CSAT Meeting AGENDA

Tuesday, May 20, 2025, Meeting Time: 8:00am-4:10pm

Dr. Victor Kenneth Champagne, Jr. (Welcome & Keynote Address) 0800-0830

Presenter	Presentation Topic	Time
Session 1: Materials in Extreme Environments (Moderator: Rob Carter, TBGA)		
1. Bradley Deuser, Missouri S&T	Design Rules for Cold Spray	0830-0900
2. Michael Schmitt, HAMR Industries	CS AM of High Temperature/Strength Aerospace Alloys	0900-0930
3. Alan Fung, Aerojet Rocketdyne	NASA Rocket Nozzle Applications of Cold Spray	0930-1000
Exhibit Area	**BREAK AND NETWORKING**	1000-1030
Session 2: Advancements in Cold Spray (Moderator: Aaron Nardi, VRC Metal Systems)		
4. Bruno Zamorano, Boeing	C-17 Window Frame Cold Spray In-Situ Repair Qualification	1030-1050
5. Steve Camilleri, SPEE3D	Advancements in CS AM, New Materials & 3D Printing	1050-1110
6. Tim Eden, Penn State University	CS Development at PSU Applied Research Laboratory	1110-1130
7. Peter King, CSIRO	Automating Repairs of Complex Parts Using Continuous3D	1130-1150
8. Jay Randolph & Fred Laguines, ES3	Advancements in Laser Assisted Cold Spray Technology	1150-1210
Exhibit Area	**LUNCH**	1210-1310
Session 3: Applications (Moderator: Bruno Zamorano, Boeing)		
9. Dan Stanley, NAVSEA	Cold Spray Applications Development at NAVSEA	1310-1330
10. Aaron Nardi, VRC Metal Systems	Cold Spray Applications, Materials, and Equipment	1330-1350
11. Neil Matthews, Titomic	Manufacturing, Repair, Coatings & Materials Development	1350-1410
Exhibit Area	**BREAK AND NETWORKING**	1410-1430
Session 4: Feedstock Powders (Moderator: Luke Brewer, University of Alabama)		
12. Joe Heelan, Powders on Demand	Elevating Cold Spray with Engineered Powders	1430-1455
13. Daniel Mumm, UCI	Refractory Powder Feedstock for Cold Spray	1455-1520
14. Joseph Stanzione, Rowan Uni.	Potential of CS to Boost Hypersonic Erosion Testing	1520-1545
15. Rajiv Mishra, Optimus Alloys	ICME Alloy Design for CS to Maximize Strength and Ductility	1545-1610
RECEPTION	**DCU Center Concourse (Poster Session–Exhibits)**	1610-1800

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VRC METAL SYSTEMS SPEE3D TITOMIC

