U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

2018 UNIVERSITY TURBINE SYSTEMS RESEARCH PROJECT REVIEW MEETING

10.30.18 – 11.1.18

EMBRY-RIDDLE Aeronautical University

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About the UTSR Meeting

The National Energy Technology Laboratory University Turbine Systems Research (NETL-UTSR) program manages a portfolio of university-based turbine research projects. The UTSR program offers a Gas Turbine Industrial Fellowship funded by sponsoring gas turbine manufacturers. This fellowship has helped to facilitate the transition of the best students from academia to the gas turbine industry, thereby helping to maintain U.S. leadership in this important area of technology.

The success of the UTSR program has been made possible by a network of universities, the collaborating gas turbine industry, and the DOE turbine program – all of which are facilitated by an annual UTSR project review meeting, which is open to the public and brings together experts from academia, industry, and government to present and discuss ongoing turbine research sponsored by the DOE Office of Fossil Energy UTSR program under existing cooperative agreements.

The UTSR program chooses meeting venues that are in close proximity to leading universities directly involved in turbine research. The 2018 UTSR project review meeting co-hosted by Embry-Riddle Aeronautical University will be held at the Hilton Daytona Beach Resort/Ocean Walk Village in Daytona Beach, FL from Oct-30 – Nov 1. The theme of this year's review meeting is synergistic research between DOE, DOD, and NASA. There will be three keynote speakers; Dr. Robert Hancock, Chief Scientist for the Turbine Engine Division of the Aerospace Systems Directorate of the Air Force Research Laboratory; Dr. Klaus Brun, Machinery Program Director at Southwest Research Institute; and Dr. Krishan Luthra, Chief Materials Scientist, General Electric Global Research. Dr. Hancock will provide an Overview of Air Force Turbine Engine Research and Development, Dr. Brun will provide an Overview of the US NG Distribution System and Compressor Stations, and Dr. Luthra will speak on History of Development and Commercialization of Structural Ceramics for Industrial Gas Turbines and Aircraft Engines at GE. The meeting will feature two panel discussions related to cross-agency collaboration: one will focus on Pressure Gain Combustion R&D and the other will focus on Ceramic Materials for Gas Turbines: CMC R&D Programs Across Federal Agencies. The projects reviews will be organized into three parallel technology tracks: Combustion/Pressure Gain Combustion, Aero/Heat Transfer/Supercritical CO_2, and Materials. The meeting will feature approximately 60 DOE sponsored projects in the form of oral and poster presentations including a majority of NETL's extramural projects for the Advanced Turbines Program, as well as internal NETL R&D projects.

UTSR Technology Summary

Since the inception of the DOE turbine program, the NETL-UTSR program has sought to support the underlying scientific research necessary to develop advanced turbines and turbine-based systems in support of the DOE's turbine program's strategic goals and program mission needs. The UTSR program has two primary goals. One is to produce results that resolve technical issues associated with DOE's Office of Fossil Energy Advanced Turbine Program and the other is to maintain and enhance university-based turbine engineering capabilities in the United States. These two UTSR Program goals will continue to be realized through the involvement of professors and students in research and development on advanced turbine technical issues, while enhancing the education of future scientists and engineers in the U.S. This is accomplished by funding university-based research projects that address scientific R&D and technical challenges in turbine-based systems and technology. This research focuses on the fundamental and applied issues associated with advancing the performance and efficiency of turbines in fossil fuel power generation beyond current state-of-the-art. Technical areas of interest include combustion, aerodynamics, heat transfer, materials, technology development for supercritical carbon dioxide based power cycles, pressure gain combustion, and oxy-fuel turbine based systems and technology.

The projects are typically three years in duration and focus on applied laboratory/bench scale R&D. Currently 10 universities and 20 projects are involved in the NETL-UTSR program. The innovations and scientific understanding generated under this program will then be transferred to industry manufacturers for incorporation into their next generation turbine technology products with the goal of producing reliable, affordable, clean, efficient, and cost-effective energy supplies.

One of the main purposes of this UTSR project review meeting is to facilitate peer-to-peer knowledge sharing and collaboration across boundaries to create a network of expertise and facilitate the acceleration of advancements in those fields.

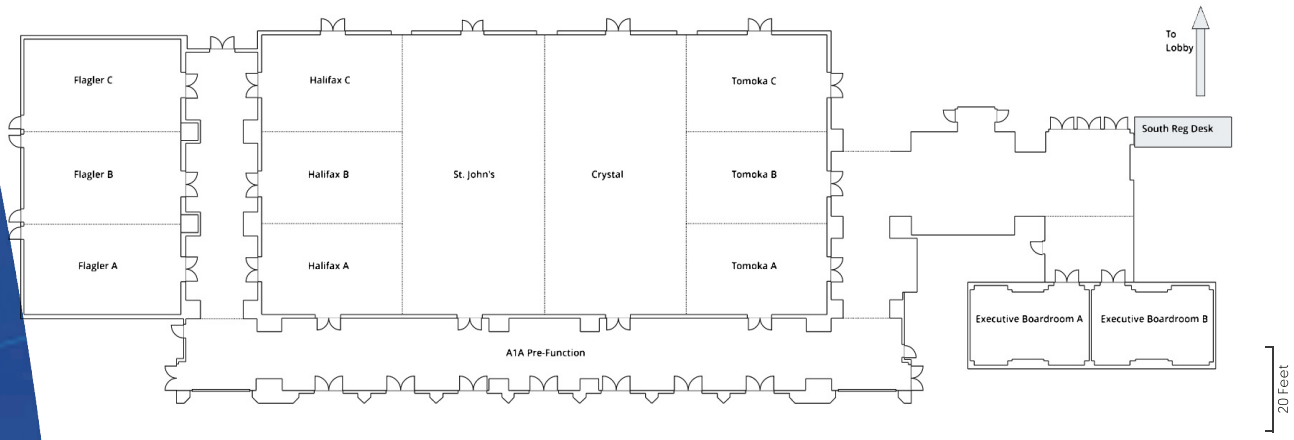
Organizing Committee

Patcharin (Rin) Burke	US DOE – NETL
Richard Dalton	KeyLogic
Bill Day	KeyLogic
Richard Dennis	US DOE – NETL
Donald Ferguson	US DOE - NETL
Edgar Lara-Curzio	Oak Ridge National Laboratory
Karen Lockhart	SSC Deltha
Scott Martin	Embry Riddle University
Greg O'Neil	US DOE – NETL

UTSR Industry Committee

John Alday	FlexEnergy
Klaus Brun	Southwest Research Institute
Michael Fox	Solar Turbines, Inc.
Scott Macadam	Gas Technology Institute (GTI)
Jonathan Li	Siemens Energy, Inc.
Joe Weber	General Electric

Hilton Daytona Beach Resort Hotel - South Tower



Laboratory Tour

We will visit three facilities on the Embry-Riddle Aeronautical University Daytona Beach campus.

- The Lehman Engineering Building houses administrative offices, five academic departments of the College of Engineering, the 3024 core Vega compute cluster, and 17 laboratories including the Gas Turbine and Composites Laboratories. In addition, the Lehman Engineering Building offers computing resources and open workspaces facilitating collaborative development for interdisciplinary student teams. Hands-on learning and learning-by-doing are enabled through a variety of student-accessible laboratories with the tools for a complete engineering design-build-test project cycle. The third floor also features a fully functional Distance Learning and Lecture Capture Studio, for creating high-quality and effective learning modules to enhance teaching at all levels.

