



IEEE Electric Ship Technologies (Virtual)
Symposium
July 27-30, 2021: Tutorials
August 3-6, 2021: Main Program

<http://ests21.mit.edu>



Welcome Message

Welcome to the 2021 Electric Ship Technology Symposium. On behalf of the 2021 ESTS organizing committee, we would like to thank each and every one of you for attending this meeting where we will exchange ideas on the future of electric ship technologies. The Electric Ship Technology Symposium began in 2005, largely as a result of U.S. Navy interest in electric ships, an interest which has grown over the subsequent years. To this end, we particularly thank the U.S. Navy and the U.S. Office of Naval Research for their support of this technical area over the years. But of course, interest in electric ships is not limited to the U.S. Navy, or even the navies of the world; indeed, electric ship technology is of strong interest in many civilian maritime applications, and so the range of contributors to this technology is quite diverse. Thus, it is our goal that this conference welcomes all who are interested in electric ships to both learn and contribute new technical knowledge to this growing area.

We are offering tutorials the week before the official opening of the conference, and hope you will be able to take advantage of these. If you cannot attend, or happen to miss one of interest, this year we are recording the sessions and will make these recordings available online; please see <https://ests21.mit.edu/> for a link to the tutorials. The tutorials are free and open to the public.

As we collectively participate in this year's symposium, please be aware of the generous support provided by our platinum sponsor, Northrop Grumman, and our gold sponsor, Typhoon HIL. Please be sure to visit their booths during the conference as they are all important contributors to electric ship technology.

We also thank the IEEE Power and Energy Society and the IEEE Power Electronics Society for technical and financial sponsorship of this conference, without which the conference would have been impossible. The committee also thanks the IEEE Transportation Electrification Community for technical sponsorship, and for helping to advertise this event. Finally, we hope that each of you will find the conference to be enjoyable, stimulating, and enlightening.

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MIT Sea Grant College Program, Massachusetts Institute of Technology
Chair, ESTS 2021

Dr. Michael "Mischa" Steurer
Center for Advanced Power Systems, Florida State University
Co-chair, ESTS 2021

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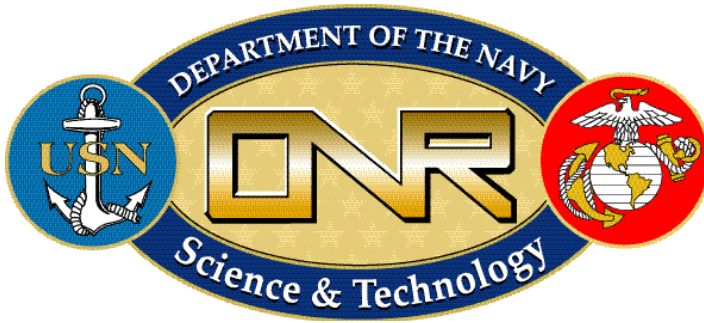
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Keynote Speaker

Rear Admiral Lorin Selby, Chief of Naval Research United States Navy



Rear Adm. Lorin Selby is a native of Baltimore, Maryland and graduated from the University of Virginia with a Bachelor of Science in Nuclear Engineering and earned his commission through the Navy's Reserve Officers Training Corps program. He also holds a Master of Science in Nuclear Engineering and a Nuclear Engineer degree from the Massachusetts Institute of Technology.

His shipboard tours include USS Puffer (SSN 652), USS Pogy (SSN 647) and USS Connecticut (SSN 22). From July 2004 to May 2007 he commanded USS Greeneville (SSN 772) in Pearl Harbor, Hawaii. During these assignments, Selby conducted several deployments to the Western Pacific, Northern Pacific, Northern Atlantic and Arctic Oceans.

Ashore, Selby's staff assignments include duty as a company officer and instructor at the U.S. Naval Academy, service as the deputy director of the Navy's liaison office to the U.S. House of Representatives and duty as the Submarine Platforms and Strategic Programs branch head in the Submarine Warfare Directorate on the Navy Staff. Following selection as an acquisition professional, he served as the program manager for both the Submarine Imaging and Electronic Warfare Systems Program Office (PMS 435) and the Advanced Undersea Systems Program Office (PMS 394).