Wednesday, May 21, 2025, Meeting Time: 8:00am-4:30pm

Session 5: Applications (Moderator: Julio Villafuerte, CenterLine Windsor Ltd)			
1.	Julio Villafuerte, Centerline	Low Pressure Cold Spray Applications	0800-0820
2.	Sam Bedard, EWI	Cold Spray Research and Development at EWI	0820-0840
3.	Ben Peterson, Honeywell	Cold Spray Weldability	0840-0905
4.	Tanaji Paul, FIU	Pushing Boundaries for Space, Electronics & Ceramics	0905-0930
	Exhibit Area	**BREAK AND NETWORKING**	0930-1000
Session 6: Quality Assurance & NDT (Moderator: Ozan Ozdemir, Northeastern University)			
5.	Tatu Leppänen, Oseir Ltd.	Cold Spray Plume Diagnostics for Quality Control	1000-1020
6.	Todd Dunford, JENTEK Sensors	In-Situ & Post Processing EC-Array Sensing for AM & CS	1020-1040
7.	David Lessard, Tecnar	Leveraging AI & Machine Learning for Thermal & Cold Spray	1040-1100
Session 7: Nitrogen Gas Cold Spray (Moderator: Brad Richards, Powders on Demand)			
8.	David Schimbäck, Airbus	CS Nitrogen: On the Way to Cost Effective Structural Repair	1100-1120
9.	Jan Kondas, Impact Innovations	CS of Al Alloys for Structural Repair Using Nitrogen	1120-1140
10.	Sinan Muftu, Northeastern Uni.	Lessons Learned: Heat Treating Nitrogen Sprayed Al 6061	1140-1200
	Exhibit Area	**LUNCH**	1200-1300
Session 8: Power (Moderator: Jack Lareau, Pacific Northwest National Laboratory)			
11.	Chris Smith, PNNL	Cold Spray Repair of Hydropower Hardware Using Nitrogen	1300-1330
12.	JP Lacy, EPRI	Cold Spray Repair for the Power Industry	1330-1400
13.	Jan Schubert, VZU Pilsen	Mobile CS of Dividing Plane of High-Pressure Turbine Vessel	1400-1430
	Exhibit Area	**BREAK AND NETWORKING**	1430-1500
Session 9: Research & Development (Moderator: Tim Eden, Pennsylvania State University)			
14.	Gregory Kubacki, Un. of Alabama	Impact of Composition on Al-Zn-Mg-Cu CS Performance	1500-1520
15.	Bryer Sousa, Triton Systems	Cold Spray for Next Generation Defense Systems	1520-1540
16.	Caroline Dowling, WPI	Thermal Treatments of Virgin Ti-6Al-4V Feedstock Powders	1540-1600
	Dr. Victor Champagne	**Wrap-Up & CSAT 2025 Poster Awards**	1600-1630
	RECEPTION	**Polar Park – WooSox Baseball Game Reception**	1700-2000

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CSAT Abstracts

Design Rules for Cold Spray

Speaker: Bradley Deuser

Organization: Missouri University of Science and Technology (S&T)

Cold Spray Additive Manufacturing (CSAM) is an emerging technology that offers distinct advantages and limitations compared to other directed energy deposition methods. This study evaluates the capabilities of CSAM, particularly in fabricating high value metallic components with complex geometries, thin-wall sections (6–9 mm), and intricate feature sets such as sharp corners and overhangs. Guidance on design rules are proposed for the SPEE3D WarpSpeed technology, focusing on specific geometric considerations to better define manufacturing constraints. These findings contribute to the development of a structured "Design for CSAM" framework, improving the adoption and optimization of cold spray in advanced manufacturing applications.

CS AM of High Temperature/Strength Aerospace Alloys

Speaker: Michael Schmitt

Organization: HAMR

With cold spray additive manufacturing (CSAM) continuing to mature, a new niche is starting to emerge: advanced materials for harsh applications. As a solid-state and blown powder method, CSAM can process unique material compositions and has the potential for true three-dimensional functional grading. The present work has leveraged these attributes and explores fabrication of high temperature alloys such as GRX-810 and high entropy alloy systems for elevated temperature applications. In addition, a reactive method has been demonstrated for fabrication of Ti-6Al-4V, with discussion on how this can be adapted to other beta and high temperature systems. Finally, the presentation will cover early results for evaluation of CSAM functional grades of dissimilar material systems.

Pushing Boundaries for Space, Electronics & Ceramics

Speaker: Tanaji Paul

Organization: ColRAD - Florida International University (FIU)

Cold spray (CS) is a versatile deposition technique with wide-reaching applications in space, energy, and advanced materials. This presentation explores three transformative uses of CS: (1) In space, CS facilitates in-situ repairs and radiation shielding by utilizing lunar regolith and ductile powders, improving mission sustainability and efficiency. (2) In power electronics, optimized CS processing creates aluminum-based porous structures that enhance the capacitance density and surface area of grid capacitors, advancing electronic component performance. (3) CS is also applied to consolidate hard ceramic particles and 2D materials, improving the mechanical and thermal properties of composites for high-temperature applications. These developments demonstrate cold spray's potential to revolutionize industries such as aerospace, energy, and advanced manufacturing.