- The 16,000-square-foot wind tunnel facility with a test section of 6 by 4 ft, was recently completed. One of the most technologically advanced subsonic wind tunnels in the United States, the Embry-Riddle facility is capable of delivering wind speeds up to 230 mph. It includes a Particle Image Velocimetry (PIV) system. The new wind tunnel will support aviation and automotive racing projects.

- The Eagle Flight Research Center (EFRC) is a unique facility providing research and testing of manned and unmanned aircraft. The EFRC has an experienced staff of professors, staff, and FAA-Designated Engineering Representatives (DERs), pilots, and technicians. Our faculty and staff are experienced with experimental aircraft, certification, instrumentation, and data gathering and analysis. Current programs include flight testing unleaded aviation fuel and building an all-electric aircraft.

Agenda-At-A-Glance

Day 1 - Tuesday, October 30, 2018										
7.30 am	Registration/Continental Breakfast - Foyer/Crystal Room									
8.30 am	General Session - St. John's and Halifax Room									
8.30 am	Welcome and Introduction, Barry Butler, President, Embry-Riddle Aeronautical University									
8.55 am	Opening Remarks – Richard Dennis, Turbine Technology Manager, NETL									
9.00 am	Keynote speech: Overview of DOE Advanced Turbines Program- Richard Dennis, Turbine Technology Manager, NETL									
9.30am	Keynote Speech: Overview of Air Force Turbine Engine Research and Development, Robert Hancock, Chief Scientist, Turbine Engine Division of the Aerospace Systems Directorate of the Air Force Research Laboratory									
10.15 am	AM Break - Crystal Room									
10.45 am	Panel Discussion: Pressure Gain Combustion Research and Development (Donald Ferguson -NETL; Chris Greene -UTRC; Adam Holley -AFRL East; Keith McManus -GE; Guillermo Paniagua -Purdue University; Eric Paulson - AFRL West)									
12.00 pm	Lunch -Flagler Room									
1.30 pm	Keynote Speech: Overview of the US NG Distribution System and Compressor Stations, Klaus Brun, Machinery Program Director, Southwest Research Institute									
2.15 pm	Change room									
	Track A - Combustion (Day 1, 2, & 3) and Pressure Gain Combustion (Day 2) - St. John's Room			**Track B - Aero and Heat Transfer (Day 1, 2, & 3) and Super Critical CO_2 (Day 2, 3)-Halifax room**			**Track C - Materials (Day 1, 2, & 3) and Super Critical CO_2 (Day 2) - Tomoka Room**			
	Moderators: Mark Freeman and Donald Ferguson			Moderators: Robin Ames and Seth Lawson			Moderators: Rin Burke and Richard Dalton			
	Organization	Title	Presenter	Organization	Title	Presenter	Organization	Title	Presenter	
2.35 pm	GE	Advanced Multi-Tube Mixer Combustion for 65% Efficiency	Michael Hughes	Penn State University	START Turbine Testing Review	Karen Thole	GE	High Temperature Ceramic Matrix Composite (CMC) Nozzles for 65% Efficiency	John Delvaux	
3.10 pm	Georgia Tech	High-Frequency Transverse Combustion Instabilities in Low-NOx Gas Turbines	Tim Lieuwen	University of Pittsburgh	Integrated Transpiration and Lattice Cooling Systems Developed by Additive Manufacturing with Oxide-Dispersion Strengthened Alloys	Minking Chyu and Bruce Kang	Clemson	Integrated TBC/EBC For SiC Fiber Reinforced SiC Matrix Composites for Next Generation Gas Turbines	Raj Bordia	
3.45 pm	PM Break - Crystal Room									
4.15 pm	Penn State University	Understanding Transient Combustion Phenomena in Low-NOx Gas Turbines	Jacqueline O'Connor	Purdue University	Effect of High Heating Load on Internal Cooling	Tom Shih	ORNL	Materials Issues for Advanced Supercritical CO2 Cycles and High Efficiency Gas Turbines	Bruce Pint	
4.50 pm	Embry Riddle	Improving NOx Entitlement with Axial Staging	Scott Martin	NETL-RIC	Film Cooling Experiments in the High Temperature High Pressure Test Facility	Sridharan Ramesh	Ohio State University	Development of High Performance Ni-Base Alloys for Gas Turbine Wheels Using a Coprecipitation Approach	Michael Mills	
5.30-7.00 pm	**Poster Session - Crystal Room**									

Agenda-At-A-Glance

Day 2 - Wednesday, October 31, 2018

7.30 am	Registration/Continental Breakfast - Foyer/Crystal Room									
8.30 am	General Session - St. John's and Halifax Room									
8.30 am	Keynote Speech: History of Development and Commercialization of Structural Ceramics for Industrial Gas Turbines and Aircraft Engines at GE, Krishan Luthra, Chief Materials Scientist, GE Global Research Center									
9.15 am	AM break - Crystal Room									
9.45 am	Panel Discussion: Ceramic Materials for Gas Turbines: CMC R&D Programs Across Federal Agencies (Richard Dennis - NETL; Joseph Grady - NASA Glenn; Allan Katz - AFRL; Edgar Lara-Curzio - ORNL)									
11.15 am	Lunch Talk: Overview of sCO2 Development Activities at Southwest Research Institute, Jeff Moore, Southwest Research Institute - Flagler Room									
	Track A - Combustion (Day 1, 2, & 3) and Pressure Gain Combustion (Day 2) - St. John's Room			**Track B - Aero and Heat Transfer (Day 1, 2, & 3) and Super Critical CO_2 (Day 2, 3)-Halifax room**			**Track C - Materials (Day 1, 2, & 3) and Super Critical CO_2 (Day 2) - Tomoka Room**			
	Moderators: Mark Freeman and Donald Ferguson			Moderators: Robin Ames and Seth Lawson			Moderators: Rin Burke and Richard Dalton			
	Organization	Title	Presenter	Organization	Title	Presenter	Organization	Title	Presenter	
12.30 pm	Georgia Tech	High Temperature, Low NOx Combustor Concept Development	Tim Lieuwen	Penn State University	Discrete Element Roughness Modeling for Design Optimization of Additively and Conventionally Manufactured Internal Turbine Cooling Passages	Robert Kunz	Altex	Corrosion and Erosion Resistant Surface Features for High Pressure Supercritical Carbon Dioxide Heat Exchangers	John Kelly	
1.05 pm	University of Michigan	A Joint Experimental/Computational Study of Non-Idealities in Practical Rotating Detonation Engines	Mirko Gamba	Ohio State University	Revolutionizing Turbine Cooling with Micro-Architectures Enabled by Direct Metal Laser Sintering	Jeffrey Bons	Thar Energy	Development of Modular, Low-Cost, High-Temperature Recuperators for the sCO_2 Power Cycle - Prototype Performance Review	Marc Portnoff	
1.40 pm	University of Michigan	Fuel Injection Dynamics and Composition Effects on Rotating Detonation Engine Performance	Mirko Gamba	GE	Low-Leakage Seals for Utility-Scale sCO_2 Turbines	Rahul Bidkar	NETL-RIC	RIC FWP - Materials Research for Supercritical CO_2 Power Cycles	Omer Dogan	
2.15 pm	PM Break - Crystal Room									
2.45 pm	Aerojet Rocketdyne	Rotating Detonation Combustion for Gas Turbines - Modeling and System Synthesis to Exceed 65% Efficiency Goal	Scott Claflin	SwRI	Development of a 1 MWth Combustor for a Direct Fired Supercritical CO_2 Power Cycle	Jacob Delimont	UCF	In-situ Optical Monitoring of Operating Gas Turbine Blade Coatings Under Extreme Environments	Seetha Raghavan	
3.20 pm	Purdue University	Advancing Pressure Gain Combustion in Terrestrial Turbine Systems	Carson Slabaugh	Cascade Technologies	LES of Oxy-Fuel Combustion for sCO_2 Power Systems	Lee Shunn	Georgia Tech	Real-Time Health Monitoring for Gas Turbine Components Using Online Learning and High Dimensional Data	Nagi Gebraeel	
3.55 pm	NETL-RIC	Overview of Rotating Detonation Combustion Study at NETL	Don Ferguson	Georgia Tech	Investigation of Autoignition and Combustion Stability of High Pressure Supercritical Carbon Dioxide Oxy-combustion	Wenting Sun	Advanced Powder Solutions	Superalloy MMC Components for Advanced Turbine Systems	Dean Baker	
4.30 pm	Oregon State University	Pulse Detonation Engine for Advanced Oxy-Combustion of Coal-Based Fuel for Direct Power Extraction Applications	David Blunck	CATER/UCF	Chemical Kinetic Modeling Development and Validation Experiments for Direct Fired Supercritical Carbon Dioxide Combustor	Subith Vasu	HiFunda	Development of a Novel Ceramic-to-Metal Seal for High-Temperature High-Pressure Applications	James Steppan	
5.15 pm-7.15 pm	**Lab tour: Embry-Riddle College of Engineering Research Facility Including the New Wind Tunnel and Eagle Flight Research Center**									