As a flag officer, Selby served as commander, Naval Surface Warfare Centers (NSWC) from October 2014 to August 2016. In this position, he led more than 17,000 scientists, engineers, technicians and support personnel, both civilian and active duty, within eight NSWC divisions located across the country.

From June 2016 until May 2020, he served as the Navy's chief engineer and the Naval Sea Systems Command (NAVSEA) Deputy Commander for Ship Design, Integration and Naval Engineering (SEA 05), where he led the engineering and scientific expertise, knowledge and technical authority necessary to design, build, maintain, repair, modernize, certify and dispose of the Navy's ships, aircraft carriers, submarines and associated combat and weapons systems.

In May of 2020, he assumed command of the Office of Naval Research as the 26th Chief of Naval Research.

Selby is authorized to wear the Distinguished Service Medal, the Legion of Merit (three awards), Meritorious Service Medal (four awards), the Navy and Marine Corps Commendation Medal (six awards) and the Navy and Marine Corps Achievement Medal (three awards) in addition to various unit awards.

Keynote Speaker

Mr. Punter Pierluigi, Senior Vice President, Design and Engineering Fincantieri Cruise Business Unit

Pierluigi Punter was born in Venice, Italy, and graduated from the University of Padua with a M.Sc. (Master of Science) Degree in Electrical Engineering.



He started his career in Fincantieri in 1990 as an electrical engineer in the Technical Department and was directly involved in designing power and electrical propulsion systems for cruise ships. He covered different roles inside Fincantieri, among others Head of the Electrical Design Department, Proposal Engineer, Ships Commissioning Manager, Deputy Director of Fincantieri Marghera Shipyard, Project manager for cruise ships (Queen Victoria, Eurodam, Costa Luminosa and Regent Seven Seas Explorer).

He is currently Head of the Design and Engineering Department of Fincantieri Cruise Business Unit, with a workforce of about 1,000 engineers. The Department includes all the technical branches of the cruise basic and detail design including hull, electrical, mechanical, air conditioning and interior design (cabins and public areas) as well as comfort design of the hotel areas.

He took part in the activities of working groups involved in the reorganization process.

He was a member of national and international electrical technical committees, including IEC for electrical installation on board ships, and is member of the Italian Classification Society (RINA) technical committee.

He is a member of the Fincantieri Research and Innovation Committee.

Plenary Session

High Power Density Electric Machines

Chair: Michael Mazzola, UNC Charlotte

The marine industry is beginning to electrify and needs new classes of High Power Density (HPD) generators and motors in the 5-50 MW power range. These HPD machines are 30-50% smaller and lighter than both conventional and permanent magnet machines in this power range. The power density is increased via the adoption of proven technologies from large utility generators in combination with new, proprietary product designs and thermal management systems. These products are targeted for applications in which weight and volume are the key drivers, such as electric ships, off-shore O&G, wind turbines and mobile power.

One option is to further develop High Temperature Superconducting (HTS) technologies; which has successfully been implemented in products ranging from motors and generators to transformers and transmission lines. The current focus for HTS is on large utility generators, but all designs and technologies are directly applicable to the lower power HPD products also.

A three-member team drawn from industry, academia, and government will explore the opportunities and challenges ahead for further developing and maturing the needed HPD products for both commercial and defense maritime applications. Panel members include:

- Bob Warren, Siemens Energy
- Dr. Scott Sudhoff, Purdue University
- Dr. John Amy, U.S. Navy

Plenary Session

Engineering Challenges of Autonomous Vessels

Chair: Raja Suresh, General Dynamics Advanced Information Systems

Autonomous and unmanned vessels are at the forefront of new technologies that have the potential to revolutionize marine transportation and operations in both the commercial and military sectors. Advances in many areas such as artificial intelligence, controls, power electronics, batteries, and sensing are enabling this revolution. The operational use of these vessels raises a plethora of new questions, requiring research and development to respond: What power and energy technologies will improve the efficiency and effectiveness of these vessels? What changes in design can be realized if personnel are never onboard underway? What improvements in robustness and resilience are necessary for the vessel to operate for extended periods without human intervention? Join our panel of experts as we discuss the latest advances in autonomous vessels and the need for new solutions to new problems. The panel members include:

- Dr. Raja Suresh, Director, R&D at General Dynamics Mission Systems
- Dr. Andrew Nuss, Program Manager in the Defense, Advanced Research Projects Agency's (DARPA) Tactical Technologies Office (TTO)
- Dr. Joseph Fontaine, Naval Surface Warfare Center, Crane
- Alex Lorman, Director of Maritime Engineering at ThayerMahan
- Dr. Jason Strickland, Technical Director, Unmanned Surface Warfare, Naval Sea Systems Command

TUTORIAL PROGRAM

Tuesday, July 27

- 10:00 am Tutorial Session I
Electrical Power and Propulsion Preliminary and Contract Design Process
Norbert Doerry, NAVSEA, United States
John Amy, NSWC Philadelphia, United States
- 12:30 pm Tutorial Session II
PESNet 3.0: A Next Generation Communication and Control Network for High-frequency Modular Power Converters
Jun Wang, University of Nebraska-Lincoln/Virginia Tech

Wednesday, July 28

- 10:00 am Tutorial Session III
High Temperature Superconducting Technology for Electric Ships
Sastry Pamidi, FAMU-FSU College of Engineering
- 12:30 pm Tutorial Session IV
Electric Power Load Analysis (EPLA)
John Amy, Naval Surface Warfare Center Philadelphia Division
Norbert Doerry, Naval Surface Warfare Center Carderock Division

Thursday, July 29

- 10:00 am Tutorial Session V
Supporting Technology Development In-Service Operation of Shipboard Power Systems with Fit-For-Purpose Modeling and Simulation
Graham Dudgeon, MathWorks, Inc
- 12:30 pm Tutorial Session VI
Control Hardware in the Loop Fundamentals
Matt Baker and Andy Sellers, Typhoon HIL
Jim Turso, Huntington Ingalls Industries

Friday, July 30

- 10:00 am Tutorial Session VII
Green Electrification of Ships and Ports
John Prousalidis, National Technical University of Athens
- 12:30 pm Tutorial Session VIII
Model Predictive Control for Ship Power Systems
Greg Sinsley, US Naval Academy

MAIN PROGRAM

Tuesday, August 03

10:00 am Opening Remarks and Keynote Address

Mr. Punter Pierluigi

Senior Vice President, Design and Engineering
Fincantieri Cruise Business Unit

10:30 am Technical Session A1L-A

Electric Propulsion and Power Generation

Co-chairs: *Dwight Alexander*, Northrup Grumman; *Zareh Soghomonian*, FRDA, LLC

Stabilization of Generator Frequency Under Pulsed Load Condition Using Regenerative Propeller Braking

Ronald Matthews, Lee Rashkin, Steven Glover, Norbert Doerry

Endurance Life of Nanostructured Insulation Material for High Torque Density Propulsion Motors

Hiep Nguyen, Yifei Wang, Joanne Ronzello, Jack Chapman, Yang Cao

Assessing the Implementation of Power Take off (PTO) System Onboard Liquefied Natural Gas (LNG) Carriers

Apostolos Souflis-Rigas, John Prousalidis, George Dimopoulos

11:00 am Technical Session A2L-B

Real-Time Simulation of Shipboard Subsystems

Co-chairs: *Harish Suryanarayana*, ABB; *Ali Davoudi*, University of Texas Arlington

The Role of Sensitivity Analysis in Stress Testing Real Time Models of Power Systems Controllers

Behshad Mohebbali, Karl Schoder, Mark Stanovich, Michael Mischa Steurer, Gordon Erlebacher

A General Common-Bus Architecture for Multiple-Interface Power Hardware-in-the-Loop Studies

Thiago Szymanski, James Langston, Michael Mischa Steurer

A Reconfigurable Megawatt-Scale Power Hardware-in-the-Loop Simulation System for Virtual Motors

Lu Wang, Yanjun Shi, Dionne Soto, James Langston, Matthew Bosworth, John Hauer, Michael Mischa Steurer

Shipboard Zonal Load Center Modeling and Characterization on Real-Time Simulation Platform

Md Multan Biswas, Tyler Deese, James Langston, Harsha Ravindra, Karl Schoder, Michael Mischa Steurer, Herbert Ginn, Christian Schegan

11:30 pm Technical Session A3L-C

Dielectric Challenges 1

Co-chairs: *Mona Ghassemi, Virginia Tech; Mike Mazzola, University of North Carolina Charlotte*

On the Likelihood of Partial Discharge Inception in Laminated Busbars from Electrified Ships

