2021 Additive Manufacturing Workshop Outbrief

21 June

Virtual

Tracy Frost (OUSD Research & Engineering)/JAMWG
Marilyn Gaska (America Makes / Lockheed Martin)
Debbie Lilu (NCMS)
Ray Langlais (OSD MR / LMI)

2021 AM Workshop Protocol

- Please keep your phones on mute unless you are presenting. **Do *NOT* put your phone on hold**. Should you have to temporarily drop off please hang up and call back.
- Questions will be addressed via “Q & A” on AdobeConnect
- Presenters - slides will be advanced by NCMS / LMI
- This is an open forum. Slides will be posted on the AMMO WG at https://ammo.ncms.org/

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2021 Additive Manufacturing (AM) Workshop Outbrief

Purpose: to provide WorkGroup Co-Leaders the opportunities to out-brief their workshop results to include:

- Objectives / Planned Deliverables
- Accomplishments & Deliverables
- Key Takeaways
- Recommendations & Next Steps

AGENDA

June 21 (Day 5)

1:00 – 5:00 pm Overview from Planning Committee

- Working Group Outbriefs – Working Group Co-Leaders
- Closing Remarks & Discussion
  - Mr. Rob Gold
  - Workshop Planning Committee

2021 AM Workshop Working Groups (Tuesday & Thursday)

- Research & Development to Advance AM Qualification and Certification – Mark Benedict, Jennifer Wolk, Jeffrey Gaddes, Brandon Ribic
- Cybersecurity - Jon Powvens, Greg Shannon, Larry Lynch, Adwoa Amofa
- Common AM Data Package Approach (JAMA) – Edilia Correa, Tony Delgado, Michael Ridgway, Chris Babcock, David Wittes
- Education and AM Workforce Development - Josh Cramer

2021 AM Workshop Working Groups (Cont'd) (Tuesday & Thursday)

- AM Standards – Defense industry priorities and addressing the Research and Development gaps – Jesse Chambers & Jim McCabe
- Integrated AM Network Response – How industry and government can work together to respond to urgent and important needs – John Wilczynski & Federico Sciammarella
- AM Decision Making – Business Case Analysis for AM in the defense industry – Stephen Kuhn-Hendricks, William Peterson, Ernesto Ureta, Timothy Vorakoumane

2021 AM Workshop Optional Sessions (Wednesday)

- **One Size Doesn't Fit All:** The Role for Technology in Meeting the Multiple Workforce Challenges in Manufacturing – Dr. Ben Armstrong (MIT)
- **Training: JAMMEX Introduction (Gov't Only) –** Catrina Murphy (DLA) & Vikas Sharma (22nd Century)
- **DoD Additive Manufacturing Draft Guidebook Review –** Michael Parkyn (OSD R&E)
- **Cybersecurity in Manufacturing Workforce –** Lizabeth Stuck (MxD) & Michael Gramoni (Workforce Development)

2021 AM Workshop

Working Group Out Briefs

2021 Additive Manufacturing Workshop

Robert A. Gold

Director
Technology & Manufacturing Industrial Base
OUSD(R&E)

2021 Additive Manufacturing (AM) Workshop Follow-On Actions

- Plenary Slides will be on AMMO Website
  - https://ammo.ncms.org
- AM Workshop Survey
  - https://www.surveymonkey.com/r/778J5JB
- Final Report
- AMMO WG

Questions?

AM Workshop Points of Contact

NCMS Event Support
EventSupport@ncms.org

Debbie Lilu
Debbie.Lilu@ncms.org
(734) 262-0758

Ray Langlais
rlanglais@lmi.org
(571) 633-8019

2021 Additive Manufacturing Workshop

14 – 21 June

Virtual

Tracy Frost (OUSD Research & Engineering)/JAMWG
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AMMO Additive Manufacturing for Maintenance Operations

America Makes

2021 Additive Manufacturing Workshop

Final Outbrief

Research & Development to Advance AM Qualification and Certification

Co Leads:

Jennifer Wolk (jennifer.wolk@navy.mil)
Jeffery Gaddes (jeffrey.s.gaddes.civ@mail.mil)
Mark Benedict (mark.benedict.2@us.af.mil)
Brandon Ribic (Brandon.Ribic@ncdmm.org)

Research & Development to Advance AM Qualification and Certification

- **Objectives**:
  1. *Identify gaps in tools, techniques, and technology relevant to qualification and certification*
  2. *Identify impact to qualification time savings*
  3. *Prioritize near term (2 years) and long term (5+ years) efforts to accelerate development in improved capability or efficiency for AM qualification*

- **Planned Deliverables**
  1. *Identified gaps aligned with AM value stream elements*
  2. *Interrelationships of gaps and qualification timeline impact*
  3. *Prioritized near term and long term opportunities to realize improved capability and efficiency for AM qualification*

Working Group Name

- **Accomplishments and Deliverables**:
  1. *Identified 95 gaps (tools, techniques, technology) across AM value stream elements including:*
     - *AM processes*
     - *Materials*
     - *Post-processing*
     - *Inspection and testing*
     - *Design*
  2. *Quantified anticipated qualification cycle time savings derived from delivery of a solution for each gap*
  3. *Determined time frame to deliver solutions to address each gap (near term [2 years], long term [7+ years])*
  4. *Identified top 5 near term and long term prioritized gaps through voting exercises*

Working Group Name

Key Takeaways:

- *Greatest number of gaps observed were in Inspection and testing (28) and AM processes (29)*
- *Inspection and machining gaps correlated with weeks of time savings*
- *Modeling/ICME, process-structure-properties (effect of defects, design allowables, materials data), standards, and in-situ process monitoring gaps correlated with largest time savings (months)*
- *Addressing gaps identified tended to offer weeks of time savings or better (76 out of 95)*
- *Longer term efforts provided more opportunities for qualification time savings*

Working Group Name

Key Takeaways:

- *Prioritized Near Term Gaps (out of 38):*
  1. *Materials data for dynamic applications including process-structure-property relationships*
     - *E.g. Fatigue data, effect of defects, design allowables*
  2. *Improved inspection throughput and techniques*
  3. *Machine calibration*
  4. *ICME tools/Distortion prediction/residual stress measurement*
  5. *In-situ monitoring and data registration with inspection data*

Working Group Name

Key Takeaways:

- *Prioritized Long Term Gaps (out of 57):*
  1. *ICME methods for qualification, including dynamic property (fatigue life) prediction*
  2. *AM equipment equivalency for qualification and vender to vendor validation*
  3. *AM material specific acceptance criteria*
  4. *AM system designs which promote reliability and repeatability (ex. sensors)*
  5. *Use of industry standards compared to proprietary standards to enable vendor certification/approval*

Working Group Name

Recommendations and Next Steps:

- *Present these findings to DoD for consideration*

Working Group Name

Questions?