Agenda-At-A-Glance

Day 3 - Thursday, November 1, 2018										
7.30 am	Registration/Continental Breakfast - Foyer/Crystal Room									
	Track A - Combustion (Day 1, 2, & 3) and Pressure Gain Combustion (Day 2) - St. John's Room			**Track B - Aero and Heat Transfer (Day 1, 2, & 3) and Super Critical CO_2 (Day 2, 3)-Halifax room**			**Track C - Materials (Day 1, 2, & 3) and Super Critical CO_2 (Day 2) - Tomoka Room**		
	Moderators: Mark Freeman and Donald Ferguson			Moderators: Robin Ames and Seth Lawson			Moderators: Rin Burke and Richard Dalton		
	Organization	Title	Presenter	Organization	Title	Presenter	Organization	Title	Presenter
8.30 am	Siemens Energy	Extension of Operating Envelope for an Extremely Low NOx Axial Stage Combustion System	Andrew North	GE	Turbine Aero-Thermal Technologies for 65% Combined Cycle Efficiency	Joe Weber	Siemens Energy	Design and Development of Low Weight, Titanium Aluminide Airfoils for High Performance Industrial Gas Turbines Meeting 65% Combined Cycle Efficiency	Sam Miller
8.55 am	GTI	Advanced Modular Sub-Atmospheric Hybrid Heat Engine	Yaroslav Chudnovsky	Echogen	Integrated Optimization and Control of a Hybrid Gas Turbine/sCO_2 Power System	Tim Held	GE	High Temperature, High AN2 Last Stage Blade for 65% Combined Cycle Efficiency	John Delvaux
9.20 am	GTI	Modular Heat Engine for Co-Production of H_2 Power and CO_2	Jeffrey Mays	GE	Novel Modular Heat Engines with sCO_2 Bottoming Cycle Utilizing Advanced Oil-Free Turbomachinery	Bugra Ertas	UTRC	Hybrid Ceramic-CMC Vane with EBC for Future Coal Derived Syngas Fired Highly Efficient Turbine Based Combined Cycle	John Holowczak
9.45 am	AM break - Crystal Room								
10.15 am	Bechtel	Turbocompound Reheat Gas Turbine Combined Cycle	S.C. (John) Gülen	SwRI	Advanced Gas Turbine and sCO2 Combined Cycle Power System	Kevin Hoopes	Siemens	Additive Manufactured Metallic-3D Ox-Ox CMC Integrated Structures for 65% Combined Cycle Efficiency	Ramesh Subramanian
10.40am				Mechanical Solutions	An Advanced Gas Foil Bearing Using Supercritical Carbon Dioxide as the Working Fluid	Peter Chapman	GE	High Temperature Additive Architectures for 65% Efficiency	Joe Weber
11.05 am	Change room								
11.20 am	Open Discussion, Workshop Summary, Closing Comments and Wrap-up - Richard Dennis, Advanced Turbines Technology Manager, NETL - St. John's and Halifax Room								
11.40 am	**Adjourn**								

TUESDAY, OCT. 30

7:30 a.m. Registration - Foyer
Continental Breakfast – Crystal Room

General Session – St. John's & Halifax Room

8:30 a.m. Welcome
P. Barry Butler, Ph.D.
President, Embry-Riddle Aeronautical University

8:55 a.m. Opening Remarks
Richard Dennis, Turbine Technology Manager, U.S. Department of Energy (DOE), National Energy Technology Laboratory (NETL)

9:00 a.m. Overview of DOE Advanced Turbines Program
Richard Dennis, Turbine Technology Manager, DOE NETL

9:30 a.m. Overview of Air Force Turbine Engine Research and Development
Robert Hancock, Chief Scientist, Turbine Engine Division of the Aerospace Systems Directorate of the Air Force Research Laboratory (AFRL)

10:15 a.m. Break – Crystal Room

10:45 a.m. Panel Discussion, Pressure Gain Combustion Research and Development - St. John's & Halifax Rooms
Don Ferguson, DOE NETL
Chris Greene, United Technologies Research Center (UTRC)
Adam Holley, AFRL East
Keith McManus, GE Global Research Center
Guillermo Paniagua, Purdue University
Eric Paulson, AFRL West

12:00 noon Lunch – Flagler Room

1:30 p.m. Overview of the US NG Distribution System and Compressor Stations
Klaus Brun, Machinery Program Director, Southwest Research Institute

TUESDAY, OCT. 30

TRACK A

Combustion & Pressure Gain Combustion – St. John's Room

Moderator – Mark Freeman and Donald Ferguson – DOE NETL

2:35 p.m. Advanced Multi-Tube Mixer Combustion for 65% Efficiency
Michael Hughes, General Electric (GE)

3:10 p.m. High Frequency Transverse Combustion Instabilities in Low-NO_x Gas Turbines
Tim Lieuwen, Georgia Tech

3:45 p.m. Break – Crystal Room

4:15 p.m. Understanding Transient Combustion Phenomena in Low-NO_x Gas Turbines
Jacqueline O'Connor, Pennsylvania State University

4:50 p.m. Improving NO_x Entitlement with Axial Staging
Scott Martin, Embry-Riddle Aeronautical University