Gian Carlo Montanari, Riddhi Ghosh, Paolo Seri, Paul Defriece, Jesse Schmeller

Electret: A Remedy for Partial Discharge and Surface Flashover in Shipboard Power Applications

Farhina Haque, Omar Faruqe, Chanyeop Park

Surface Flashover Characteristics of Solid Dielectrics in Shipboard Atmospheric Conditions

Omar Faruqe, Farhina Haque, Han Berdiyev, Chanyeop Park

Characterizing the Surface Charge Distribution and Its Impact on the DC Surface Flashover Voltage of Insulators

Ning Guo, Minuk Lee, Jeong Ho Choi, Tushar Damle, Lukas Graber

12:00 pm Technical Session A4L-D

Power System Control and Stability

Co-chairs: *Fletcher Fleming, DRS Technologies; David Wetz, University of Texas at Arlington*

Active Damping Poles Repositioning for DC Shipboard Microgrids Control

Andrea Alessia Tavagnutti, Daniele Bosich, Giorgio Sulligoi

Modeling and Stability Analysis of Radial and Zonal Architectures of a Bipolar DC Ferry Ship

Sachin Yadav, Nils van der Blij, Pavol Bauer

Degradation Aware Predictive Energy Management Strategy for Ship Power Systems

Satish Vedula, Mehrzad Mohammadi Bijaieh, Ellis Oti Boateng, Olugbenga Moses Anubi

Low-Bandwidth Modular Mathematical Modeling of DC Microgrid Systems for Control Development with Application to Shipboard Power Systems

Mehrzad Mohammadi Bijaieh, Satish Vedula, Olugbenga Moses Anubi

12:30 pm Technical Session B1L-E
Model-Based Systems Engineering 1
Co-chairs: *Terry Ericson*, Ericson Innovations, LLC; *Mohamad Zahzah*, Ultra EMS

Naval Smart Grid Preliminary Integration Onboard Electric Ships *Andrea Vicenzutti, Giorgio Sulligoi, Vittorio Bucci, Serena Bertagna, Michele Cataneo, Paolo Borghese*

Early Stage Modeling of Naval DC Power System for Digital Twin Development Miles
Leonard-Albert, Davis Hobbs, Jack Hannum, Enrico Santi, Kristen Booth

Concept Design Methodology to Enable Naval Smart Grid Onboard Electric Ships
Giorgio Sulligoi, Giorgio Trincas, Andrea Vicenzutti, Luca Braidotti, Michele Cataneo

Subdivision Blocks and Component Placement in Early-Stage Ship Design
Marisa Hoosen, Julie Chalfant

Wednesday, August 04

10:00 am Opening Remarks and Plenary Session 1
High-Density Machines
Chair: Michael Mazzola, UNC Charlotte

11:30 am Technical Session B2L-A
Model-Based Systems Engineering 2
Co-chairs: *Terry Ericson*, Ericson Innovations, LLC; *Mohamad Zahzah*, Ultra EMS

Integrating Electrical and Operational Load Models for Control Evaluation
Mark Stanovich, Greg Sinsley, Harsha Ravindra, Daniel F. Opila, John Stevens, Michael Mischa Steurer

Evolution of Operability-Based Performance Metrics for Assessment of Mission Performance
Musharrat Sabah, Isuje Ojo, Aaron Cramer

Reduced Order Model of a Four Zone Medium Voltage DC Electric Ship
Wayne Weaver, Rush Robinett III, David Wilson, Steven Glover

On Estimating the Port Power Demands for Cold Ironing Applications
Fabio D'Agostino, Giacomo Piero Schiapparelli, Stefanos Dallas, Dimosthenis Spathis, Vassilis Georgiou, John Prousalidis

12:00 am Technical Session B2L-B
Modeling & Analysis of Shipboard Subsystems
Co-chairs: *Harish Suryanarayana*, ABB; *Ali Davoudi*, University of Texas
Arlington

Hybrid Analytical and Data-Driven Modeling Techniques for Digital Twin Applications

Andrew Wunderlich, Kristen Booth, Enrico Santi

Averaged-Value Modeling and Modelability Analysis for an Operational Megawatt-Scale Medium-Voltage Modular Multilevel Converter

Lu Wang, Yanjun Shi, Dionne Soto, James Langston, Matthew Bosworth, John Hauer, Michael Mischa Steurer