NASA Rocket Nozzle Applications of Cold Spray

Speaker: Alan Fung

Organization: Aerojet Rocketdyne

Over the past 15 years, Metal Additive Manufacturing (AM) has fundamentally transformed the design, manufacturing, and testing of space propulsion systems at Aerojet Rocketdyne L3 Harris (AR). The majority of our investment has been directed towards laser powder bed fusion (LPBF) due to its ability to produce complex, near-net-shaped parts, significantly reducing machining and forging lead times. Cold spray technology presents unique opportunities to complement laser powder bed fusion. This presentation will focus on two specific implementations of cold spray: the bi-metallic structural jacket application during the ALPACA NASA ACO program and the C-103 nozzle skirts. Cold spray offers unique advantages for bi-metallic applications since there the material is applied without melting. For larger development components like nozzles, cold spray is particularly beneficial due to its low initial material requirements, minimal non-recurring engineering (NRE) costs for low-rate production, and flexibility in feedstock. We will discuss the challenges and successes encountered in these development programs, highlighting the implementation of cold spray for rocket propulsion and aerospace applications.

Automating Repairs of Complex Parts Using Continuous3D

Speaker: Peter King

Organization: CSIRO Manufacturing

Cold spray repair of high-value metal components is a complex, multistage process. While the use of robots is preferred for the precision and repeatability they offer, datum identification, alignment, programming and testing add considerable overhead. Accurate measurement of the repair site's depth and shape is critical for creating an effective cold spray toolpath. Continuous3D, a technology developed by CSIRO, uses machine vision, robotic path planning and a software interface to provide a digital twin of the process. This presentation highlights how incorporating digital tools paves the way for the future development and adoption of cold spray technology.

C-17 Window Frame Cold Spray In-Situ Repair Qualification

Speaker: Bruno Zamorano

Organization: Boeing

Cold spray technology has the potential to revolutionize the repair of aircraft structures. Corrosion damage is typically blended out, resulting in reduced thickness. Cold spray can effectively "restart the corrosion clock" of a part by filling in the blended area, restoring the part to its original dimensions and, in certain cases, recovering some of the lost load-carrying capability. The business case is particularly strong when the repair can be accomplished in situ, thereby avoiding the costs associated with removal and replacement. However, there are significant qualification challenges that need to be addressed to provide a complete picture. In this presentation, Boeing will describe some of the challenges and lessons learned from the effort to obtain approval for an in situ repair demonstration on a C-17 aircraft. Topics such as machine stability, spray envelope, and witness coupon development will be discussed.

Cold Spray for Next Generation Defense Systems

Speaker: Bryer Sousa

Organization: Triton Systems

In this presentation, we will highlight Triton's comprehensive RDT&E efforts in cold spray technology for advanced aerospace and defense applications. By showcasing cross-cutting insights from multiple programs, we will illustrate how integrated partnerships with government, industry, and academia drive novel

approaches to advanced bonding, near-net-shape fabrication, and fieldable systems. We will discuss essential powder developments, prototype-scale achievements, and how our state-of-the-art facility enables accelerated technology readiness. Accordingly, this presentation will provide a deep technical perspective on how Triton's evolving cold spray ecosystem, including integrated manufacturing solutions, promises to advance next-generation defense capabilities.

Low Pressure Cold Spray Applications

Speaker: Julio Villafuerte

Organization: CenterLine Windsor Limited

For over 65 years, we've been solving technical challenges for industries like automotive, manufacturing, aerospace, and defense. Our Supersonic Spray Technologies (SST™) use compressed air or nitrogen to accelerate particles, enabling efficient, low-heat repairs that avoid the risks of traditional thermal spray methods. In this presentation, discover how CenterLine SST™ has revolutionized repairs for military aircraft, where sourcing decades-old replacement parts is challenging. SST™ provides quick, cost-effective solutions by restoring components, significantly reducing downtime and environmental impact. Our innovative cold spray technology has evolved beyond repairs, now being increasingly used as a mass production tool for automotive, energy, microelectronics, and architectural applications. By collaborating closely with our customers, we continue to push the boundaries of cold spray technology, offering reliable and advanced solutions to meet the growing demands of diverse industries.