5:30 -7:00 p.m. Poster Session – Crystal Room

TRACK B

Aero & Heat Transfer & Supercritical CO_2 – Halifax Room

Moderator – Robin Ames and Seth Lawson – DOE NETL

2:35 p.m. START Turbine Testing Review
Karen Thole, Pennsylvania State University

3:10 p.m. Integrated Transpiration and Lattice Cooling Systems Developed by Additive Manufacturing with Oxide Dispersion Strengthened Alloys
Minking Chyu, University of Pittsburgh and Bruce Kang, West Virginia University

3:45 p.m. Break – Crystal Room

4:15 p.m. Effects of High Heating Loads on Internal Cooling
Tom Shih, Purdue University

4:50 p.m. Film Cooling Experiments in the High Temperature High Pressure Test Facility
Sridharan Ramesh, DOE NETL

5:30-7:00 p.m. Poster Session – Crystal Room

TUESDAY, OCT. 30

TRACK C

Materials & Supercritical CO_2 – Tomoka Room

Moderator – Rin Burke and Richard Dalton – DOE NETL

2:35 p.m. High Temperature Ceramic Matrix Composite (CMC) Nozzles for 65% Efficiency
John Delvaux, GE

3:10 p.m. Integrated TBC/EBC for SiC Fiber Reinforced SiC Matrix Composites for Next Generation Gas Turbines
Rajendra Kumar Bordia, Clemson University

3:45 p.m. Break – Crystal Room

4:15 p.m. Materials Issues for Advanced Supercritical CO_2 Cycles and High Efficiency Gas Turbines
Bruce Pint, Oak Ridge National Laboratory

4:50 p.m. Development of High Performance Ni-Base Alloys for Gas Turbine Wheel Using a Coprecipitation Approach
Michael Mills, The Ohio State University

5:30-7:00 p.m. Poster Session – Crystal Room

WEDNESDAY

WEDNESDAY, OCT. 31

7:30 a.m. Registration - Foyer
Continental Breakfast – Crystal Room

General Session – St. John's & Halifax Room

8:30 a.m. History of Development and Commercialization of Structural Ceramics for Industrial Gas Turbines and Aircraft Engines at GE
Krishan Luthra, Chief Materials Scientist, GE Global Research Center

9:15 a.m. AM Break – Crystal Room

9:45 a.m. Panel Discussion: Ceramic Materials for Gas Turbines: CMC R&D Programs Across Federal Agencies
Anindya Ghoshal, U.S. Army Research Laboratory
Joseph Grady, NASA Glenn
Allan P. Katz, AFRL
Bruce Pint, Oak Ridge National Laboratory

11:15 a.m. Lunch – Flagler Room
Overview of sCO_2 Development Activities at Southwest Research Institute
Jeffrey Moore, Southwest Research Institute

TRACK A
Combustion & Pressure Gain Combustion – St. John's Room

Moderators – Mark Freeman and Donald Ferguson – DOE NETL

12:30 p.m. High Temperature, Low NO_x Combustor Concept Development
Tim Lieuwen, Georgia Tech

1:05 p.m. A Joint Experimental Computational Study of Non-Idealities in Practical Rotating Detonation Engine Performance
Mirko Gamba, University of Michigan

1:40 p.m. Fuel Injection Dynamics and Composition Effects on Rotating Detonation Engine Performance
Mirko Gamba, University of Michigan

2:15 p.m. Break – Crystal Room

WEDNESDAY, OCT. 31

2:45 p.m. Rotating Detonation Combustion for Gas Turbines – Modeling and System Synthesis to Exceed 65% Efficiency Goal
Scott Claflin, Aerojet Rocketdyne

3:20 p.m. Advancing Pressure Gain Combustion in Terrestrial Turbine Systems
Carson Slabaugh, Purdue University

3:55 p.m. Overview of Rotating Detonation Combustion Study at NETL
Don Ferguson, DOE NETL

4:30 p.m. Pulse Detonation Engine for Advanced Oxy-Combustion of Coal-Based Fuel for Direct Power Extraction Applications
David Blunck, Oregon State University

5:15-7:15 p.m. Lab Tour: Embry-Riddle College of Engineering Research Facility, including the New Wind Tunnel and Eagle Flight Research Center

TRACK B
Aero & Heat Transfer & Supercritical CO_2 – Halifax Room

Moderators – Robin Ames and Seth Lawson – DOE NETL

12:30 p.m. Discrete Element Roughness Modeling for Design Optimization of Additively and Conventionally Manufactured Internal Turbine Cooling Passages
Robert Kunz, Pennsylvania State University

1:05 p.m. Revolutionizing Turbine Cooling with Micro-Architectures Enabled by Direct Metal Laser Sintering
Jeffrey Bons, The Ohio State University

1:40 p.m. Low-leakage Seals for Utility-scale sCO_2 Turbines
Rahul Bidkar, GE

2:15 p.m. Break – Crystal Room

2:45 p.m. Development of a 1MWth Combustor for a Direct Fired Supercritical CO_2 Power Cycle
Jacob Delimont, Southwest Research Institute

3:20 p.m. LES of Oxy-Fuel Combustion for sCO_2 Power Systems
Lee Shunn, Cascade Technologies

3:55 p.m. Investigation of Autoignition and Combustion Stability of High Pressure Supercritical Carbon Dioxide Oxy-combustion
Wenting Sun, Georgia Institute of Technology

WEDNESDAY, OCT. 31

4:30 p.m. Chemical Kinetic Modeling Development and Validation Experiments for Direct Fired Supercritical Carbon Dioxide Combustor
Subith Vasu, University of Central Florida Center for Advanced Turbine and Energy Research (UCF/CATER)

5:15-7:15 p.m. Lab Tour: Embry-Riddle College of Engineering Research Facility, including the New Wind Tunnel and Eagle Flight Research Center

TRACK C
Materials & Supercritical CO_2 - Tomoka Room

Moderators – Rin Burke and Richard Dalton – DOE NETL

12:30 p.m. Corrosion and Erosion Resistant Surface Features for High-Pressure Supercritical Carbon Dioxide Heat Exchangers
John Kelly, Altex

1:05 p.m. Development of Modular, Low-Cost, High-Temperature Recuperators for the sCO_2 Power Cycle – Prototype Performance Review
Marc Portnoff, Thar Energy, LLC

1:40 p.m. RIC FWP – Materials Research for sCO_2 Power Cycles
Omer Dogan, DOE NETL

