Research Request Number: CSCO-2017-01 rev A.

Commercial Space Research Request
NASA/HEOMD/CSDD
Date: July 6, 2018
Research Request Number: CSCO-2017-01 rev A.

1) **Program:** Commercial Space Capabilities Office

2) **Research Title:** Characterization of C-18150 Additively Manufactured material

3) **Research Overview:**

NASA is requesting proposals to perform the task below which it has identified as important for furthering the engineering knowledgebase of material properties used in spaceflight.

NASA is evaluating a copper-alloy, C-18150 (Cu-Cr-Zr), as a low-cost material for additive manufacturing of regeneratively-cooled combustion chambers and nozzles. This material is being developed using the selective laser melting (SLM) process at industry vendors. Material properties and usability of is highly dependent on build parameters using the SLM process, but also upon the hot isostatic pressure (HIP) conditioning and solution treatment and aging (STA) to obtain full mechanical properties as required in design. The purpose of this task is to characterize the material in the as-built condition and also optimize the heat treatment through the STA conditioning to maximize material properties. NASA is completing some basic studies on HIP and STA and data available as a starting reference. NASA will provide SLM samples (incl machining where noted) to the EPSCoR awardee. The task shall include the following at minimum:

1. Micrograph characterization of AM C-18150 material relative to grains, grain size, orientation, porosity, material thickness variations, and general observations in comparison to wrought material. A virgin AM SLM C-18150 specimen will be provided from a component which has varying cross-sectional areas for characterization.
2. Perform heat treatment on samples provided by NASA, and complete heat treatment studies on AM material to optimize tensile properties in comparison to wrought properties
3. Complete SEM characterization of C-18150 material in comparison to wrought.
4. Complete mechanical testing* of the following samples, machined samples will be provided. This testing is a guideline and may be adjusted slightly to meet intent of design property data.
    a. Minimum of (5) RT tensile samples
    b. Minimum of (5) 800F tensile samples
    c. Minimum of (15) RT samples to determine effects of heat treatments
    d. Minimum of (7) 800F tensile specimens following heat treatment optimization
    e. Minimum of (5) RT Low Cycle Fatigue (LCF) specimens
    f. Minimum of (5) 400F LCF Specimens
    g. Minimum of (5) 800F LCF specimens
    h. Minimum of (3) reserve (spares for use in any of the above tests)

5. Complete micrograph characterization of large-scale part to determine variations in material following HIP and STA. This shall include a minimum of 30 specimens in various orientations and locations within the SLM build.
6. Provide recommendations during process development, interim and final reports. It is expected that university partner communicate regularly with NASA technical leads to ensure characterization and testing meets intent of data based upon ongoing test results. A minimum monthly telecom is expected to provide updates.

4) NASA Contact

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5) Commercial entity:

a. Company Name: na
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6) Partner contribution

No NASA Partner contributions

7) Intellectual property management:

No NASA Partner intellectual property concerns

8) Additional Information:

* Test to ASTM (e.g. LCF per E606/E606M) or identify alternate established standard in Proposal.

NASA has identified the following potential EPSCoR institutions (jurisdictions) with probable current capability – there may be others with capability:
University of Alabama Huntsville (AL)
Auburn University (AL)

NASA CSCO will coordinate support from NASA MSFC as needed. EPSCoR awardee will work with NASA to provide feedback and process inputs.

7. NASA expects that it will receive a copy of the resulting data so that NASA can make it available in its MAPTIS database https://maptis.nasa.gov/ . NASA welcomes opportunities to co-publish results proposed by EPSCoR awardee.

Research Request Number: CSCO-2017-02 rev A.

Commercial Space Research Request
NASA/HEOMD/CSDD
Date: July 6, 2018
Research Request Number: CSCO-2017-02 rev A.

