AM Implementation Opportunities and Challenges

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Presented to:

NAVAIR AM Industry Day

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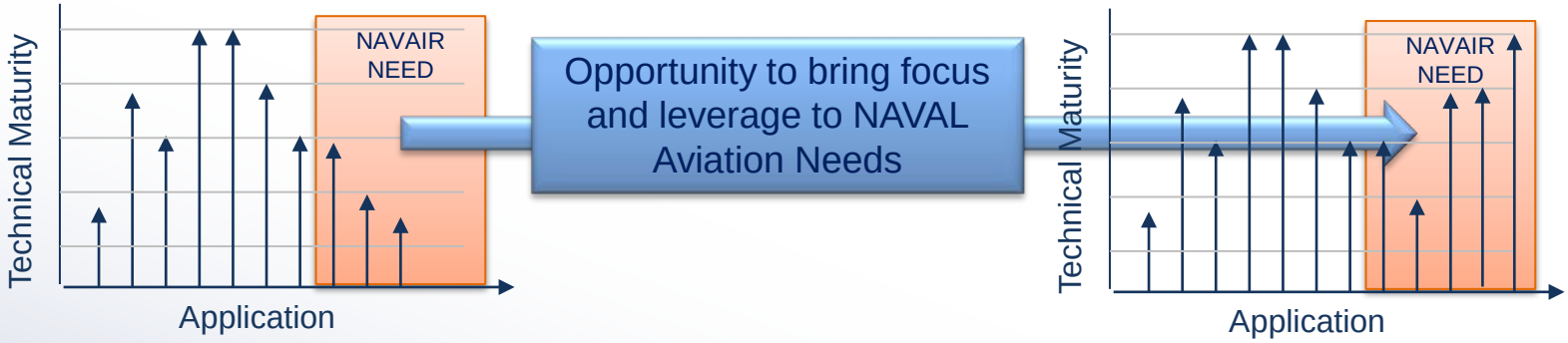
Opportunity

- Clear understanding of our “Applications” can/will drive interest and promote opportunity for teaming.
- Defense Industry Applying AM today, some applications to Naval Aviation.
- Our Objectives are to Leverage and Expand AM Across our Portfolio
  - Drive Action Thru Clear Goals
  - Decompose Goals to Tangible Work
  - Maximize Partnerships
  - Focus Work on a Few but Critical Capabilities
- Goals are designed to *accelerate* the introduction of AM.



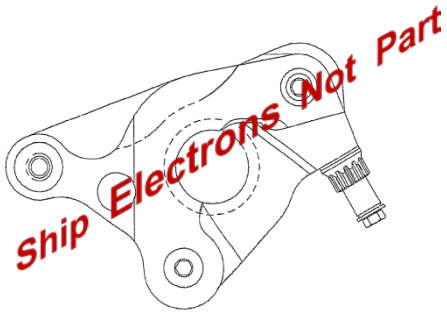
Example of Need

Problem Statement: The Navy's inventory of aircraft is being pressed into service beyond their design life. As a result, components fail that were never expected to be repaired or replaced. With no replacements available in the supply system, long lead times develop for the repair or manufacture.