2:15 p.m. Break – Crystal Room

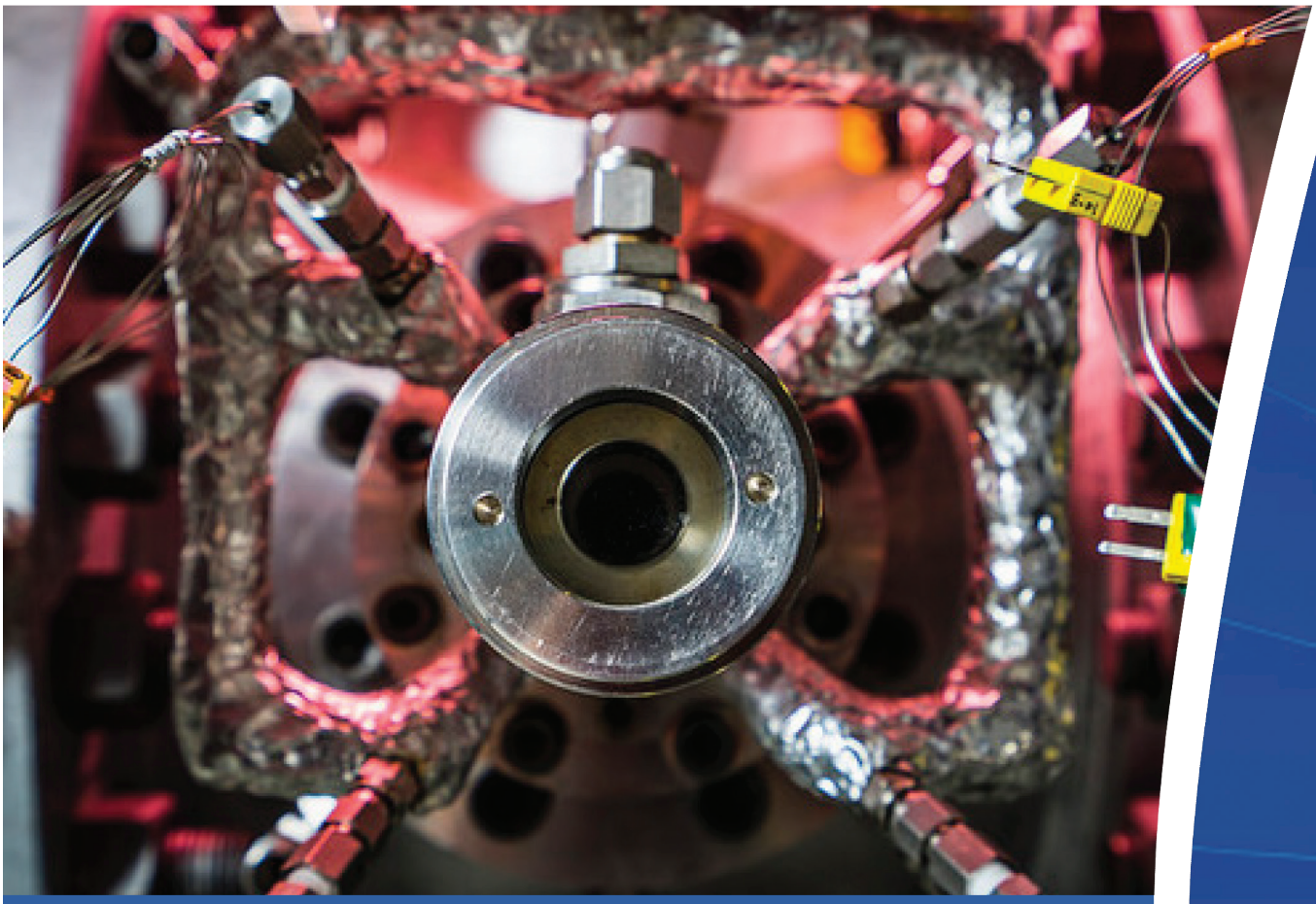
2:45 p.m. In-Situ Optical Monitoring of Operating Gas Turbine Blade Coatings Under Extreme Environments
Seetha Ragavan, University of Central Florida

3:20 p.m. Real-Time Health Monitoring for Gas Turbine Components Using Online Learning and High Dimensional Data
Nagi Gebraeel, Georgia Institute of Technology

3:55 p.m. Superalloy MMC Components for Advanced Turbine Systems
Dean Baker, Advanced Powder Solutions, Inc.

4:30 p.m. Development of a Novel Ceramic-to-Metal Seal for High-Temperature High-Pressure Applications
James Steppan, HiFunda LLC

5:15-7:15 p.m. Lab Tour: Embry Riddle College of Engineering Research Facility, including the New Wind Tunnel and Eagle Flight Research Center



THURSDAY

THURSDAY, NOV. 1

7:30 a.m. Registration - Foyer
Continental Breakfast – Crystal Room

TRACK A
Combustion & Pressure Gain Combustion – St. John's Room

Moderators – Mark Freeman and Donald Ferguson – DOE NETL

8:30 a.m. Extension of Operating Envelope for an Extremely Low NO_x Axial Stage Combustion System
Andrew North, Siemens Energy, Inc.

8:55 a.m. Advanced Modular Sub-Atmospheric Hybrid Heat Engine
Yaroslav Chudnovsky, Gas Technology Institute

9:20 a.m. Modular Heat Engine System for Co-Production of H_2 Power and CO_2
Ganesan Subbaraman, Gas Technology Institute

9:45 p.m. Break – Crystal Room

10:15 a.m. Turbocompound Reheat Gas Turbine Combined Cycle
S.C. (John) Gülen, Bechtel Infrastructure & Power

11:05 a.m. General Session – St John's and Halifax Rooms

11:20 a.m. Open Discussion, Workshop Summary, Closing Comments and Wrap-Up
Richard Dennis, DOE NETL

11:40 a.m. Adjourn

TRACK B
Aero & Supercritical CO_2 – Halifax Room

Moderators – Robin Ames and Seth Lawson – DOE NETL

8:30 a.m. Turbine Aero-Thermal Technologies for 65% Combined Cycle Efficiency
Joe Weber, General Electric

8:55 a.m. Integrated Optimization and Control of a Hybrid Gas Turbine/sCO_2 Power Systems
Tim Held, Echogen Power Systems

9:20 a.m. Novel Modular Heat Engines with sCO_2 Bottoming Cycle Utilizing Advanced Oil-Free Turbomachinery
Bugra Ertas, GE Research Center

9:45 p.m. Break – Crystal Room

THURSDAY, NOV. 1

10:15 a.m. Advanced Gas Turbine and sCO_2 Combined Cycle Power System
Kevin Hoopes, Southwest Research Institute

10:40 a.m. An Advanced Gas Foil Bearing Using sCO_2 as the Working Fluid
Peter Chapman, Mechanical Solution, Inc.

11:05 a.m. – General Session – St. John's and Halifax Room

11:20 a.m. Open Discussion, Workshop Summary, Closing Comments and Wrap-up
Richard Dennis, DOE NETL

11:40 a.m. Adjourn

TRACK C
Materials & Supercritical sCO_2 – Tomoka Room

Moderators – Rin Burke and Richard Dalton – DOE NETL

8:30 a.m. Design and Development of Low Weight, Titanium Aluminide Airfoils for High Performance Industrial Gas Turbines Meeting 65% Combined Cycles Efficiency
Sam Miller, Siemens

8:55 a.m. High Temperature. High AN2 Last Stage Blade for 65% Combined Cycle Efficiency
John Delvaux, GE

9:20 a.m. Hybrid Ceramic-CMC Vane with EBC for Future Coal Derived Syngas Fired Highly Efficient Turbine Based Combined Cycle
John Holowczak, United Technologies Research Center

9:45 p.m. Break – Crystal Room

10:15 a.m. Additive Manufactured Metallic 3D Ox-Ox CMC Integrated Structures for 65% Combined Cycle Efficiency
Ramesh Subramanian, Siemens Energy, Inc.

