Which Legacy Parts are Additive Manufacturing Candidates?*

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* DLA Weapon System Sustainment Program R&D Project

Issue

- Military Services are actively pursuing AM capabilities, but, DoD (DLA and Services) don't have a standard process to quickly and consistently determine if a legacy part is a good candidate for AM

- DLA sponsored an R&D Task to address the issue

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R&D Approach Overview

- **Identify Part Attributes Required to Inform AM Decisions**

- Examine DLA Data for Required Part Attributes

- Develop AM Decision Support Process

- Test AM Decision Support Process
  - Supply Chain participants
  - Military Service participants

- Document functional requirements

Part Attributes

Determining amenability of legacy parts to AM production requires detailed knowledge of the:

- Technical Attributes
- Logistics Attributes

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Technical Attributes

- Material/part specifications
  - Composition
  - Tensile strength
  - Elastic modulus
  - Elongation at break
  - Hardness
  - Heat-deflection temperature
  - Melting point
  - Density
  - Fire safety
  - Toxicity
- Overall part size
- Secondary Processing Requirements
  - Heat treatment
  - Machining
- Surface finish specifications
- Surface treatment (Plating, Anodizing, Painting, Passivating)

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Technical Attributes (cont)

- Individual feature dimensions

- Mating surfaces and interfaces

- Machining allowances

- Internal holes and features

- Application environment (some polymers are sensitive to light, humidity, temperature)

- Profile and dimensional tolerances

- Datum targets for machined features

- Attributes that might disqualify AM for part fabrication:
  - Thin walls (will vary by machine and by build orientation)
  - Thick parts (particularly in metals, thick/bulky parts will fail to build)
  - Features with very high aspect ratios (vary by machine and build orientation
  - Over-/under-hangs (particularly in metals; may be built depending on orientation, supports)

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Material and size are primary physical determinants for AM Decision Support Process

Logistics Attributes

- Supply Class (only Class IX)
- Item characteristics/special designations (CSI, FSCAP, nuclear, SubSafe, structural part, COTS…)
- Procurement contract type (competitive, IDIQ, long term….)
- Annual demand (past 2 years), purchase quantities
- Supply/stock status (not stocked, items on hand/ordered/backordered)
- Days on backorder
- PLT/ALT
- Unit price, unit of issue
- Technical data package existence/availability
- Data rights type/class
- QSL, QMSL, QAP
- Acceptance/test/qualification requirements

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Data Availability

- Ground rules for defining AM candidate domain
  - Consider only DLA-managed Class IX parts (~4.5M items)
  - Some dimensional data must be available
  - Exact match to common AM material required
    - No material substitution allowed/considered

- Dimensional data availability
  - ~2.35M items with some dimensional data

- AM material matches
  - ~1.7M items where material is Steel or Aluminum
    - Specific alloy unknown
    - Not considered an exact match
  - ~300K items where material is a polymer
    - Specific polymer unknown
    - Not considered an exact match
  - ~140K items with exact match to common AM materials
    - 72% polymers
    - 28% metals

- Material match + dimensional data availability = 43K legacy Items

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Current AM Candidate Domain: ~300K legacy items

Business Process: AM Pre-screening Tool

- Web-based system to test efficacy of AM Business Process
  - Hosted by XSB, Inc.
  - Limited access (controlled by R&D team)
- User interface permits variety of searches based on four scenarios
  - Full Capability Search
    - Accommodates general exploration of potential AM candidates
    - User has no particular part/system in mind, just wants to explore possibilities
    - Provides maximum search flexibility; can perform all other searches below
  - 'Hard To Get Item' Search
    - Accommodates searches for items that are historically hard to procure
    - User wants info on specific part(s); user has FSC, NIIN, PLT info etc.
  - 'Weapon System' Search
    - Accommodates searches for items related to a specific weapon system
    - User wants info for parts for a specific platform (e.g., F-22)
  - 'AM System' Search
    - Accommodates searches for candidates based on a specific AM machine/system
    - User has access to a specific AM system and wants to know what part(s) can be produced on that system

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DLA Legacy Parts AM Prescreening Tool: Input Display

DLA Legacy Parts AM Prescreening Tool: Results Screen

Testing the Business Process

- >55 Military Service and DLA personnel performed operational testing
  - US Air Force: AFMC, AFRL
  - UA Army: G4, CASCOM, RDECOM
  - US Navy: NAVAIR, NAVSEA
  - US Marine Corps: I&L, WL
  - DLA Supply Chains: AVN, L&M, TS
  - DLA HQ: J34 R&D, J344
- Legacy Parts AM Prescreening Tool tested November 2015 – July 2016

