistance, sustainability, recyclability, manufacturability (additive manufacturability), light-based imaging (e.g., UV/VIS/NIR), electrochemical testing.

Appendix C. Detailed Voucher Service Provider Capabilities: AMERICAN-MADE NETWORK

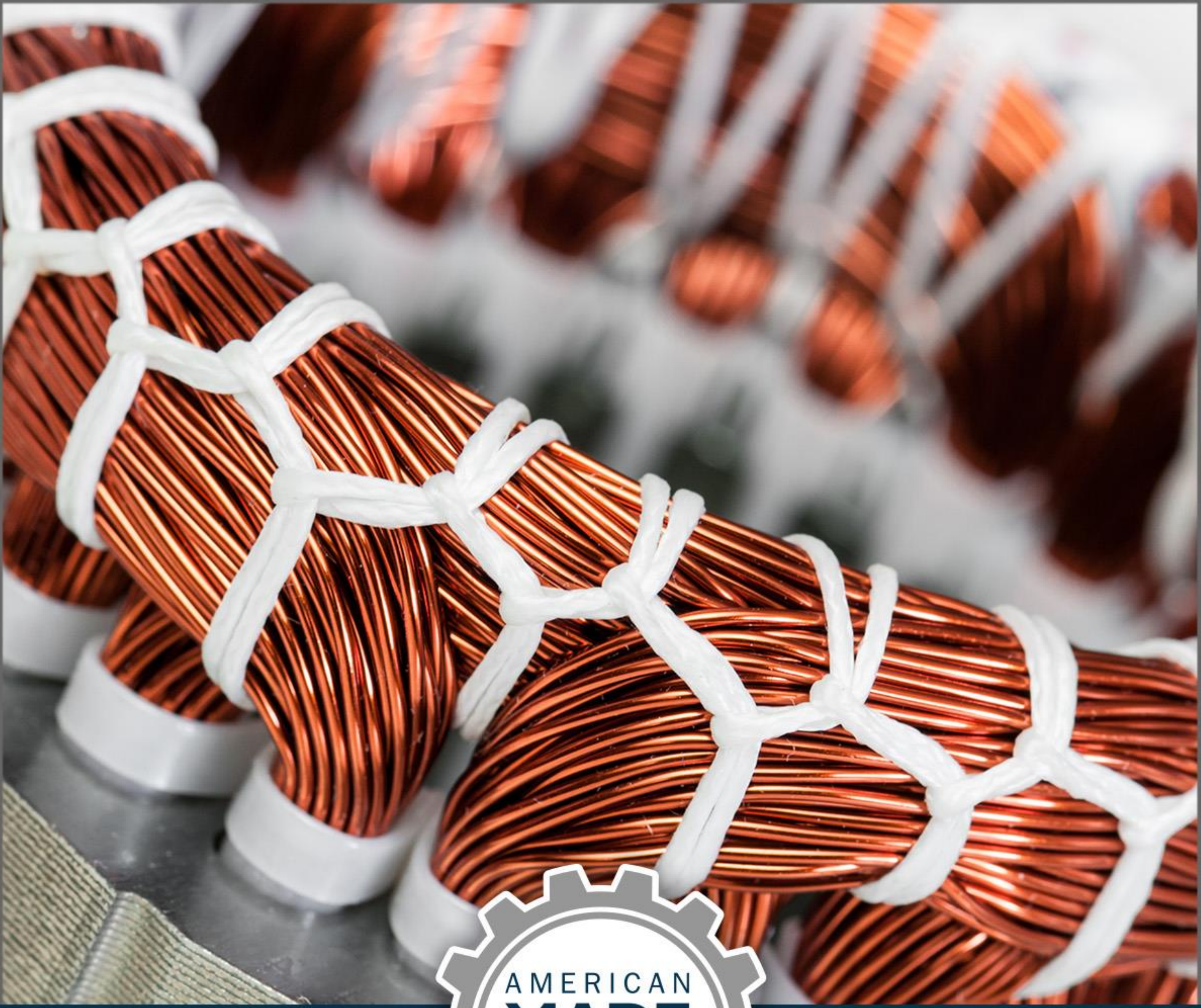
Prysmian Group / General Cable Capabilities

Voucher Technical Representative: Donald Parris (don.parris@prysmiangroup.com)

CABLE-Specific Capabilities Overview

Prysmian Group's Indianapolis Technology Center (ITC) provides the foundation for extensive research and development efforts in the wire and cable industry. This center of excellence combines advanced materials development, cutting-edge compounding, extrusion and processing capabilities, and comprehensive testing and analysis with a highly qualified team of engineers and scientists whose sole mission is to deliver innovative cable technologies that meet the changing needs of our customers. Electrical Testing Capacitance, tan delta, insulation resistance (IR) and volume resistivity (VR), AC breakdown of coiled wire, plaque and tape specimens, IR measurement and AC withstand of 3-phase armored cables, Current cycling aging of wire samples, Impulse and insulation voltage endurance, Square wire accelerated aging, Dust and fog tracking and Tree cell testing Physical, Mechanical, Thermal and Flame Lab Testing Tensile strength and elongation of un-aged, air oven aged and oil/fluid aged specimens, Cure and rheological properties, Thermal transitions and flame performance, Chemical composition and abuse performance, Zwick® universal tester, Instron® tester, Brittle point tester, Optical microscope, Air oven labs, Impact resistance, Scoring resistance, Abrasion resistance, Specific gravity, CSA FT1 and FT2, UL VW-1 and FV-1, Limiting oxygen index tester, Microcalorimeter analyzer, Differential scanning calorimetry (DSC), Thermogravimetric analysis (TGA), Mooney MV 2000 viscometer, Haake™ Viscotester™, Fourier Transform Infrared (FTIR) analyzer, Moisture analyzer Metallurgical Testing Wire drawing, heat treatment, chemical analysis, mechanical testing, metallurgical testing

Capability	Available
Electrical Characterization	X
Mechanical Characterization	X
Thermal Characterization	X
Other	X



AMERICAN MADE MANUFACTURING PRIZE

U.S. DEPARTMENT OF ENERGY