Broken Part

Reverse Engineer
if necessary

Build Package Database

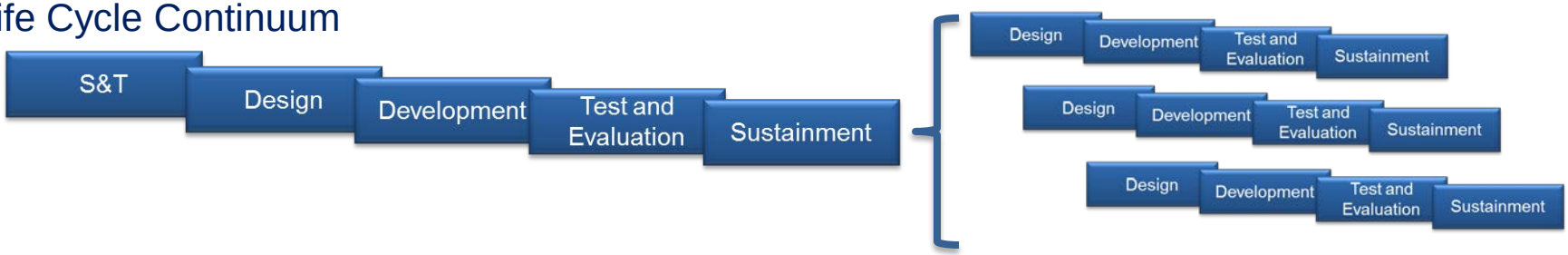


Rapid Manufacture
Using AM Technology

Aircraft Ready for Tasking
Parts on Demand

Engineering Perspective

Life Cycle Continuum



Organizational Elements (Air Vehicle Focus)

- COMNAVAIRSYSCOM AIR-00
  - Research and Engineering Group (AIR-4.0)
    - Air Vehicle Engineering Department (AIR-4.3)
      - Systems Engineering Division (AIR-4.3.1)
      - Aeromechanics Division (AIR-4.3.2)
      - **Structures Division (AIR-4.3.3)**
      - **Materials Division (AIR-4.3.4)**
      - Subsystems Division (AIR-4.3.5)

AM Opportunity Impact

- Affordability
- Parts Availability
- Parts Optimization
- New Design Solutions
- Reduce Waste
- Infrastructure

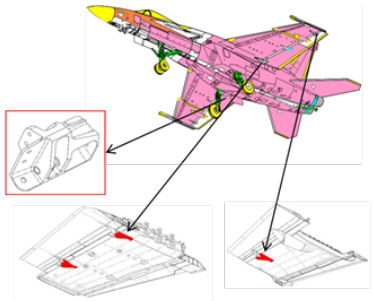
Enhanced Systems Availability
Adaptable Weapon Systems
Reduced Logistics Burden
Improved Readiness

Additive Manufacturing Technology Implementation Pathway

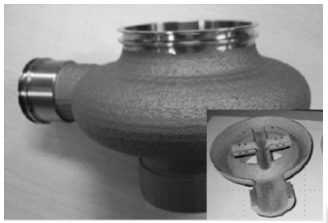
- Activity w/Application
- Activity w/Limited Application
- No Activity

Challenges

- Rapid qualification and certification
- Technology fusion and system interoperability
- Validated structure-process-property models
- Machine-to-machine variability
- Real-time, closed-loop, integrated sensing and control
- Organic capability



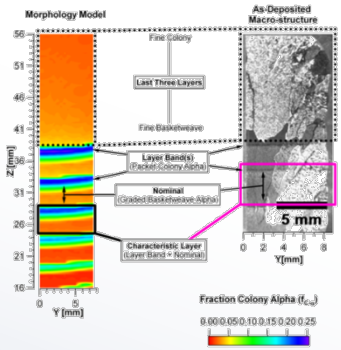
Trailing Edge Flap / Aileron Wing Hinges
MLG Strut Door Hinge



UCAS-D Warm Air Mixer

Proof of Concept Repairs on
Stage 3 Compressor Blades

J69 Jet Engine
Vane Bending Tool



Structure-Property-Processing

Forward Deployed

Flight Worthy

Repair

Tooling

R&D

Advantages and Applications

Additive manufacturing is generally suited for applications that meet the following criteria:

- Low production volume
- Complex part geometry
- Expensive materials

Advantages

- Rapid part turnaround
- Shortened design time
- Inexpensively obtain geometric complexity
- Reduction in material waste
- Limited tooling required
- Reduced labor costs