10:40 a.m. High Temperature Additive Architectures for 65% Efficiency
Joe Weber, General Electric

11:05 a.m. – General Session – St. John's and Halifax Room

11:20 a.m. Open Discussion, Workshop Summary, Closing Comments and Wrap-up
Richard Dennis, DOE NETL

11:40 a.m. Adjourn

KEYNOTE SPEAKERS

Klaus Brun

Dr. Brun is the Machinery Program Director at Southwest Research Institute where he leads an organization of more than 60 that focuses on R&D for the energy industry. His past experience includes positions in engineering, project management, and management at Solar Turbines, General Electric, and Alstom. He holds eight patents, authored over 350 papers, and published three textbooks on energy systems and turbomachinery. Dr. Brun is a Fellow of the ASME and won an R&D 100 award in 2007 for his Semi-Active Valve invention. He also won the ASME Industrial Gas Turbine Award in 2016 and ASME Oil & Gas Committee Best Paper/Tutorial awards in 1998, 2000, 2005, 2009, 2010, 2012, 2014, 2016, and 2017. Dr. Brun is the past chair of the ASME-IGTI Board of Directors, the ASME Oil & Gas Applications Committee, and ASME sCO_2 Power Cycle Committee. He is also a member of the API 616 Task Force, the ASME PTC-10 task force, the Asia Turbomachinery Symposiums Committee, the Fan Conference Advisory Committee, and the Supercritical CO_2 Symposium Advisory Committee. Dr. Brun is the past Editor of Gas Turbine News and currently the Executive Correspondent of Turbomachinery International Magazine and Associate Editor of the ASME Journal of Gas Turbines for Power.

P. Barry Butler

Dr. P. Barry Butler is the sixth president of Embry-Riddle Aeronautical University. Before joining Embry-Riddle in 2017, he was executive vice president and provost at the University of Iowa.

At Iowa, he previously served as dean of the College of Engineering, associate dean of academic programs and chair of the Department of Mechanical Engineering. Butler is a strong advocate for research and discovery-driven education, partnerships with industry, and K-12 science, technology, engineering and mathematics (STEM) programs.

He earned his bachelor's and master's degrees in aeronautical and astronautical engineering, and his doctorate in mechanical engineering from the University of Illinois Urbana-Champaign.

Richard A. Dennis

Mr. Richard Dennis is currently the Technology Manager for Advanced Turbines and Supercritical Carbon Dioxide Power Cycle Programs at the U.S. Department of Energy's National Energy Technology Laboratory (NETL). These programs support university, industry and U.S. national laboratory research, and development and demonstration projects. Rich has a BS and MS in Mechanical Engineering from West Virginia University. From 1983 to 1992 Mr. Dennis worked in the on-site research group of NETL where he conducted research related to pressurized fluidized bed combustion, gasification and gas stream particulate cleanup for advanced coal based power generation. From 1993 to 2000 Mr. Dennis managed contracted research for the DOE Office of Fossil Energy in advanced fossil fuel power generation including coal combustion, gasification, fuel cells, and gas turbines. In 2002 Richard was selected as a Technology Manager. Currently Richard is serving as the Technology Manager for Advanced Turbines and Supercritical Carbon Dioxide Power Cycles programs at NETL. Additionally, Richard is the leader of the American Society of Mechanical Engineers (ASME) Gas Turbine Segment (GTS) and works to execute the Annual ASME International Gas Turbine Institute Turbo Expo Conference amongst other strategic planning duties relevant to the GTS.

KEYNOTE SPEAKERS

Robert Hancock

Dr. Robert Hancock is the Chief Scientist for the Turbine Engine Division of the Aerospace Systems Directorate of the Air Force Research Laboratory. He graduated with a Bachelor of Science and Master of Science in mechanical engineering from Brigham Young University and with a doctorate in mechanical engineering from the University of Illinois at Urbana-Champaign. He is responsible for the in-house research and development activities of the Turbine Engine Division and for R&D interactions with universities, small businesses and engine manufacturers. Dr. Hancock is a fellow of the American Society of Mechanical Engineers and an associate fellow of the American Institute of Aeronautics and Astronautics. Dr. Hancock served for four years as an officer in the United States Air Force prior to his career as a civilian in the Air Force Research Laboratory.

Krishan L. Luthra

Dr. Luthra got his Bachelor and Master degrees in Metallurgical Engineering from India and his Ph.D. in Metallurgy & Materials Science from the University of Pennsylvania, USA, in 1976. Since then he has been at GE Global Research, head quartered in Niskayuna, NY, USA, where he has had a variety of technical and management roles. From 2008 – 2010, he worked as the Global Technology Leader for Ceramic & Metallurgy Technologies, leading an organization of ~230 technologists working at sites in Niskayuna, NY, USA, Bangalore, India and Shanghai, China. Currently, he is working as a Chief Materials Scientist at GE Global Research.

Dr. Luthra is the recipient of the Coolidge award, highest honor awarded to a researcher at GE Global Research. He is a Fellow of the American Ceramic Society.

Dr. Luthra is perhaps best known for his work on Ceramic Matrix Composites (CMCs). In May 2015, he was profiled by Associated Press for his work on CMCs, a story that was then published by newspapers worldwide.

PANELISTS

Don Ferguson

Dr. Don Ferguson is a research engineer in the Energy Conversion Engineering Group at the Department of Energy's National Energy Technology Laboratory (NETL). Since starting at NETL in 2002, he has been engaged in experimental and computational combustion studies. Current research interest focus on exploring the potential of utilizing continuous detonation wave combustion to enhance thermal efficiency for gas turbine engines. Work in this area has facilitated the development of formal and informal collaborations with additional government agencies (Air Force Research Laboratory, Naval Research Laboratory and NASA Glenn Research Facility, among others). Additional opportunities for collaboration have resulted from Don's current role as the Department of Energy's representative on the PPSA Leadership Team and VAATE/ATTAM Steering Committee. He is an active member of AIAA and ASME, as well as participating in a STEM/STEAM activities such as DOE's Science Bowl and as a coach for First Lego League Junior. In addition to work as a Research Engineer, Dr. Ferguson is also a member of DOE's Emergency Support Function – Energy Team (ESF-12) provided in-field disaster support to FEMA and states/territories as an Energy and GIS Subject Matter Expert (SME). Education includes a doctorate and master's in mechanical engineering (West Virginia University), Bachelor of Science in aerospace engineering (West Virginia University) and a master's in geographical information systems (Penn State University).

Joseph Grady

Joseph E. Grady is Manager of the Ceramic & Polymer Composites Branch in the Materials and Structures Division at NASA Glenn Research Center in Cleveland. In addition to his recent work toward the development, characterization and life prediction of a 2700ºF CMC for turbine engine environments, he has worked at NASA as a Project Manager for aviation safety, engine noise reduction and several engine materials programs. He has a Ph.D. in Aeronautics & Astronautics from Purdue University, and has conducted fundamental research in experimental structural mechanics, structural dynamics, and computational methods for high temperature structural composites.