CS of Al Alloys for Structural Repair Using Nitrogen

Speaker: Leonhard Holzgaßner

Organization: Impact Innovations

Aluminum alloys, such as AA6061 and AA7050 are widely used in the aircraft industry. Therefore, cold spraying has high potential in the field of repairs of worn-out parts. However, many repair applications are limited to using expensive helium as a propelling gas to achieve the desired mechanical properties and adhesion strength. The latest developed hardware solution and cold spray parameters were investigated in relation to the mechanical properties of the deposited Al alloys. Flat and round tensile specimens were extracted from the thick cold sprayed deposits to measure the tensile properties and adhesion strength. The results indicate significant improvements, e.g. in case of Al7050 adhesion strength >230 MPa, tensile strength >360 MPa and elongation >3.5%.

Cold Spray Plume Diagnostics for Quality Control

Speaker: Tatu Leppanen

Organization: Oseir Ltd.

With longer spray runs and large scale additive manufacturing demands for the quality control have risen tremendously. Traditionally diagnostics has been done before or after the spraying which is useful for optimization and maybe for short spray runs and low cost components but for the longer runs, more demanding products and AM, full time diagnostics is the only effective means for the quality control. With the introduction of full time plume diagnostics (V, position, plume density) the user has also possibility e.g. to automate features like stopping the systems when nozzle clogging is predicted. Theoretical part is backed up with examples.

Lessons Learned: Heat Treating Nitrogen Sprayed Al 6061

Speaker: Sinan Muftu

Organization: Northeastern University

Using N2 as the carrier gas and achieving satisfactory structural properties has been challenging for cold spray. In this work, we investigate the impact of various thermal and thermomechanical treatments on the structural properties of N2-sprayed Al 6061 as free-standing material. Three approaches were examined: the first group underwent post-spray heat treatments, including hot isostatic pressing (HIP) and conventional heat treatments; the second group was subjected to thermomechanical treatments; and the third group was fabricated using in-situ laser-assisted cold spray technique. The mechanical properties of the deposited materials were comprehensively evaluated and compared with deposits sprayed with He-gas and wrought materials. The results revealed that the mechanical properties of N2-sprayed deposits show significant improvement after post-treatment and in-situ laser heating. A model of the cold-spray deposition process was developed and micromechanical changes during laser-assisted cold spray were investigated to shed light on the remarkable experimental results. This work shows what can be achieved by post-sprayed heat treatments. Also, it indicates that comprehensive studies can lead to industrial standards, allowing cold spray to become a mainstream repair and manufacturing technology.

In-Situ & Post Processing EC-Array Sensing for AM & CS

Speaker: Todd Dunford

Organization: JENTEK Sensors

EC-Arrays, and specifically the MWM®-Array technology, are capable of non-contact, in-process sensing, in addition to more common inspections post-production. This presentation provides a description of specific applications for cold spray and other AM processes. This includes a discussion of specific challenges for implementation in-process for Additive Friction Stir Deposition (AFSD), Laser Powder Bed Fusion (LPBF) and other Directed Energy Deposition (DED) applications. The MWM-Array methods for non-contact in-process implementation are described in detail, along with the advantages of MWM-Arrays and model-based inverse methods for inspection of relatively rough as-processed surfaces post-production. This includes detection of local defects, characterization of material properties, and geometric feature imaging/measurement. Data from recent in-process demonstrations is presented for LPBF. Also, example data for cold spray coatings on steel are described in detail. This includes installation and automation challenges for both in-process and post-production applications.