Applications

Examples

Rapid prototyping

- Design iterations
- Geometric fit-checks
- Scale models
- Working prototypes

Design comparison

Rapid tooling

- Custom fixtures
- Injection molds
- Sand casts
- Trimming tools

Custom trim tools

Rapid manufacturing

- In-house manufacture
- Printed assemblies
- Legacy part development

Prosthetic foot

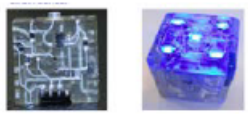
Repair

- Machining errors
- Casting errors
- Worn parts

Over-machining repair

Electronics

- Embedded sensors
- Structural health monitoring
- Printed electronics



Circuits and dice

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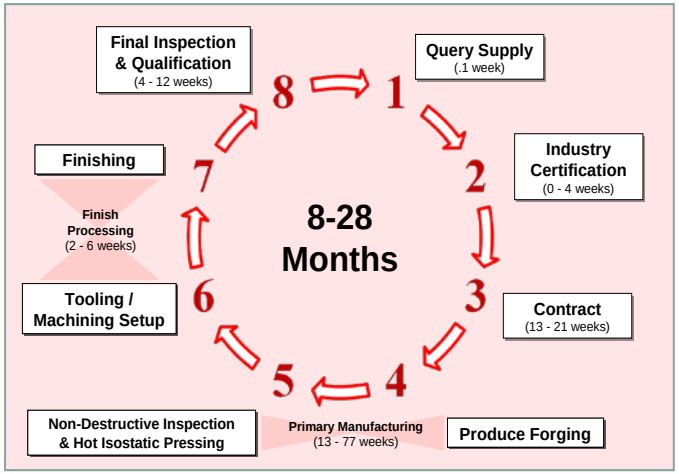
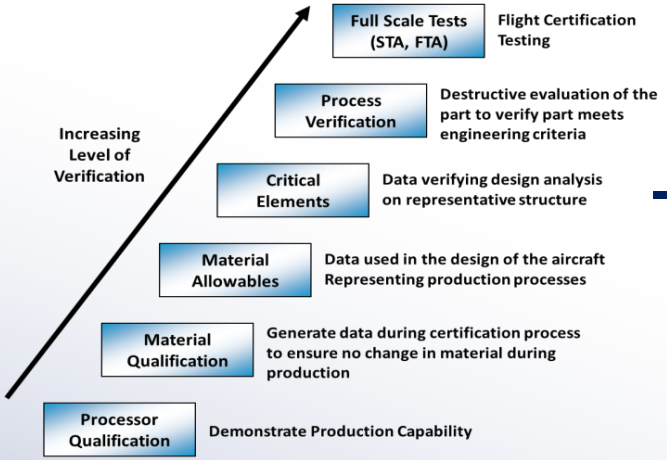
Changing the Paradigm
Accelerated AM Implementation

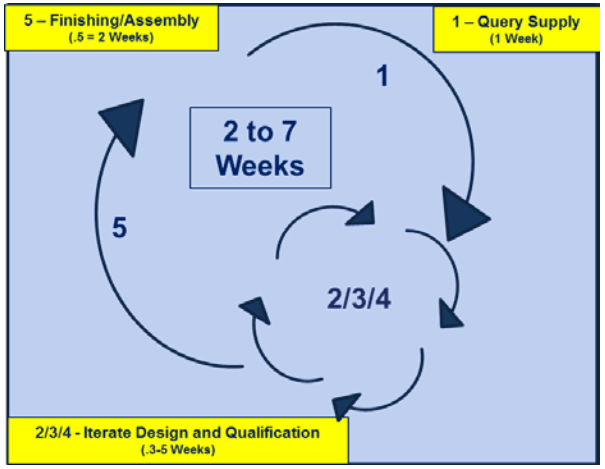
Current Process



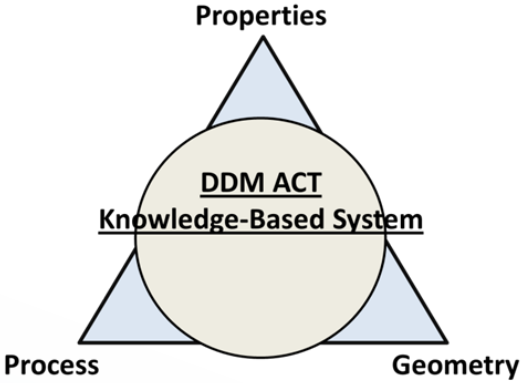
- **Linear Building Block Qualification Process**
- **Engineer Confidence based upon Statistically Substantiated Test Data**