1) **Program:** Commercial Space Capabilities Office

2) **Research Title:** Characterization of Inconel 625 or Haynes 230 Blown Powder Freeform Deposition material

3) **Research Overview:**

NASA is requesting proposals to perform the task below which it has identified as important for furthering the engineering knowledgebase of additive material properties used in spaceflight.

NASA is evaluating freeform blown powder deposition, or directed energy deposition (DED), technology as a large-scale additive manufacturing technology for large scale rocket components. This technology has been demonstrated on development subscale components and at the coupon level to evaluate vendor capabilities using variations of the DED process. Additive manufacturing of Inconel 625 (UNS N06625, Alloy 625) or Haynes 230 typically completes hot isostatic pressure (HIP) conditioning and solid-solution strengthening using the selective laser melting (SLM) process. However, with increased scale of parts using the DED process, HIP processing may not be available and solution strengthening may be challenging due to scale. The purpose of this task is to evaluate the Inconel 625 or Haynes 230 (or both) material in the as-built condition from a series of industry vendors, evaluate HIP and solution heat treatments and how they might affect material and associated mechanical, properties. NASA has equal interest in both alloys. The Proposer shall define scope in their proposal which alloy (Inconel 625 and/or Haynes 230) their work is for, and NASA will provide the necessary samples or both to the EPSCoR awardee in the form of “racetracks” or flat plates to be sectioned for evaluation and testing. The task shall include the following at minimum:

1. Micrograph characterization of DED Inconel 625 and/or Haynes 230 material relative to grains, grain size, orientation, porosity, and general observations in comparison to wrought material. This would include a minimum of (2) samples from each of (4) different vendors.
2. Develop etchant techniques for Inconel 625 and/or Haynes 230.
3. Perform heat treatment, and complete heat treatment studies on AM DED Inconel 625 or Haynes 230 material to optimize tensile properties in comparison to wrought solution properties. Hot Isostatic Pressing (HIP) may also be considered if access to facilities and/or process exists. It should be noted that data associated with HIP cycles is required to be protected as ITAR/Export Controlled.
4. Complete SEM characterization of DED Inconel 625 and/or Haynes 230 material in comparison to wrought for each vendor.
5. Complete mechanical testing* of samples provided by each of (4) vendors. Although final matrix will be finalized, a minimum of (25) samples from each of the (4) vendors will be provided. Basic information relative to tensile properties should be evaluated in

addition to some elevated temperature tensile (800, 1200, 1500F) and some initial Low Cycle Fatigue (LCF) specimens at room temperature and elevated. This testing is a guideline and may be adjusted with NASA to meet intent of design property data.

6. Micrograph characterization of DED Inconel 625 or Haynes 230 material from a demonstrated component build to determine differences in orientations and various feature types (thin-wall, ribs, ID surface, OD surface).
7. Characterization of raw powder from the fabricated specimens, if powder available and provided.
8. Comment and propose any additional testing that might be considered complementary as part of this research activity to develop design data (ie. Surface Roughness, Thermophysical Properties, Chemical Analysis, etc)
9. Provide recommendations during process development, interim and final reports.
10. Comment on the ability to handle and process ITAR data per #3.
11. It is expected that university partner communicate regularly with NASA technical leads to ensure characterization and testing meets intent of data based upon ongoing test results. A minimum monthly telecom is expected to provide updates.

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6) Partner contribution

No NASA Partner contributions

7) Intellectual property management:

No NASA Partner intellectual property concerns

8) Additional Information:

* Test to ASTM or identify alternate established standard in Proposal.

NASA has identified the following potential EPSCoR institutions (jurisdictions) with probable current capability – there may be others with capability:
University of Alabama Huntsville (AL)
Auburn University (AL)

NASA CSCO will coordinate support from NASA MSFC as needed. EPSCoR awardee will work with NASA to provide feedback and process inputs.

NASA expects that it will receive a copy of the resulting data so that NASA can make it available in its MAPTIS database https://maptis.nasa.gov/ . NASA welcomes opportunities to co-publish results proposed by EPSCoR awardee.