AMMO Additive Manufacturing for Maintenance Operations

America Makes

2021 Additive Manufacturing Workshop

Final Outbrief

Cybersecurity Working Group: From Current to Future State

Co Leads:

Jon Powvens

Greg Shannon

Larry Lynch

Adwoa Amofa

Cybersecurity Working Group: From Current to Future State

Objectives:

1. Identify and document current cybersecurity baseline across the DIB, i.e., best practices, lessons learned, and gaps.
2. Identify current and future cybersecurity R&D.
3. Inform future cybersecurity roadmap activities to enhance cybersecurity across the DIB.
4. Traditional, existing approaches to cybersecurity manufacturing are **often outdated** and not pervasive, not resilient and are expensive and obtrusive.
5. The **biggest challenge** is to see where we are succeeding and expanding on that.
    a. Example: Two-factor authentication has gotten usable and scalable allowing for automatic updating and is common for many consumer products.

Planned Deliverables:

1. Whitepaper describing the current DIB cybersecurity baseline to include technology/capability gaps.
2. Recommendations on future R&D activities.
3. We, in the cybersecurity community, owe our customers and stakeholders a **PURE cybersecurity method: P**ervasive, **U**nobtrusive, **R**esilient/reliable, and **E**conomical/efficient.

Cybersecurity Working Group: From Current to Future State

Accomplishments and Deliverables

- Summed up best practices with NIST and Markforged
- Cover up of what the landscape is today with projects and presentations from MxD and CyManII
- Manufactures are leasing equipment so there are no controls; must be authorized
- Top 5 needs:
  1. Make security more invisible and unobtrusive
  2. Make key security properties or controls “built in”
  3. Additive Manufacturing machine providers provide secure machine environments
  4. Case studies of where security improvements paid of in ways that matter to manufacturer/different messaging
  5. Keeping the security posture up to date so it doesn’t get stale/ vulnerable

Cybersecurity Working Group: From Current to Future State

Key Takeaways

- SMMs are leasing equipment with no control abilities so they aren't able to make security improvements
- Statement by NIST that SMM can implement cybersecurity easier than large manufacturers and the dependence of SMMs implementing cybersecurity rests with the CEO
    - SMM have flatter organizations that allow quicker actions when the choice is made

Cybersecurity Working Group: From Current to Future State

Recommendations and Next Steps:

- Getting experts on what we need to do differently to get effective messages
- Kick offs meetings discussing methods and research on disciplinary areas
- Cyber case studies and multiple outreach efforts that include demos

Cybersecurity Working Group: From Current to Future State

Questions?

AMMO Additive Manufacturing for Maintenance Operations

America Makes

2021 Additive Manufacturing Workshop

Final Outbrief

Joint Additive Manufacturing Acceptability (JAMA) AM Data Package

Co Leads:

Edilia Correa (Edilia.Correa@dla.mil)
Tony Delgado (Luis.Delgado@dla.mil)
Michael Ridgway (miridgway@deloitte.com)
Chris Babcock (cbabcock@deloitte.com)
David Wittes (dwittes@deloitte.com)

JAMA AM DATA PACKAGE OBJECTIVE AND PLANNED DELIVERABLE

America Makes

Objective:

1. Capture participant input to refine the Common JAMA AM Data Package risk categorization, content, structure, and formatting

Planned Deliverable:

1. List of recommendations to refine the Common JAMA AM Data Package risk categorization, content, structure, and formatting

JAMA AM DATA PACKAGE ACCOMPISHMENTS AND DELIVERABLES

America Makes

1. Presented our AM Data Package approach to the Common JAMA AM Data Package risk categorization, content requirements, structure, and formatting

2. Gathered feedback from industry peers through workgroup surveys and open dialogue

3. Developed recommendations based on our feedback to refine our approach to AM Data Package risk categorization, content requirements, structure and formatting

JAMA PROJECT OVERVIEW

America Makes

The DLA R&D office and OSD are funding the JAMA II project to develop streamlined frameworks and DoD acceptance processes for additive manufacturing.

Where We've Been: JAMA I

In the first iteration of the JAMA effort, Deloitte aligned cross-Military Service stakeholders on a consensus-driven approach, successfully delivering the outputs below across four lines of effort.

AM Part Selection	Provided initial **Common AM Part Selection Process** and **Prioritization Model**
AM Data Packages	Established a **Common AM Data Package** Prototype and standardized AM Risk Categories
AM Acceptance Criteria	Identified common **AM Qualification** and **Certification (Q&C) requirements**
Enabling Digital Collaboration	Mapped AM systems and recommended **future state system capabilities**

Where We're Going: JAMA II

JAMA II builds on our success in JAMA I by using actual Military Service technical data to test, refine, and validate our outputs while continuing the consensus-driven approach to alignment.

AM Candidate Selection	**Common AM Part Selection guidance document** and **calculation toolset**
AM Acceptance Process	**Report** documenting an acceptance process for AM items based on risk categories
AM Remote Inspection Pilot	**Recommendation** of remote inspection tools and testing procedure adjustments
AM Data Management	**Assessment** of DLA's current digital capability to support AM procurement

During this working group, we reviewed JAMA team's recommendations for Common AM Data Package risk categories, content requirements, structure and formatting and invited the audience to provide input

AM DATA PACKAGE GOALS

The JAMA team developed recommendations for the AM Data Package while aiming to meet the four goals below.

Components

Content

What is included in an AM data package, stratified by risk category

Structure

How AM data package content (i.e. files and attachments) is grouped together

Format

How AM data package content is represented visually

Common AM Data Package Goals

1 **Controllability**
AM data package enables processes reflective of Military Department (MILDEP) cognizant engineering authority