Chris Greene

Prior to joining UTRC in 2011 to research Pressure Gain Combustion (PGC) as a member of the Pratt & Whitney Vulcan program funded under DARPA, Mr. Greene spent 10 of his nearly 20 year career at Rocketdyne where he worked on J-2X, Space Shuttle Main Engine, THAAD, and several R&D projects which include Rotating Detonation Engines (RDEs). In addition, Mr. Greene spent two years outside of Rocketdyne employed at Jeff Bezos's Blue Origin company to commercially develop space travel. Since the completion of the Vulcan program, Mr. Greene has expanded his research in PGCs including Co-PI for an ARPA-E funded RDE for natural gas power generation and PI for a DARPA funded study of Low Loss Inlets for RDEs.

PANELISTS

Adam Holley

Dr. Adam Holley works at the Air Force Research Laboratory (AFRL) in the combustion branch of the turbine engine division. His research areas include gas turbine combustor design, small engines, and detonation research. The detonation research includes the development of Rotating Detonation Engines and advancing the underlying technology. Prior to joining AFRL he received his degrees from the University of Southern California and worked in industry for 9 years at United Technologies Research Center.

Allan P. Katz

Dr. Allan P. Katz is a Senior Program Manager in the Composites Branch at the Air Force Research Laboratory's Materials and Manufacturing Directorate. He received his Bachelor's Degree in Metallurgy and Materials Science from MIT and holds a Doctorate in Metallurgical Engineering from The Ohio State University.

Dr. Katz entered government service at Wright-Patterson Air Force Base upon completion of his graduate studies. His career has spanned a range of research and management positions. Dr. Katz's work has focused on high temperature ceramics, both monolithic and composite, for structural applications. The former includes research on refractory carbides and nitrides for turbine and rocket propulsion. The latter has focused on development of advanced fibers and fiber-reinforced composites for a variety of air and space applications.

Dr. Katz now leads the Air Force Program to develop very high temperature (2700°F) SiC-based composites for application in the hot section of aerospace turbine engines. He is also a champion for international collaboration, engaging in a variety of formal partnerships with organizations outside the United States.

In 2013 Dr. Katz was named a Fellow of the American Ceramic Society, and in 2017 he became a Fellow of the Air Force Research Laboratory.

Edgar Lara-Curzio

Edgar Lara-Curzio is a Distinguished Research Staff member and leader of the Mechanical Properties & Mechanics Group in the Materials Science & Technology Division (MSTD) at the Oak Ridge National Laboratory (ORNL), where he leads the scientific and technical operations of a group focused on the development and characterization of functional and structural materials for applications in energy and national security. Lara-Curzio also directs the High Temperature Materials Laboratory (HTML) and co-directs the Fossil Energy Program at ORNL. Lara-Curzio is currently a U.S. Department of Energy Technologist in Residence with Arconic Inc. (formerly Alcoa Inc.).

Lara-Curzio received a B.Sc. degree in Engineering Physics from the Metropolitan University (Mexico City) and a Ph.D. degree in Materials Engineering from Rensselaer Polytechnic Institute (Troy, NY). Since joining ORNL in 1992, he has been a principal investigator for several research projects sponsored by the U.S. Department of Energy, other Federal Agencies and industry. His areas of expertise include: mechanical behavior of materials, in particular materials for power generation and for the conversion, transmission, utilization and storage of energy.

Lara-Curzio has authored or co-authored more than 230 articles in peer-reviewed journals or conference proceedings, four book chapters, six U.S. Patents and edited or co-edited 16 books. He received the 2014 FLC Award for Excellence in Technology Transfer, three R&D100 Awards, the Arthur Frederick Greaves-Walker Award from ACerS and the National Institute of Ceramic Engineers, the Richard M. Fulrath Award from ACerS, the Advanced Ceramics Award from ASTM, the Award of Merit from ASTM and the 1997 HENAAC Hispanic Engineer of the Year Award for Outstanding Technical Achievements. Lara-Curzio is a Fellow of both ACerS and ASTM and a member of Alpha Sigma Mu the International Metallurgical Honorary Society.

PANELISTS

Keith McManus

Dr. Keith McManus has been at the GE Global Research Center since November 1999 as a Senior Engineer and contributed to a variety of programs in the Thermo-Sciences organization including pressure-gain combustion programs. He has led projects on low-emissions and fuel flexible combustion systems for GE's gas turbine and jet engines. He has also employed the use of optical diagnostics and imaging to elucidate physical processes associated with turbulent combustion and combustion-acoustic interactions. Since 2011 he has served in several managerial roles at GE GRC and most recently is the Manager of the Combustion Science team. Dr. McManus has approximately 33 years of experience and is an internationally recognized contributor to fundamental studies and applications of advanced combustion technology.

Prior to joining GE, Dr. McManus worked on active control of thermo-fluid systems during a 2-year post-doctoral visit to the C.N.R.S. combustion laboratory in Paris. He then joined Physical Sciences Inc. where he worked for seven years continuing to work in active flow control with aircraft aerodynamics as the focus. He led several government funded programs in this area that were funded by NASA, US Air Force, and the US Army.

Keith received his B.S. in Mechanical Engineering from Cornell University in 1982, a M.S.M.E. from Rennselaer Polytechnic institute in 1985 and a PhD from Stanford University in 1990. Dr. McManus is a Fellow of the American Society of Mechanical Engineers and an Associate Fellow of the American Institute of Aeronautics and Astronautics. He serves as a reviewer for several technical publications including the AIAA Journal, AIAA Journal of Propulsion and Power, Combustion and Flame, The International Combustion Symposium (proceedings), Combustion Science and Technology and the ASME Journal of Engineering for Gas Turbines and Power.

Guillermo Paniagua

Guillermo Paniagua, Professor in Mechanical Engineering at Purdue University is considered a world authority in high speed turbines. He has made contributions to the understanding of the complex high speed flows using a combination of experimental breakthroughs and aero-thermal analysis using CFD. Prof. Paniagua has over twenty years of experience in thermal fluid machinery systems, working toward the efficient transformation of thermal energy into mechanical power. His research has advanced the state-of-the-art in the Precise characterization of high-pressure turbines, and Measurement techniques. He has authored 82 articles in archival journals, 58 fully reviewed conference papers, 96 conference proceedings, 20 contributions to books, and has authored six patents. He has served as Editor of 14 books, is editor of the Elsevier Journal Measurement, and associate Editor of the Journal of Turbomachinery. Prof. Paniagua is a Fellow of the American Society of Mechanical Engineers (ASME) and an Associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA). Prof. Paniagua spent 18 years at the von Karman Institute (VKI) for Fluid Dynamics, a world-renowned organization for Fluid Mechanics research, before joining Purdue in November 2014.

Eric Paulson

Mr. Eric Paulson is a Senior Aerospace Engineer at AFRL's Aerospace Systems Directorate at Edwards AFB. He began his career at AFRL in 2001 as a vehicle & propulsion systems analyst. Eric is currently the deputy project manager & a principal investigator for AFRL's Rotating Detonation Rocket Engine program developing the technology for DoD rocket applications. He has a B.S. in Engineering Physics from North Dakota State University & an M.S. in Aerospace Engineering from the University of Colorado-Boulder. He is a senior member of AIAA, and is the former chair & current Air Force representative on the Technical Steering Group for the JANNAF Propulsion Committee's Modeling and Simulation Subcommittee.