Leveraging AI & Machine Learning for Thermal & Cold Spray

Speaker: David Lessard

Organization: Tecnar

Consistent coating quality in thermal and cold spray processes is challenging due to inherent complexity, operator-dependent controls, and evolving equipment conditions. While the use of advanced sensors for real-time process monitoring has grown, the effective integration of diverse data streams and the application of modern analytics remain limited. This paper presents the AccurasprayHub, a centralized data platform designed to harmonize booth parameters, in-situ plume measurements, maintenance schedules, and coating quality evaluations. By combining domain expertise with advanced analytics, including initial steps toward machine learning, the AccurasprayHub establishes robust datasets, identifies stable process windows, and provides proactive insights for process improvements. The approach is rooted in a realistic understanding of the complexities of thermal and cold spray operations, emphasizing careful data construction, iterative refinement, and pragmatic adoption of informatics. Preliminary on-site trials with an aerospace industry

partner have confirmed the platform's value in improving process consistency and establishing a reliable foundation upon which more sophisticated AI-driven process control can be developed over time.

CS Nitrogen: On the Way to Cost Effective Structural Repair

Speaker: David Schimbäck

Organization: Airbus

Cold spray is a promising repair technology for on-aircraft damage of aluminum components, for which aerospace industry is currently lacking repair methods. Traditionally, helium has been the process gas of choice for structural cold spray repairs, although it is significantly more expensive than nitrogen. As a result, Airbus is now further developing the use of nitrogen as an alternative, aiming to expand the potential of cold spray into a more accessible and cost-effective technology. Material testing with this newly developed nitrogen-based cold spray process revealed properties that could help to bridge the gap between helium and nitrogen propelled cold spray.

Mobile CS of Dividing Plane of High-Pressure Turbine Vessel

Speaker: Jan Schubert

Organization: VZU Pilsen

In light of the current global development, the nuclear energy sector demands more rapid and sophisticated repair methods over conventional procedures. VZU Pilsen executed one of the first successful applications of mobile Cold Spray (CGS) technology. Between October 22 and 26 2024, a specialized repair was conducted on a damaged section of the dividing plane in the high-pressure component during a scheduled shutdown. This repair preceded a meticulous preparation and qualification process that assessed and selected the optimal repair method, comparing traditional weld repair to CGS technology. The repair process encompassed several critical steps: defect identification, surface preparation, manual grinding using a turbine grinder, application of CGS spray, 3D scanner measurement, and final surface finishing. The successful repair demonstrates the promising potential of Cold Spray technology for applications within the nuclear energy sector.

Cold Spray Repair of Hydropower Hardware Using Nitrogen

Speaker: Chris Smith

Organization: Pacific Northwest National Laboratory (PNNL)

The cold spray coating technology has been demonstrated to have the potential to improve cavitation erosion performance of hydropower components very significantly with cold spray deposits having five to ten times better performance than base materials commonly used in the hydropower industry. Furthermore, even greater improvements over the heat affected zone of welds in these base materials has also been demonstrated. However, this level of improvement has required the use of helium as a carrier gas, which can be 2 orders of magnitude more costly than nitrogen. While the cost of cold spray with helium can be justified for hydropower repair applications, a need to use helium would certainly limit the application space for cold spray. Thus, there has been a desire to enable the use of nitrogen as a carrier gas to significantly lower the cost of cold spray and/or expand its potential application space. However, early trials with the use of nitrogen resulted in far inferior cavitation performance with nitrogen-based cold sprays unable to meet the cavitation performance of the base materials. Nevertheless, given the major difference in cost of these gasses, efforts to try to develop a cold spray process that could use nitrogen were not disbanded. More recent approaches in attempting to optimize the cold spray process have demonstrated very substantial improvements in cavitation erosion performance compared to early trials. While cold spray deposits with helium still perform better,

significant enough improvements using nitrogen have been demonstrated to consider use of nitrogen as a carrier gas for the cold spray cavitation repair application.