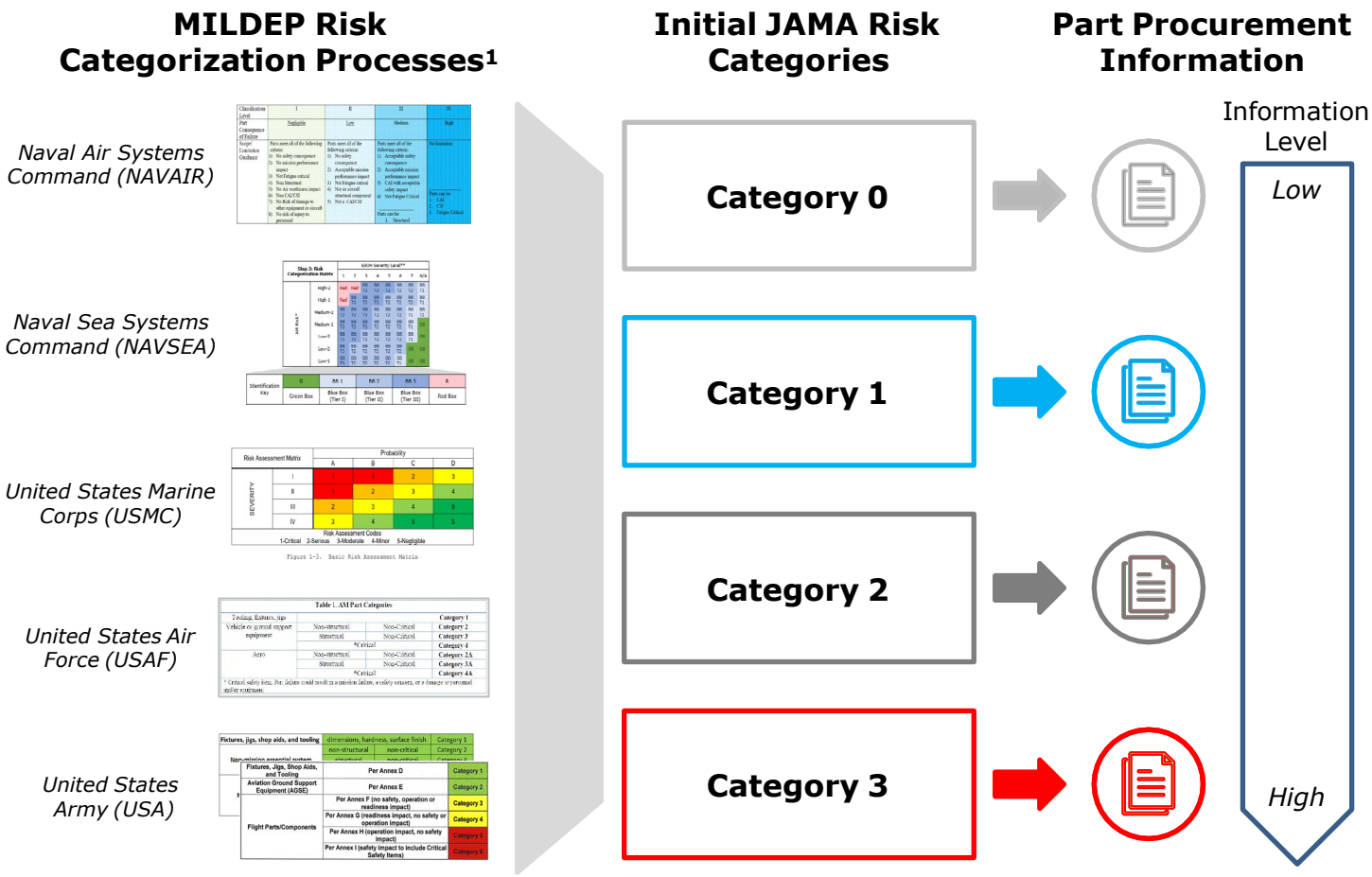
2 **Flexibility**
AM data package is flexible and extensible to cover MILDEP needs, along with part risk needs

3 **Exportability**
AM data package is easily exportable to suppliers for AM procurement of parts

4 **Consistency**
AM data package is consistent with both military and industry standards

COMON AM RISK CATEGORIES – INTRODUCTION

The **initial** JAMA risk categories allow the DLA to look at AM parts through a common lens when identifying information needed for an AM part procurement.



[1] *Refer to slides 16 and 49-64 for greater detail on the risk categorization processes for each MILDEP*

COMMON AM RISK CATEGORIES – DEFINITIONS

The JAMA team developed these **initial** risk categories to stratify the content requirements for the Common AM Data Package through ongoing MILDEP discussions.

Risk Categories

Category 0	Category 1	Category 2	Category 3
Items that pose no risk of damage to other equipment or personnel (e.g., not CSI[1] or CAI[2])	Items that pose little to no risk of damage to other equipment or personnel (e.g., not CSI or CAI)	Items that pose a risk of damage to other equipment or personnel (e.g., CAI)	Items that pose a severe risk of damage to other equipment or personnel (e.g., CSI)

MILDEP cognizant engineering authority will retain the authority to define what risk category an AM part aligns to.

[1] *Critical Safety Item (CSI)*
[2] *Critical Application Item (CAI)*

AM DATA PACKAGE CONTENT REQUIREMENTS

America Makes

Module	Requirement	Purpose
TDP (Technical Data Package)	3D TDP PDF	Contains general information, 3D drawing, part specifications, parts list, notices, statements, technical and admin notes
	Model Validation Certificate	Validates model data and geometric integrity to identify errors in conversion across file types
	STEP File	3D model in neutral file type
	Native Computer-Aided Design (CAD) Model and Version	3D Native CAD model and CAD version
Manufacturing	Manufacturing Requirements *(Post Processing, Environmental)*	Prescribes manufacturing process, environmental, and support structure requirements
	AM Process Parameters and Software Requirements	Outlines authorized material, printers, and associated process parameters and settings
	STL/AMF File	Shows part's surface geometry to support build of an AM part
	Build Files	Dictates specific manufacturing of the part, can be loaded onto AM machine
Testing	Material Verification Plan *(Testing Plan and Testing Coupons)*	Outlines the testing plan for material, along with testing coupon descriptions and requirements
	FAT Requirements and Plan	Outlines first article testing plan and requirements for the part
	QA Requirements and Plan	Outlines QA plan and requirements for the part builds on processes associated with part criticality
	Equipment Calibration and Maintenance Requirements	Definition of equipment calibration process and frequency and maintenance tasks and frequencies
	QIF (XML)	Enables effective exchange of data throughout quality measurement process

AM DATA PACKAGE STRUCTURE COMPARISON

America Makes

The JAMA team recommends the modular approach based on overall AM data package goals and current system capabilities.