POSTER PRESENTATIONS

Multiphase Effects in Supercritical CO_2 Compressors: Off Design Conditions and Water Contamination Modeling
Tim Weathers, Combustion Research and Flow Technology, Inc. (CRAFT Tech)

An Analysis of Supercritical CO_2 Counter-Flow Diffusion Flame Structure
R V Manikantachari (Raghu) Kancherla, University of Central Florida

Innovative, Multifunctional Layered Coatings for High Temperature Ceramic Matrix Composites
Wanhuk Brian Choi, ReliaCoat Technologies LLC

Durable All-Oxide Thermal Environmental Barrier Coatings (T-EBCs) Capable of High Temperature Operation
Michael Schmitt, HAMR Industries LLC

High Speed Imaging of the Dynamics of H_2/O_2 Ignition
Samuel Barak, University of Central Florida

Ultra-Fast Laser Diagnostics for RDE Devices
Kyle Thurmond, University of Central Florida

Mechanical Properties of Coatings by Electron-Beam Physical Vapor Deposition and Plasma-Spray Physical Vapor Deposition Compared Using Synchrotron X-Ray Diffraction
Matthew Northam, University of Central Florida

Configurations for Luminescence-Based Temperature Sensing of Thermal Barrier Coatings
Quentin Fouliard, University of Central Florida

Synchrotron X-Ray Diffraction Measurements of Thermal Barrier Coating Configurations with Rare Earth Elements for Phosphor Thermometry
Sandip Haldar, University of Central Florida

Computational Study of Combustion Reaction $C_2H_6=CH_3+CH_3$ in Supercritical CO_2 Environment
Chun-Hung Wang, University of Central Florida

Turbulence Effects on Chemical Flame Structure for Lean Premixed Flames
Debolina Dasgupta (Presenter Tim Lieuwen), Georgia Institute of Technology

POSTER PRESENTATIONS

High Frequency Transverse Combustion Instabilities in Low NO_x Gas Turbines
Jeong Won Kim, Georgia Institute of Technology

Flame Response to Transverse Acoustic Forcing
Raghul Manosh Kumar (Presenter Tim Lieuwen), Georgia Institute of Technology

Testing of Thermal Barrier Coatings
Ian Potts, UTSR, GE & BYU

Deposition Research at the Ohio State University
Ian Potts, The Ohio State University

Revolutionizing Turbine Cooling with Micro-Architectures Enabled by Direct Metal Laser Sintering
Arif Hossain, The Ohio State University

Additively Manufactured Advanced Transpiration and Lattice Geometries for Enhanced Cooling
Zheng Min, University of Pittsburgh

Coal Fueled PDE for Direct Power Extraction
David L. Blunck, Oregon State University

High-Fidelity Numerical Analysis of the Detonation Wave Structure
Supraj Prakash, University of Michigan

High-Fidelity Simulations of Rotating Detonation Engines
Takuma Sato, University of Michigan, Ann Arbor

Nitrogen Oxide Emissions from Premixed Reacting Jets in a Vitiated Crossflow
Matthew Sirignano (Presenter Tim Lieuwen), Georgia Institute of Technology

Integrated TBC/EBC for SiC Fiber Reinforced SiC Matrix Composites for Next Generation Gas Turbines
Rajendra K. Bordia, Clemson University

Effect of Injection Geometry on Operation Mode in a Round RDE and Race Track RDE
Mirko Gamba, University of Michigan

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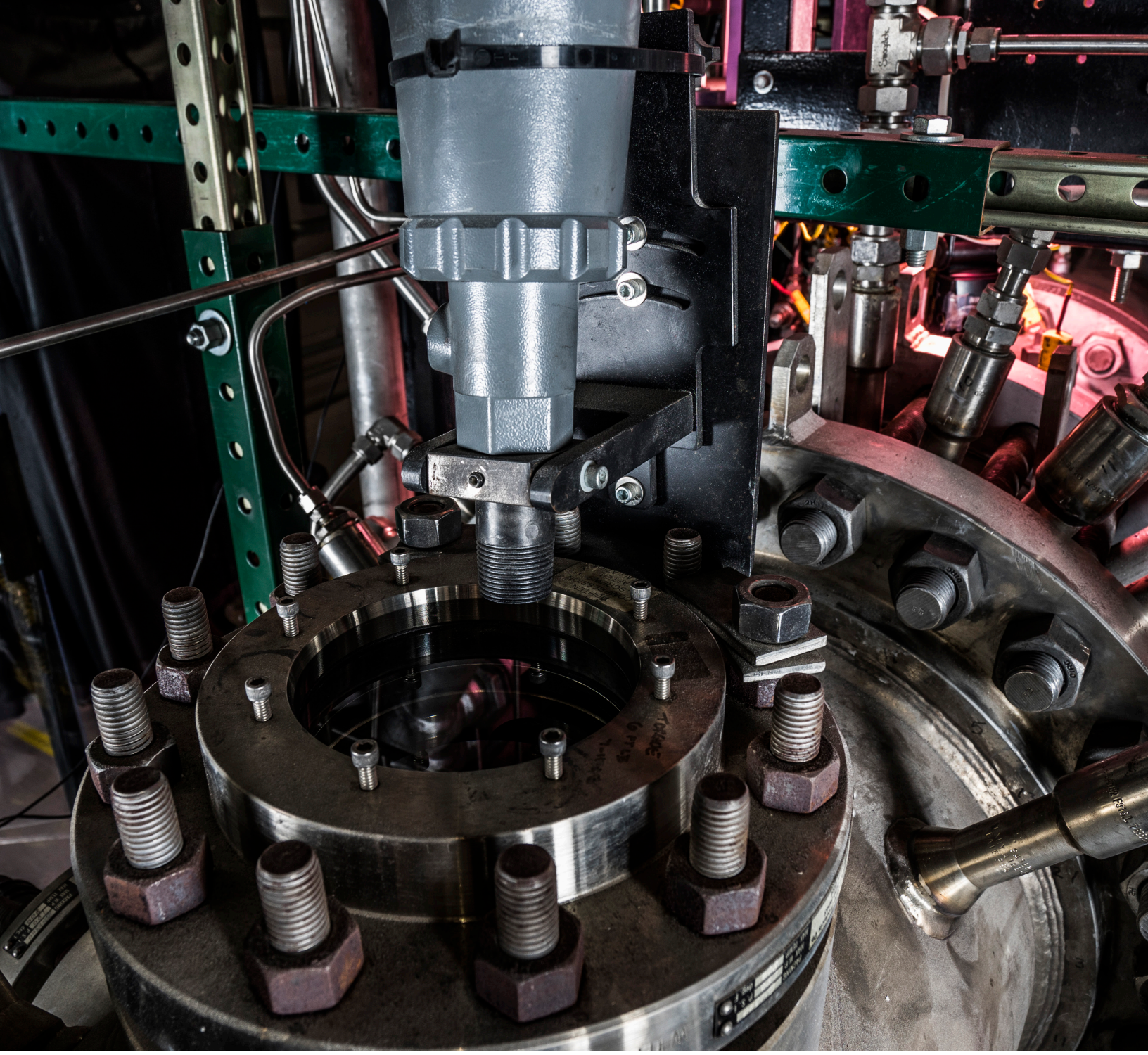

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