Potential of CS to Boost Hypersonic Erosion Testing

Speaker: Joe Stanzione

Organization: Rowan University

Current methods used to characterize high strain rate particle impacts relevant to hypersonic erosion are useful and informative. However, there exists the possibility to complimentary utilize light gas gun and cold spray technologies, with and without ultra-high-speed video capture, to assist in fundamentally understanding and visually interpreting particle-substrate interactions. Single-shot single particle, multiple particles in series, and plumes of particles experiments can be performed using the light gas gun system at Rowan's Advanced Materials & Manufacturing Institute (AMMI). Particle sizes can range from the millimeter scale to the micron scale. Particle temperature and velocity can be precisely controlled along with the substrate temperature. Such experiments can include a strain gauge attached to the backside of the substrate for real-time mechanical measurement data. Angles of incidence can also be swept 180 degrees. Real-time ultra-high-speed videography data can be captured via using either a 41k fps camera or a 10M fps camera. Furthermore, continuous plumes of micron-size particle experiments can be performed using AMMI's custom-built benchtop cold spray system as well as its VRC Metal Systems Gen III Cold Spray system with control of particle velocities and angles of incidence. Substrate post impact characterizations can be performed via optical microscopy, SEM, AFM techniques, among others. This presentation highlights these ideas and AMMI capabilities with example experiments and potential forward-thinking collaborations.

Thermal Treatments of Virgin Ti-6Al-4V Feedstock Powders for Improved Cold Spray Deposition

Speaker: Caroline Dowling

Organization: Worcester Polytechnic Institute

Titanium alloys, such as Ti-6Al-4V, propose substantial benefits for cold spray applications by producing high specific strength parts and coatings at a reduced manufacturing cost; however, the alloy's high yield strength challenges its ability to plastically deform and obtain high deposition efficiency. This work explores a matrix of thermal feedstock powder treatments to soften the microstructure of Ti-6Al-4V powder, directly improving its ability to cold spray effectively, while maintaining optimal mechanical properties. Virgin Ti-6Al-4V powder was heat treated with the goal of softening the martensitic microstructure of the as-received atomized powders to directly improve the deposition efficiency and mechanical properties of the cold sprayed specimens when compared to their untreated counterparts. Powder characterization methods included chemical analysis, scanning electron microscopy (SEM), X-ray diffraction (XRD), powder particle compression testing, and nanoindentation. Results indicate that heat treating virgin Ti-6Al-4V powders prior to deposition can achieve reduced strength, thus enhancing cold spray performance verified by an observed phase change and improved mechanical properties. The results of this work demonstrate that the heat-treatment of Ti-6Al-4V powder is possible and paves the way for future research into the optimization of titanium heat treating to achieve a superior microstructure that is advantageous for cold spray.

Advancements in Laser Assisted Cold Spray Technology

Speaker: Jay Randolph & Fred Laguines

Organization: ES3

ES3, along with our team member Laser Fusion Technologies, have evaluated the use of lasers hybridized for integration with Cold Spray; as an in-situ processing technique known as Laser Assisted Cold Spray (LACS). This emerging processing technique has demonstrated enhanced particle adhesion and improved the deposition, particularly with challenging materials. As part of these efforts, ES3 and LFT have retrofitted Cold Spray systems within the industry to perform LACS and developed equipment and process improvements related to the technology. This presentation will review advancements made in the LACS system architecture and provide example coatings of magnetic materials, tungsten and Diamalloy 4060 NS/Stellite 6.

Cold Spray Applications, Materials, and Equipment

Speaker: Aaron Nardi

Organization: VRC Metal Systems

This talk will focus on DOD and commercial applications, recent materials developments, and the latest in equipment developments from VRC metal systems. Application discussions will include high value assets, field repair applications, and Cold Spray additive manufacturing. This will also discuss the latest in process developments for a variety of materials and the influence of gas composition on the results and mechanical properties that can be obtained with secondary processing of cold sprayed materials. Finally, VRC will discuss the latest in equipment and how this equipment affects the available application space.