			Our Recommendation
	Option 1: All-In-One	**Option 2: Referenced**	**Option 3: Modular**
	All document are attached within a singular PDF	***All documents are saved separately and referenced within one another***	***Documents and attachments lie within three (3) distinct modules***
Controllability	Revising a part of the AM data package requires review and approval of the whole data set	Individual control of each document allows for separate approval process for each document	Revising any part within a module requires review and approval process for that module
Flexibility	Attachments within the AM data package can be required based on part criticality or MILDEP needs	Individual referenced documents can be required based on part criticality or MILDEP needs	Modules and attachments within modules can be required based on part criticality or MILDEP needs
Exportability	AM data package all saved in one PDF, allows for easy packaging for vendors and storage within the repository	Documents are saved individually, therefore not pre-packaged to send to vendors	Data stored in three (3) pre-packaged modules, allows for easy packaging for vendor and storage within the repository
Consistency with Standards	Conflicts with military standard definition of a technical data package[1]	Meets military standards	Meets military standards

[1]*Per Military Standard (MIL-STD) 31000B*

RECOMMENDATION: MODULAR APPROACH

America Makes

AM Data Package

Data List and Model Metadata

TDP (3D PDF)

Includes general information, part specifications, 3D drawing, parts/notes list, notices, statements, and revisions

Attachments

- Standard for the Exchange of Product Data (STEP) File
- Model File Validation Certificate

**Where the procuring activity has approved a critical manufacturing process, the manufacturing reqs. module is attached in the TDP*

Manufacturing Requirements

Includes manufacturing process detailing machine verification, material inspection, load feedstock, and inspection instructions

Attachments

- AM Process Parameters and Software Requirements
- Tessellated File (Standard Tessellation Language (STL)/Additive Manufacturing File Format(AMF))
- Build Files

Testing Requirements

Overviews the testing plan, Quality Assurance (QA) requirements, and First Article Test (FAT) requirements

Attachments

- Material Verification Plan (Testing Requirements + Coupons)
- QA Requirements and Plan
- FAT Requirements and Plan
- Quality Information Framework (QIF) Extensible Markup Language (XML) Files

JAMA AM DATA PACKAGE RECOMMENDATIONS

America Makes

AM Risk Categories Session	
Feedback	**Recommendation**
"Risk is a product of two (2) independent variables one being consequence of failure and other one being the likelihood of something happening. So something that could have a very serious consequence of failure say like an asteroid pounding into the earth may have very little risk because it's highly unlikely as opposed to an automobile accident which might have a high risk because it has a much higher likelihood even if the consequence of failure is not that great." – John Schmelzle - NAVAIR	Revise our definition of risk categories that address the consequence of a failure and the likelihood of that failure occurring.
The audience provided many additional and different ways their organizations define risk and required some clarity on how JAMA defined risk.	No change necessary. JAMA common AM risk categories map to the respective five MILDEP risk schemas, simplified into four (4) categories so inherently definitions will be more generalized.
AM Data Package Content Requirements Session	
Feedback	**Recommendation**
Native CAD Files are included in the JAMA AM Data Package which could increase risk if a vendor was to have access to the native CAD file.	Consider removing the native CAD file from the JAMA AM Data Package and instead use it as a data source to develop the TDP.
"What about 3MF files as an option/addition to STL? What about JT as a neutral file along with/ instead of 3DPDF?" - Randy Langmead - Siemens	Consider including 3MF and JT file types as options in the AM data package pending DLA and MILDEP stakeholder approval.

JAMA AM DATA PACKAGE RECOMMENDATIONS

America Makes

AM Data Package Structure Session	
Feedback	**Recommendation**
Participants do not currently use the JAMA recommended Modular Approach to AM Data Packages.	Maintain fidelity to MIL-STD-31000B definition of a TDP by separating elements that do not align with the MIL-STD definition of TDP from the TDP document. This could be done with the modular or referenced approach.
The modular approach invites the risk and complication of sending information to different audiences that do not necessarily need the information. For instance, the third module has testing requirements but would be sent to the manufacturer.	To better meet our goals of flexibility, exportability, controllability, and consistency, consider the referenced approach rather than modular. Weigh the benefits versus the configuration management risks of a larger number of documents.
AM Data Package Format Session	
Feedback	**Recommendation**
"[a MILDEP] has printed parts but they don't have the part to be useable for the lifetime of their systems. They just need it temporarily so they can get the longer lead traditional part." – LtCol Peters -DLA R&D	Include an option in the JAMA AM Data Package to denote if a part will be a temporary or permanent part.
Siemens uses a digital briefcase for transfer of data sets instead of less secure methods such as SharePoint.	Increase understanding of data access, transfer, and sharing functionality and DoD requirements as part of JAMA II Task 4 (Data Management Framework).
"An AM data set is the same thing as a product definition data set as defined in ASME Y14.41-2019" – John Schmelzle - NAVAIR	Change the nomenclature of AM Data Set to AM Data Package in order to avoid confusion with ASME Y14.41-2019.

Joint Additive Manufacturing Acceptability (JAMA) AM Data Package

Questions?

2021 Additive Manufacturing Workshop

Final Outbrief

Education and Workforce Development

Co Leads:

Josh Cramer (josh.cramer@ncdmm.org)
Michael Britt-Crane (michael.d.britt-crane.civ@mail.mil)
Karla O'Conner (Karla.OConnor@dau.mil)

Education and Workforce Development

- **Objectives:**
  1. *Instructor led training on the utilization of Additive MFG technologies in various manufacturing settings.*
  2. *Participants will engage in an interactive training session exploring streamline the manufacturing process, improve product life cycles, and allow for mass customization, which can lead to improved profitability*
  3. *Participants will work collaboratively and with a virtual coach to build business case scenarios specific to their roles, technologies, and facilities*

- **Planned Deliverables:**
  1. *Participants will build detailed action plans leading to business case scenarios to deploy within their roles/companies in successful integration of additive manufacturing*

Education and Workforce Development

- **Accomplishments and Deliverables**
  1. *Deployed a pilot of the "Optimizing for Additive MFG" Instructor Led Training*
     1. *Mix of DoD (6), Industry (4), Academia (3) and Workforce Organizations (4)*
  2. *Gathered feedback of the participants for full modification and amended full scale version deployment*
     1. *Broad engagement of engineering/engineering techs/fabrication techs in the adoption and understanding of AM integration into traditional settings*
     2. *Logistics – Supply Chain considerations "Just because you have a printer doesn't mean you can start printing parts" – consideration for additional content*
     3. *Safety considerations was more of a gap that initially thought*
     4. *Disposal Chains was suggested as additional content as well*
     5. *This opportunity highlighted that in AM we are still a very diverse group and that many of the folks engaged are part of the "club"*

Working Group Name

Key Takeaways – Some snapshots…

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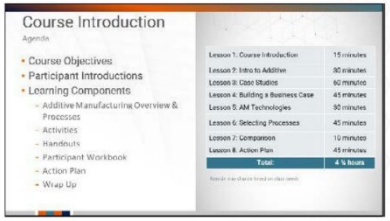
COMPARISON CHART

Traditional Manufacturing	Both		Additive Manufacturing
	How does this look under TM?	How does this look under AM?	
• Higher Throughput • Lower Cost of Material - Larger Choice of Materials • Part Complexity is Costly and Drives Setting to Look for Lower Complexity/Cost • Can't Manufacture Generative Design Parts - Lightweighting is Harder • Difficult to Change Designs so Mass Customization is Harder • Product Development Tends to be Slower • Higher Tooling Costs			• Lower Volume of Production • Higher Cost of Material - However, Lower Waste, Lower Scrap Cost • Thrives with Higher Part Complexity, Makes More Sense from a Financial Standpoint • Can Manufacture Generative Design Parts - Lightweighting is Easier • Mass Customization is Easier • Product Development Can Happen Faster • Lower Tooling Costs

This material is based upon research supported by, or in part by, the U.S. Office of Naval Research under award number N00014-18-1-2881 led by the National Center for Defense Manufacturing and Machining (NCDMM).