Research Request Number: CSCO-2017-03 rev A.

Commercial Space Research Request
NASA/HEOMD/CSDD
Date: July 6, 2018
Research Request Number: CSCO-2017-03 rev A.

1) **Program:** Commercial Space Capabilities Office

2) **Research Title:** Characterization of GRCop-42 Additively Manufactured material

3) **Research Overview:**

NASA is requesting proposals to perform the task below which it has identified as important for furthering the engineering knowledgebase of material properties used in spaceflight.

NASA is evaluating a dispersion strengthened copper-alloy, GRCop-42, as a low-cost material for additive manufacturing of regeneratively-cooled combustion chambers and nozzles. This material is being developed using the selective laser melting (SLM) process at industry vendors. Material properties and usability of is highly dependent on build parameters using the SLM process, but also upon the hot isostatic pressure (HIP) conditioning to obtain full mechanical properties as required in design. The purpose of this task is to characterize the material in the as-built condition and also optimize the hot isostatic pressure (HIP) conditioning to maximize material properties. NASA is completing some basic studies on HIP and as a starting reference. NASA will provide samples to the EPSCoR awardee. The task shall include the following at minimum:

1. Micrograph characterization of AM GRCop-42material relative to grains, grain size, orientation, porosity, and general observations in comparison to wrought material.
2. Perform heat treatment on samples provided by NASA, and complete heat treatment studies on AM material to optimize tensile properties in comparison to wrought properties. Hot Isostatic Pressing (HIP) may also be considered if access to facilities and/or process exists. It should be noted that data associated with HIP cycles is required to be protected as ITAR/Export Controlled.
3. Complete SEM characterization of GRCop-42material in comparison to wrought
4. Complete mechanical testing* to include elevated temperature tensile specimens, room temperature and elevated temperature Low Cycle Fatigue (LCF), room temperature and elevated temperature High Cycle Fatigue (HCF). Temperatures should include a range up to 1300F to determine if any ductility dips occur as experienced with wrought material. NASA will provide machining of samples. This testing is a guideline and may be adjusted with NASA to meet intent of design property data.
5. Complete micrograph characterization of small-scale part(s) to determine variations in material following HIP. This shall include a minimum of 15 specimens in various orientations and locations within the SLM build.
6. Complete characterization of virgin powder and build to build variations.
7. Comment and propose any additional testing that might be considered complementary as part of this research activity to develop design data (ie. Surface Roughness, Thermophysical Properties, Chemical Analysis, etc)

8. Provide recommendations during process development, interim and final reports.
9. Comment on the ability to handle and process ITAR data per #2.
10. It is expected that university partner communicate regularly with NASA technical leads to ensure characterization and testing meets intent of data based upon ongoing test results. A minimum monthly telecom is expected to provide updates.

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5) Commercial entity:

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6) Partner contribution

No NASA Partner contributions

7) Intellectual property management:

No NASA Partner intellectual property concerns

8) Additional Information:

* Test to ASTM or identify alternate established standard in Proposal.

NASA has identified the following potential EPSCoR institutions (jurisdictions) with probable current capability – there may be others with capability:
University of Alabama Huntsville (AL)
Auburn University (AL)

NASA CSCO will coordinate support from NASA MSFC and GRC as needed. EPSCoR awardee will work with NASA to provide feedback and process inputs.

NASA expects that it will receive a copy of the resulting data so that NASA can make it available in its MAPTIS database https://maptis.nasa.gov/ . NASA welcomes opportunities to co-publish results proposed by EPSCoR awardee.

Research Request Number: CSCO-2017-04 rev A.

Commercial Space Research Request
NASA/HEOMD/CSDD
Date: July 6, 2018
Research Request Number: CSCO-2017-04 rev A.