Modeling of Sources and Power Electronic Converters Installed in a Medium Voltage AC/DC Testbed

Zachary Bailey, Alexander Johnston, David Wetz, Gregory Turner, Christian Schegan, John Heinzl

Optimization Design of Medium-Voltage Modular Converter with Terminal Transient Response Constraint

Qian Li, Igor Cvetkovic, Dushan Boroyevich, Rolando Burgos

12:30 pm Technical Session B4L-C

Dielectric Challenges 2

Co-chairs: *Mona Ghassemi*, Virginia Tech; *Mike Mazzola*, University of North Carolina Charlotte

Behaviour of Surface Electric Field in DC Ship Spacers Under Real Operation Conditions: Voltage Transients and Ripple, Temperature Gradient and Pollution

Robin Ramin, Gian Carlo Montanari, Peter Cheetham, Michael Mischa Steurer

Modeling and Measurement of Internal Partial Discharges in Voids Artificially Made Within 3D-Printed Polylactic Acid (PLA) Block

Moein Borghei, Mona Ghassemi, Behzad Kordi, Derek Oliver

Effects of 7-Level ANPC SiC Inverter on Motor Stator Insulation and Cable Insulation in an Electric Ship Propulsion Drive

Arshiah Mirza, Ali Bazzi

Discrimination of Single- and Multi-Source Corona Discharges Using Deep Residual Network

Moein Borghei, Mona Ghassemi

Thursday, August 05

10:00 am Opening Remarks and Keynote Speaker

Rear Admiral Lorin Selby

Chief of Naval Research

United States Navy

10:30 am Technical Session C1L-A

EMI, EMC, and Common-Mode Behavior

Co-chairs: *Rob Cuzner*, University of Wisconsin Milwaukee; *Aaron Brovont*, PC Krause & Associates

Common-Mode Capacitance of Bus-Bar-Based Common-Mode Inductors

Harshita Singh, Scott Sudhoff, Robert Swanson

Eliminating Common Mode Conducted Emissions in Three-Phase Four-Leg Inverters

Alexander Julian, Giovanna Oriti, Arthur Krener

Impact of Output Terminations on Conducted Emissions Evaluation of Interface Converters

Andrew Lemmon, Aaron Brovont

11:00 am Technical Session C2L-B

Power System Control and Risk Mitigation

Co-chairs: *Fletcher Fleming*, DRS Technologies; *David Wetz*, University of Texas at Arlington

Advanced Load Shedding for Integrated Power and Energy Systems

Bang Nguyen, Tuyen Vu, Colin Ogilvie, Harsha Ravindra, Mark Stanovich, Karl Schoder, Michael Mischa Steurer, Charalambos Konstantinou, Christian Schegan

Redundant Actuators Without Direct Communication for Reactor Control Rod Positioning

Arthur Devine, Daniel F. Opila

A Low Latency Parallel Bus Interface for High-Speed Multi-FPGA RT-Simulations

Michele Difronzo, Herbert Ginn, Andrea Benigni

Evaluation of Communication Network Models for Shipboard Power Systems

Juan Ospina, Charalambos Konstantinou, Mark Stanovich, Michael Mischa Steurer

11:30 pm Technical Session C3L-C
Protection, Reconfiguration, Survivability
Co-chairs: *Marie Lawson*, Ingalls Industries – Newport News Shipbuilding; *Ali Bazzi*, University of Connecticut

Robust 5 kA, 1 kV Solid-State DC Circuit Breaker for Next Generation Marine Power Systems

Rostan Rodrigues, Yuzhi Zhang, Utkarsh Raheja, Pietro Cairoli, Luca Raciti, Antonello Antoniazzi

System Inductance for MVDC Circuit Breakers

Norbert Doerry, John Amy Jr.