COURSE OBJECTIVES

By the end of this course, you should be able to do the following:

- Define AM
- Describe the business case for adopting and optimizing AM
- Compare AM with other processes
- Write an action plan regarding AM specific to their organization
- Describe the equipment requirements for AM

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ACTION PLAN

Topic: Implementing Additive Manufacturing at in

Plan Created By:	
Plan Presented To:	
Define Plan:	

Improvements to be Made	Likely Impact

Resources Comparison		
	Additive Manufacturing	Traditional Manufacturing
Equipment/ Tooling Costs		
Training		
Facility Requirements		
Ancillary Equipment		

This material is based upon research supported by, or in part by, the U.S. Office of Naval Research under award number N00014-18-1-2881 led by the National Center for Defense Manufacturing and Machining (NCDMM).

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Plan Created By:	
Plan Presented To:	

Material Identification:	

Potential Processes	Use Cases

Monetary Costs	Monetary Benefits	Net Value

Working Group Name

Recommendations and Next Steps:

- *Further engagement with core team subject matter experts to review and assess feedback*
- *Deploy suggested amendments through continuous improvement for full scale deployment*
- *The team would be open to working with interested groups in future deployments*
- *Our next Instructor Led Training will be on "Managing a Digital MFG Facility" – reach out to engage*

Working Group Name

Questions?

2021 Additive Manufacturing Workshop

Final Outbrief

AM Standards

Co Leads:

Jesse Chambers, DSPO (Jesse.Chambers@dla.mil)
Jim McCabe, ANSI (jmccabe@ansi.org)

AM Standards

Objectives

1. Determine defense industry AM standardization priorities from the gaps identified in the America Makes and ANSI AMSC *Standardization Roadmap for Additive Manufacturing*
2. Develop recommendations for those gaps that are good candidates for research & development (R&D) projects

AM Standards

Accomplishments and Deliverables*:*

1. Received 66 responses to a pre-workshop survey on top defense industry standards gaps in the AMSC roadmap
2. Reduced this list to 15 gaps
3. Developed final list of 10 with recommendations for R&D

Top Priorities for R&D Projects

1. Gap QC2: AM Part Classification System for Consistent Qualification Standards
2. Gap PC4: Machine Qualification
3. Gap D17: Contents of a TDP
4. Gap QC1: Harmonization of AM Q&C Terminology
5. Gap FMP4: Design Allowables
6. Gap PC2: Machine Calibration and Preventative Maintenance
7. Gap FMP1: Material Properties
8. Gap PC7: Recycle & Re-Use of Materials
9. Gap PM7: AM Process-Specific Metal Powder Specifications
10. Gap D15: Design of Test Coupons

Gap QC2: AM Part Classification System for Consistent Qualification Standards

- **Good candidate for an R&D project (Y/N):** Y
- **Rationale:** Important for Q&C path. Definitions, parameters, geometries across different materials, machine types, and processes.
- **Recommendation (R&D needed):** Have different teams focused on alloys, polymers, ceramics? Intended to be material agnostic. JWG FAA and EASA focused on low criticality parts. A paper study/landscape analysis moreso than R&D. Is it flight critical? Look at definitions. Direct it to JAMWG
- F42.07.01 working on standard (led by John Schmelzle, NAVAIR). Committee also working on a standard guide on cross referencing of part classifications methodologies in use by government agencies. Status: 

- **Investment:** Moderate (Options: Modest, Moderate, or Substantial)

Gap PC4: Machine Qualification

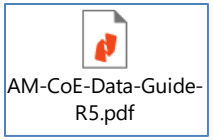
- **Good candidate for an R&D project (Y/N):** Y
- **Rationale:** Important toward industrialization. Getting consistent results in build process. That machine is doing what we ask it to do. Needed for certification by qualifying agencies.

- **Recommendation (R&D needed):** SAE AMS7032, additive manufacturing machine qualification, is underway. There is a need for research. Possibly ASTM AM CoE? Address variability between machines. SAE creating framework but needs data. NIST did round robin testing in 2012.
- Framework for this exists in ISO/ASTM 52904 when a machine is calibrated with ISO/ASTM 52941

- **Investment:** Substantial

Gap D17: Contents of a TDP

- **Good candidate for an R&D project (Y/N):** Y
- **Rationale:** Remove parenthetical from gap: "(or revise MIL-STD-31000A, *Technical Data Packages*)." It is not the standard you want to use to come up with requirements for building your TDP.
- Beyond that the gap makes sense. We need a process outcome more than a process definition. What are the key process variables? Do the priorities vary between the different service branches (e.g., corrosion is an issue for the Navy)?
- What data needs to be in the TDP and in what format?
- Attachment is the Strategic Guide: Additive Manufacturing Data Management and Schema, jointly developed by ASTM and America Makes.
- ASTM AM CoE can support the landscape analysis.



- **Recommendation (R&D needed):** A paper study/compilation of best practices.
- **Investment:** Modest (will take time, not necessarily dollars)

Gap QC1: Harmonization of AM Q&C Terminology

- **Good candidate for an R&D project (Y/N):** Y
- **Rationale:** No one can generate all the data that is required. Data format and terms are not consistent. Bring consistency, minimize market confusion, and enable sharing of data. Makes it easier for manufacturer to talk to customer, regulatory agencies, suppliers down the chain.

- Should be done in ISO/ASTM 52900 on terminology

- **Recommendation (R&D needed):** Again, white paper/secondary research, not testing per se. Get input from DOD, NASA, FAA/EASA

- **Investment:** Modest

Gap FMP4: Design Allowables

- **Good candidate for an R&D project (Y/N):** Y
- **Rationale:** CMH-17 and MMPDS active area of research/statistical analysis. Methodologies may not change but we do need to look at different types of metals, as well as other materials. Workflows will be impacted. Is the data from one or multiple machines? There are variations between sites, machines, OEMs.

- **Recommendation (R&D needed):** Ties into machine qualification. Nothing specific suggested. We are capturing orientation, parameters, to some extent.

- **Investment:** Moderate or Substantial

Gap PC2: Machine Calibration and Preventative Maintenance

- **Good candidate for an R&D project (Y/N):** Y
- **Rationale:** Important prerequisite to get to qualification. ASTM working on multi-beam machines. Need research on preventative maintenance, machine health. SAE AMS7032 near completion but not detailed in terms of protocols for maintenance and calibration.