1) **Program:** Commercial Space Capabilities Office

2) **Research Title:** Characterization of Bimetallic Joints using Copper-based alloys

3) **Research Overview:**

NASA is requesting proposals to perform the task below which it has identified as important for furthering the engineering knowledgebase of material properties used in spaceflight.

NASA is evaluating bimetallic joints for propulsion applications using a variety of joining methods, including Additive Manufacturing (AM) to wrought. These joints are bimetallic joints and include the use of copper-alloys (C-18150 and GRCop-84) as one material and a 300 Series Stainless Steel or Inconel-based superalloy as the other material. Processes used for these joints include Explosive Bonding or Explosive Welding (EXW), Electron Beam welding, and laser cladding deposition. NASA has interest to aid in characterizing these joints (in Heat Affected Zone, HAZ, and base metal) and perform detailed studies of optimization of heat treatments to maximize material properties trading the limitations of both materials. NASA will provide samples for characterization to the EPSCoR awardee as follows if requested by ESPCoR awardee as part of the characterization and mechanical testing study to aid with sample evaluation and heat treatment studies:

a) Explosively Bonded C-18150 to Stainless 347 (provided as plates, 6" 304 and 2" C-18150, sliced from thick forging)
b) EB Welded C-18150 or GRCop-84 to Stainless 304/316 (provided as welded cap plugs)
c) Direct Energy Deposition Inconel 625 onto C-18150 or GRCop-84 (provided as cylinders cladded on OD, same samples as provided in b)
d) (option if budget permits – indicate in Proposal) SLM Inconel 625 to GRCop-84
e) (option if budget permits – indicate in Proposal) Laser Deposited Inconel 625 to GRCop-84

The task shall include the following at minimum:

1. Micrograph characterization of each of the bimetallic material combinations relative to grains, grain size, orientation, porosity, HAZ, alloy-mixing, and general observations.
2. Perform heat treatment on samples provided by NASA, and complete heat treatment studies on bimetallic material combinations to optimize tensile and fatigue properties trading limits of both materials (ie. Inconel 625 cannot be fully homogenized / solution treated with the melt limit of copper-alloy).
3. Complete SEM characterization of bimetallic material combinations at interface. Complete mechanical testing* to include room temperature, elevated temperature tensile specimens, room temperature and elevated temperature Low Cycle Fatigue (LCF), room temperature and elevated temperature High Cycle Fatigue (HCF).

Temperatures should include a range up to 1000F to determine if any ductility dips occur at any temperature ranges. This testing is a guideline and may be adjusted with NASA to meet intent of design property data. Tensile test in longitudinal and transverse direction to seam or as further discussed with NASA based on allowable specimens. The primary interest is to determine a joint strength, so concepts of unique testing approaches should be presented. Joints in actual hardware will not have full thicknesses of samples and will be much thinner, so this should be considered.

4. Provide recommendations during process development, interim and final reports.
5. Comment and propose any additional testing that might be considered complementary as part of this research activity to develop design data (ie. Microhardness, Thermophysical Properties, Chemical Analysis, etc)
6. It is expected that university partner communicate regularly with NASA technical leads to ensure characterization and testing meets intent of data based upon ongoing test results. A minimum monthly telecom is expected to provide updates.

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6) Partner contribution

No NASA Partner contributions

7) Intellectual property management:

No NASA Partner intellectual property concerns

8) Additional Information:

* Test to ASTM or identify alternate established standard in Proposal.

NASA has identified the following potential EPSCoR institutions (jurisdictions) with probable current capability – there may be others with capability:
University of Alabama Huntsville (AL)
Auburn University (AL)

NASA CSCO will coordinate support from NASA MSFC as needed. EPSCoR awardee will work with NASA to provide feedback and process inputs.

NASA expects that it will receive a copy of the resulting data so that NASA can make it available in its MAPTIS database https://maptis.nasa.gov/ . NASA welcomes opportunities to co-publish results proposed by EPSCoR awardee.