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Summary

- Wide range of AM variables and paucity of online technical data precludes fully-automated AM decision support process
  - Variability in parts (microstructure) made from same AM system
  - Variability in parts made using different AM processes
  - No DoD-approved AM process protocols for build orientation
  - No DoD-approved table of equivalencies for material substitution
  - No DoD-approved testing standards
  - Technical data recorded in unintelligent, 2D raster drawings
- Prescreening decision support process to identify "potential AM candidates" is feasible
  - Prescreening gets us 'in the ballpark'
  - Engineering review of tech data required for final decision
- DLA R&D initiated follow-on effort (Oct 2016) to refine the AM Pre-screening Tool and identification process for 'problematic parts'
  - Focused on using AM as solution for problematic parts

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Back Up Slides

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Common Metallic AM Materials

- Titanium alloys: Ti64, Ti64 ELI, Ti6242, commercially pure Ti,

- Nickle-based alloys: In718, In625, Waspalloy

- Aluminum alloys: AlSi10Mg, 4047

- Stainless Steel alloys: 17-4, 316, 15-5, 13-8, 304, 316, 410, 420

- Cobalt-chrome alloys: CoCrMo, Stellite 21

- Others: Bronze alloy

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Common Polymeric AM Materials

- ABS (Acrylonitrile butadiene styrene)
- ABS/Acrylic
- ABS/PBT (Polybutylene terephthalate)
- ABS/PP (Polypropylene)
- Acrylic
- ASA (Acrylonitrile Styrene Acrylate)
- Epoxy
- Oxycetane
- PA (Polyamide)
- PC (Polycarbonate)

- PEEK (Polyether ether ketone)
- PEI (Polyetherimide)
- PMMA (Polymethyl methacrylte)
- PP (Polypropylene)
- PPS (Polyphenylene sulfide)
- PS (Polystyrene)
- Rubber
- Silicone
- TPE (Thermoplastic elastomer)

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Task 3: Part Attribute Data Availability

NIIN Count	Material	Material Type
59416	POLYAMIDE (NYLON)	polymer
18842	EPOXY	polymer
15796	TITANIUM ALLOY UNS R56400	metal
12482	TITANIUM	metal
7448	POLYCARBONATE	polymer
5286	POLYPROPYLENE	polymer
4367	STEEL ALLOY UNS S30403	metal
4142	PLASTIC ACRYLIC	polymer
2829	STEEL ALLOY UNS S43100	metal
2255	ACRYLONITRILE BUTADIENE STYRENE	polymer
2078	STEEL ALLOY UNS S30800	metal
1915	STEEL ALLOY UNS S42000	metal
1635	POLYSTYRENE	polymer
769	POLYMETHYL METHACRYLATE	polymer
636	POLYPHENYLENE SULFIDE	polymer
202	TITANIUM UNS R50550	metal
181	POLYBUTYLENE TEREPHTHALATE	polymer
129	POLYETHERETHERKETONE	polymer
124	POLYETHERIMIDE	polymer
109	TITANIUM ALLOY UNS R56401	metal
20	COBALT ALLOY UNS R30006	metal
18	COBALT ALLOY UNS R30106	metal
9	ALUMINUM ALLOY UNS A95356	metal
7	ALUMINUM ALLOY UNS A92319	metal
3	ALUMINUM ALLOY UNS A94047	metal
2	NICKEL MOLYBDENUM ALLOY UNS N10276	metal
2	STEEL ALLOY UNS T30106	metal
2	STEEL ALLOY UNS T20813	metal
0	COBALT ALLOY UNS R30012	metal
0	STEEL ALLOY UNS S30400	metal
0	STEEL ALLOY UNS S30803	metal
0	STEEL ALLOY UNS T20812	metal
0	ACRYLONITRILE STYRENE ACRYLATE	polymer

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~140K items with exact AM material matches

User Feedback

- Tool and decision support process of significant value in identifying potential AM candidates

- Web-based app must be Internet Explorer compatible

- Gather/include input data from service databases

- Include service-managed parts

- Expand list of parts to include those that are not exact material matches or do not have dimensional information

- Include filters for supply chain, TDP availability, technical data rights, part demand, and backorder status

- Identify AM systems owned by service/OEM partners

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