Multiple Line-to-Ground Fault Characterization and Mitigation in MVDC Shipboard Electrical Systems

Jacob Gudex, Robert Cuzner

Deep Learning-Based Fault Detection, Classification, and Locating in Shipboard Power Systems

Soroush Senemmar, Jie Zhang

12:00 pm Technical Session C4L-D
Energy Storage and Pulsating Loads

Co-chairs: *Ben Ford*, Hepburn & Sons; *Stephen Kuznetsov*, Raytheon

Using Power Hardware-in-the-Loop Simulation to Study Control of Energy Storage Within Limited-Inertia Power System

James Langston, Kazuki Watanabe, John Hauer, Karl Schoder, Mark Stanovich, Harsha Ravindra, Michael Mischa Steurer

Strategies for Preserving the Battery SOC in DC Shipboard Power Systems

Andrea Alessia Tavagnutti, Daniele Bosich, Giorgio Sulligoi

Battery Management System (BMS) Test Stand Utilizing a Hardware-in-the-Loop (HIL) Emulated Battery

Cole Tschritter, David Wetz, Gregory Turner, John Heinzl

The Optimal Control of an Electric Warship Driven by an Operational Vignette

Joseph Young, David Wilson, Marvin Cook

Priority-Based Management of Energy Resources During Power-Constrained Operation of Shipboard Power System

James Langston, Harsha Ravindra, Michael Mischa Steurer, Tom Fikse, Christian Schegan, Joseph Borraccini

Friday, August 06

- 10:00 am Plenary Session II
Engineering Challenges of Autonomous Vessels
- 11:30 pm Technical Session D1L-A
Electrical Power Conversion for DC Distribution
Co-chairs: *Giorgio Sulligoi*, University of Trieste; *Patrick Lewis*, Hepburn & Sons
- Medium Voltage Ring-Bus Grid Design Employing Current-Fed, Three-Port Dual Active Bridge Converters with Average Power Flow Control**
Zachary Smith, Brandon Grainger
- Two-Phase Milli/Microchannel Cooling for SiC Power Module Using Dielectric Fluid Coolant**
Bo Tian, Wei Chang, Enrico Santi, Chen Li, Tianyu Zhang, Lang Yuan
- Design of a High-Frequency Transformer and 1.7 kV Switching-Cells for an Integrated Power Electronics Building Block (iPEBB)**
Narayanan Rajagopal, Ravisekhar Raju, Taha Moaz, Christina Dimarino
- Preliminary Investigation Into Liquid-Cooled PEBBs**
Joushua Padilla, Julie Chalfant, Chryssostomos Chryssostomidis, Chathan Cooke
- 12:00 pm Technical Session D2L-B
Electrical & Thermal Modeling of Converter Components
Co-chairs: *Harish Suryanarayana*, ABB; *Ali Davoudi*, University of Texas Arlington
- Packaging of an 8-kV Silicon Carbide Diode Module with Double-Side Cooling and Sintered-Silver Joints**
Zichen Zhang, Jiaxiang Zhang, Jiayu Xu, Khai Ngo, Guo-Quan Lu, Emily Cousineau, Paul Paret, Sreekant Narumanchi
- Electrothermal Management Using In-Situ Junction Temperature Monitoring for Enhanced Reliability of SiC-Based Power Electronics**
Dehao Qin, Gokhan Ozkan, Christopher Edrington, Zheyu Zhang
- Empirical Procedure for Estimating Mutual Coupling in High-Performance Power Modules**
Ali Shahabi, Andrew Lemmon, Brian Deboi, Troy Beechner, Robert Mayo
- vemPEBB: Rapid PEBB Thermal Management Tool**
Sam Yang, Juan Ordonez, Yue Xu, Igor Cvetkovic

Component Evaluation and PSpice Modeling for Charge Pump Based Cell Voltage Balancer Development

Mostafa Negm, Manuel Morales, William Lynch

12:30 pm Technical Session D3L-C

MVDC Power Distribution

Co-chairs: *MikeMazzola*, University of North Carolina Charlotte; *Mona Ghassemi*, Virginia Tech

Coaxial Insulated Bus Pipe, a Low Magnetic Signature Solution for Medium Voltage Direct Current Shipboard Power Distribution

Terrence Northington, Patrick Lewis, Ehsan Alavi, Dustin Carver, Matthew Bosworth

Application of IEC-61800-5 Insulation Coordination to Shipboard Equipment Scaling Studies

Robert Cuzner, William Koebel

HTS Technology Driven Shipboard Power Distribution Architecture – Electrical

Peter Cheetham, Srikar Telikapalli, Taylor Stamm, Chul Kim, Sastry Pamidi

HTS Technology Driven Shipboard Power Distribution Architecture – Cryogenics

Srikar Telikapalli, Peter Cheetham, Chul Kim, Sastry Pamidi