- Machine calibration process is called out in ISO/ASTM 52941. Preventive maintenance is called out in ISO/ASTM 52904 (per machine manufacturer's recommendation). There is an active work item on calibration of AM machines with multiple energy sources (ASTM WK72317). AM CoE recently funded a project on preventative maintenance. This topic still needs research.

- **Recommendation (R&D needed):** ASTM collecting data? AWS D20.1 discusses to some extent on requalification of a machine
- **Investment:** Moderate

Gap FMP1: Material Properties

- **Good candidate for an R&D project (Y/N):** Y
- **Rationale:** What materials are of high priority to the customer? To DOD? That would help drive research priorities.
- Artificial intelligence (AI) and machine learning (ML) are becoming more relevant vis a vis properties, along with integrated computational materials engineering (ICME)

- **Recommendation (R&D needed):** MMPDS working on the analysis, but there are only a few submittals. NCAMP/NIAR doing testing.
- Engage DOD in discussion of priorities for materials development (e.g., AFRL working on supersonics) beyond sustainment if that is a priority for DOD

- **Investment:** Substantial

Gap PC7: Recycle & Re-Use of Materials

- **Good candidate for an R&D project (Y/N):** Y
- **Rationale:** *SAE AMS7031, Process Requirements for Recovery and Recycling of Metal Powder Feedstock for Use in Additive Manufacturing of Aerospace Parts* just went through balloting looks at powder re-use. Research done by Carnegie Mellon on number of times you can recycle a material.
- Will contribute to industrialization of AM by lowering costs.
- Understand issues of storage, use in the field
- Issue for metal powder. Not an issue for filament or wire

- Terminology for reuse strategy is at ballot in F42.07.03. AM CoE recently funded two R&D projects on re-use of Metal and Polymer powders. This topic still needs research.

- **Recommendation (R&D needed):** Create experiments around this.
- **Investment:** Moderate

Gap PM7: AM Process-Specific Metal Powder Specifications

- **Good candidate for an R&D project (Y/N):** Y
- **Rationale:**
- SAE has looked at powder morphologies. Has not looked at flowability, particle size, etc. SAE would support but has not done active research.
- A standard suite of these would be very useful. Standard attributes.
- Handling and transport of these standards also important.

- This has always been the strategy of F42

- **Recommendation (R&D needed):** A paper study not an R&D Project. It would be a major endeavor to do this justice. A wish list. Get info from producers.

- **Investment:** Modest to Moderate

Gap D15: Design of Test Coupons

- **Good candidate for an R&D project (Y/N):** Y
- **Rationale:**
- Moving away from homogeneous material. How do you test a lattice structure?
- Huge area of need. Is attainable. Could produce a good return on investment.
- An issue for aerospace as well as medical

- **Recommendation (R&D needed):** ASTM can look at?

- **Investment:** Modest or Moderate

AM Standards

Questions?

2021 Additive Manufacturing Workshop

Final Outbrief

Integrated Additive Manufacturing Network Plan

Co Leads:

John Wilczynski
Georgette Nelson

Integrated AM Network Plan

Objectives:

1. Demonstrate the Advanced Manufacturing Crisis Production Response (AMCPR) Program
2. Identify gaps in the Program's capabilities as a crisis management system
3. Engage with the AM Ecosystem to prioritize program objectives and sustainment

Integrated AM Network Plan

Accomplishments and Deliverables:

Day 1

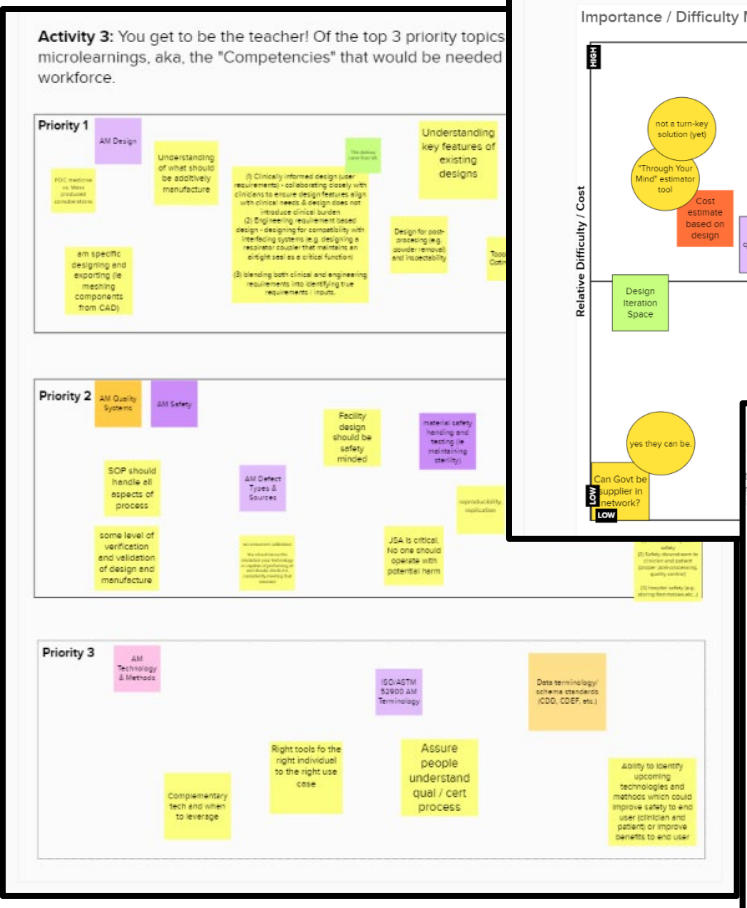
1. Identified 5 key educational gaps and challenges that need to be addressed in times of crisis
   - AM Design
   - AM Quality Systems
   - AM Technology & Methods
   - AM Post Processing
   - AM Materials

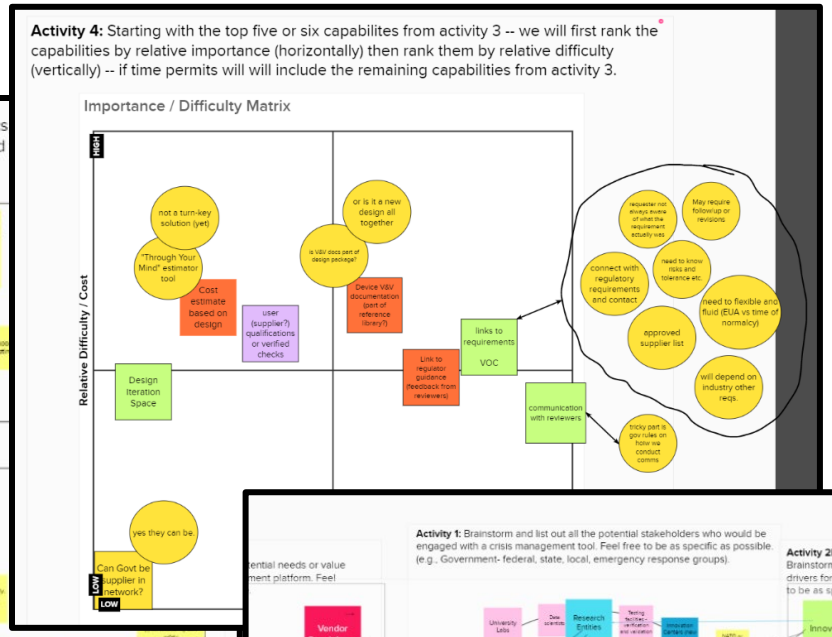
2. Prioritized desired expansion capabilities for the online Exchange platform
   - Design Collaboration Space
   - Visibility to suppliers who have printed designs and feedback provided by requesters
   - Incorporate tool to estimate cost of printed part

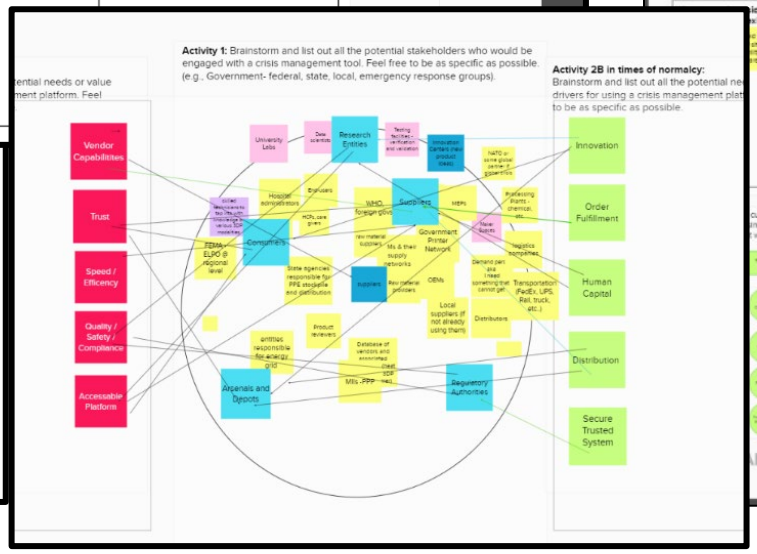
Day 2

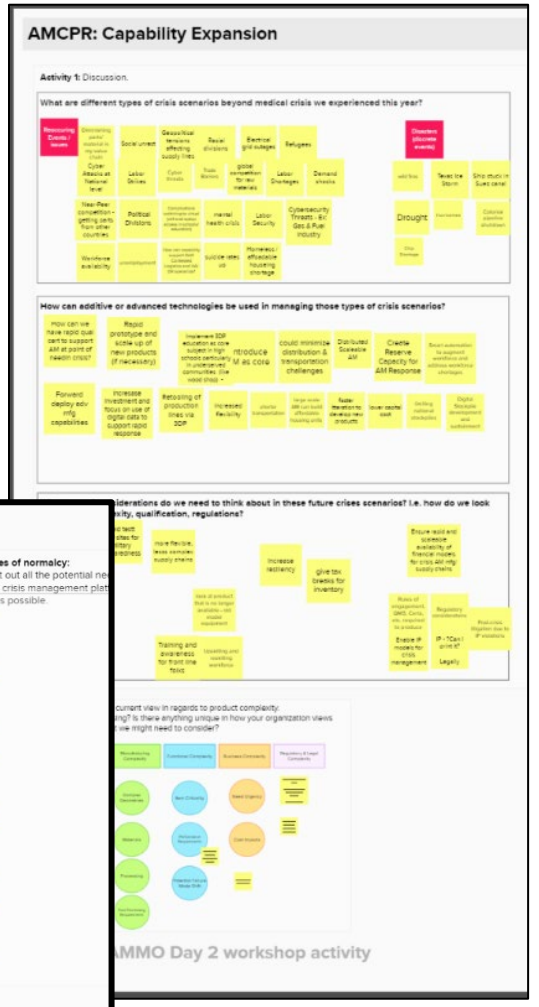
1. Defined and grouped stakeholders and identified their value drivers for using the AMCPR program in times of crisis and normalcy.
   - Defined 5 major stakeholders
   - Mapped stakeholders to 10 different value drivers
2. Brainstormed future crisis scenarios and the capabilities needed to enable an effective response.
   - Recurring crisis events
   - disaster events
3. Discussed how we expand our understanding of regulatory challenges as our definition of crisis evolves

Integrated AM Network Plan









Integrated AM Network Plan

Key Takeaways:

- An integrated AM Network is important in times of crisis and normalcy, to convene, catalyze, and coordinate AM efforts across the ecosystem
- There are critical needs along two primary pathways
  1. Drive Innovation & Collaboration to enable effective response and technology development
  2. Be the source of truth to help the AM ecosystem navigate the regulatory complexities of a crisis response

Integrated AM Network Plan

Recommendations and Next Steps:

- Continue to:
  - ✓ identify and execute systematic and discrete crises test scenarios to continuously evaluate and improve the systems capabilities
  - ✓ grow database of designs, suppliers, and reviewers.
- Develop a distributed network of designs and response organizations.
- Establish Design Collaboration & Innovation Space
- Explore connection between access to vendor capabilities via a platform which enables order fulfillment.
- Enhance platform capability related to requirements: regulatory, quality management systems, approved suppliers, etc.

Integrated AM Network Plan

Upcoming Event – Interactive AMCPR Exchange Training

Make sure to mark your calendar!

AMCPR Exchange

Join us for an **Interactive AMCPR Exchange Training** on June 21st, 2:00 – 3:00pm ET.

This hands-on training will provide a deep dive into the model repository and platform and give users the opportunity to engage with AMCPR leaders and ask questions about access, functionality, and troubleshooting.

RSVP here!

Integrated AM Network Plan

Questions?

AMMO Additive Manufacturing for Maintenance Operations

America Makes

2021 Additive Manufacturing Workshop

Final Outbrief

AM Decision Making: AM Business Case

Co Leads:

Stephen Kuhn-Hendricks, PhD (stephen.kuhn-hendric@navy.mil)
William Peterson (william.t.peterson2@navy.mil)
Ernesto Ureta (ernesto.ureta@navy.mil)
Timothy Vorakoumane (timothy.vorakoumane@navy.mil)

AM Decision Making: AM Business Case

- **Objectives:**
  1. *Define equations of the AM business case*
  2. *Identify business data opportunities and challenges*
  3. *Address the influence of AM use cases on the business case*

- **Planned Deliverables:**
  1. *Draft business case equations*
  2. *Mathematical frameworks for objective evaluation of business case*

AM Decision Making: AM Business Case

Governing Equation

$$A_{CC} = C_{TR} - C_{AM} \geq 0$$

Traditional Manufacturing

$$C_{TR} = C_{Start-Up}^{(TR)} + C_{Purchase}^{(TR)} + C_{Shipping}^{(TR)} + C_{Storage}^{(TR)} + C_{Contracting}^{(TR)} + C_{Readiness}^{(TR)}$$

Additive Manufacturing

$$C_{AM} = C_{NRE}^{(AM)} + C_{Production}^{(AM)} + C_{Shipping}^{(AM)} + C_{Storage}^{(AM)} + C_{Contracting}^{(AM)} + C_{Readiness}^{(AM)}$$

AM Decision Making: AM Business Case

Part Costs Only

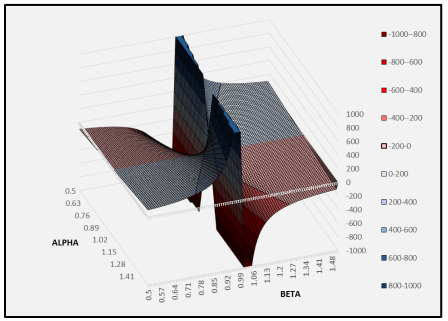
Non-Zero Start-Up, AM NRE, Equal Quantity

$$n = \frac{c_{start} - \alpha c_{start}}{\beta c_p - c_p}$$

n: number of parts

α: ratio of start-up to AM NRE

β: ratio of per part cost trad. and AM



Zero Start-Up, AM NRE, Equal Quantity

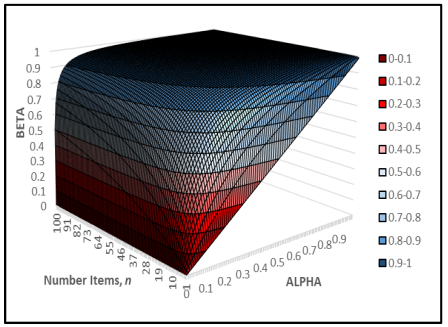
$$\frac{\beta}{\alpha(1-\beta)} - \frac{\beta}{1-\beta} = n$$

$$\beta < \frac{n\alpha}{1 + n\alpha - \alpha}$$

n: number of parts

α: 1-%AM NRE

β: ratio of per part cost trad. and AM



Zero Start-Up, AM NRE, Unequal Quantity

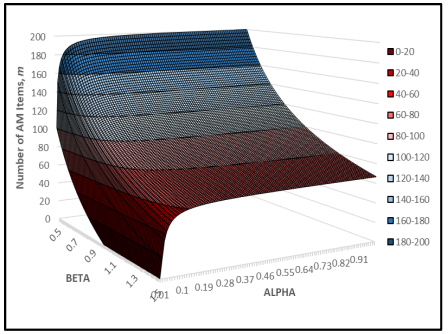
$$1 - \frac{1}{\alpha} + \frac{1}{\beta} n = m$$

n: number of trad. parts

m: number of AM parts

α: 1-%AM NRE

β: ratio of per part cost trad. and AM



AM Decision Making: AM Business Case

Cost Time Trade-Off

Derivation from Governing Equation

$$C_{TR} - C_{AM} \geq 0$$

$$C^{(TR)}_{Start-Up} + C^{(TR)}_{Purchase} + C^{(TR)}_{Readiness} - C^{(AM)}_{NRE} - C^{(AM)}_{Production} - C^{(AM)}_{Readiness} \geq 0$$

$$C^{(TR)}_{Start-Up} + C^{(TR)}_{Purchase} + \tau\left(T^{(TR)} - T^{(AM)}\right) \geq C^{(AM)}_{NRE} + C^{(AM)}_{Production}$$

Implementation Equation

$$\frac{1}{d\sigma}\left[\beta c_t\left(\frac{1+n\alpha-\alpha}{\alpha}\right) - c_t n\right] \leq \tau$$

n: number of parts
α: 1-%AM NRE
β: ratio of per part cost trad. and AM
d: number of days saved per order
σ: number of orders

τ is the cost in dollars per day that the DoD is willing to pay save time with an AM solution

AM Decision Making: AM Business Case

Shipping

$$\boldsymbol{W_{ij} = D_{ij} \odot \Psi_{ij} + Q_{ij}}$$

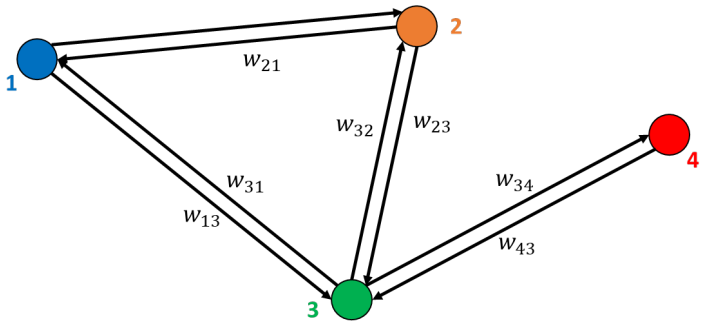
$$\boldsymbol{C_{ij} = m R_{ij} \odot D_{ij} \odot \Psi_{ij}}$$

D_{ij}: distance matrix

Ψ_{ij}: travel rate matrix

Q_{ij}: Queue time matrix

R_{ij}: Cost rate matrix



Storage

$$A_{Storage} = rt\left\lceil \frac{np_v}{C_V} \right\rceil - rt\left\lceil \frac{mp_v}{C_V} \right\rceil$$

r: Cost rate
t: Storage time
p_v: Part volume
C_v: Cube volume
n, m: Number of trad., AM parts

Contracting

$$C_{Contracting} = \sum_{i=1}^{n} r_i t_i$$

r: Labor rate

t: Contracting time

AM Decision Making: AM Business Case

Potential Use Cases for AM

1) New AM Designs
   - Rapid Prototyping
   - Obsolescence
   - Part performance
2) Entirely replace the traditional part supply with AM supply
   - Lifecycle economics/value
3) Supplement supply chain for traditional part with AM supply
   - Hybrid (integration with supply chain logic)
4) AM lead time replacements
   - Operational/expeditionary

AM Decision Making: AM Business Case

Recommendations and Next Steps:

- *White paper of overarching AM business case equations and analysis*
- *DoD to decide on overarching business goals for AM*
- *Standardize lower level equations (e.g. how to calculate AM cost, how to estimate costs) across DoD*
- *Standardize and require in policy the collection of data necessary to evaluate the AM business case across the DoD*

AM Decision Making: AM Business Case

Questions?