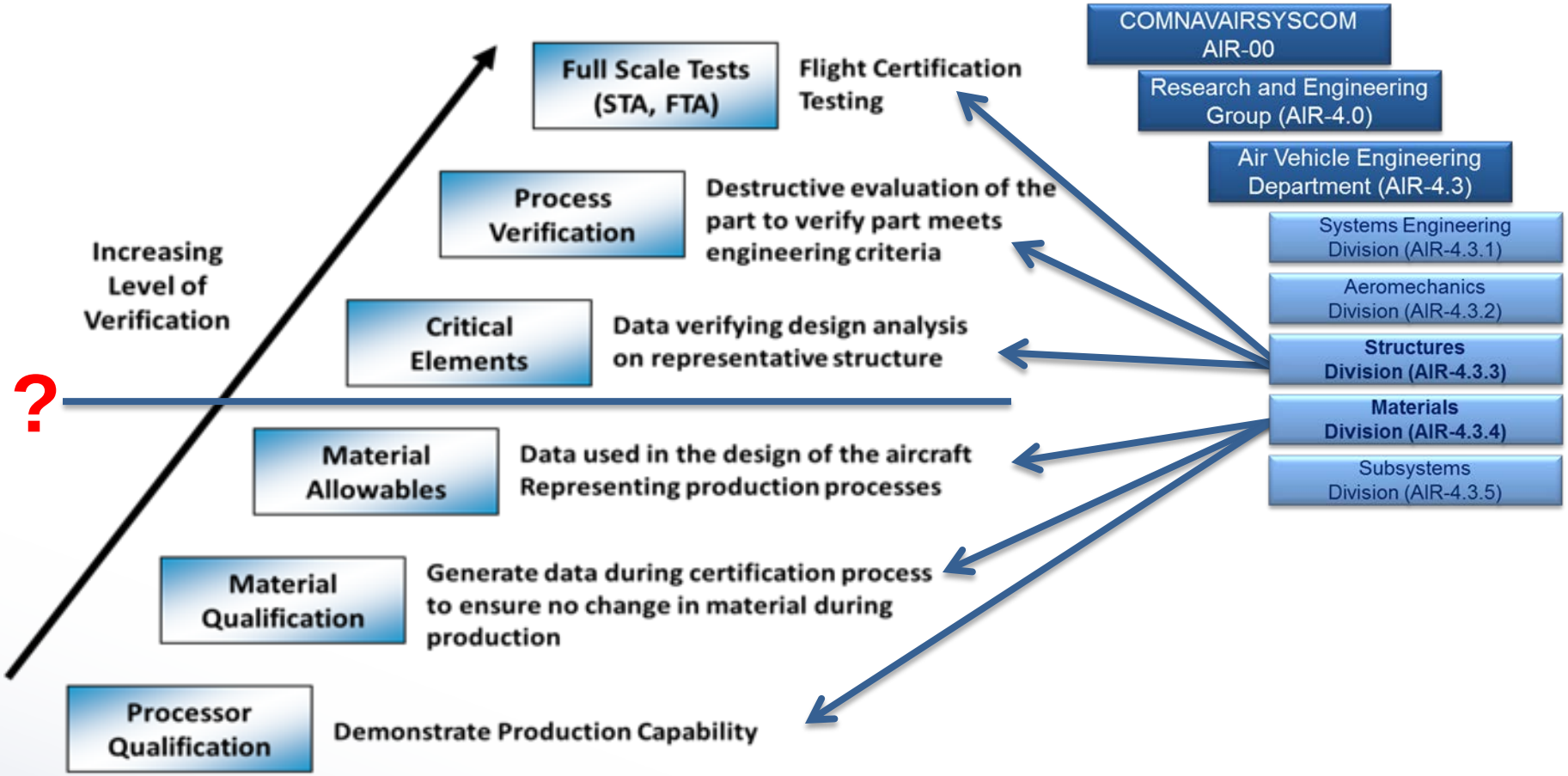
On-demand Vision State



- **Design Process <u>Incorporates</u> Qualification/Certification**
- **Engineering Confidence based upon Validated Integrated Models and Simulation Tools.**

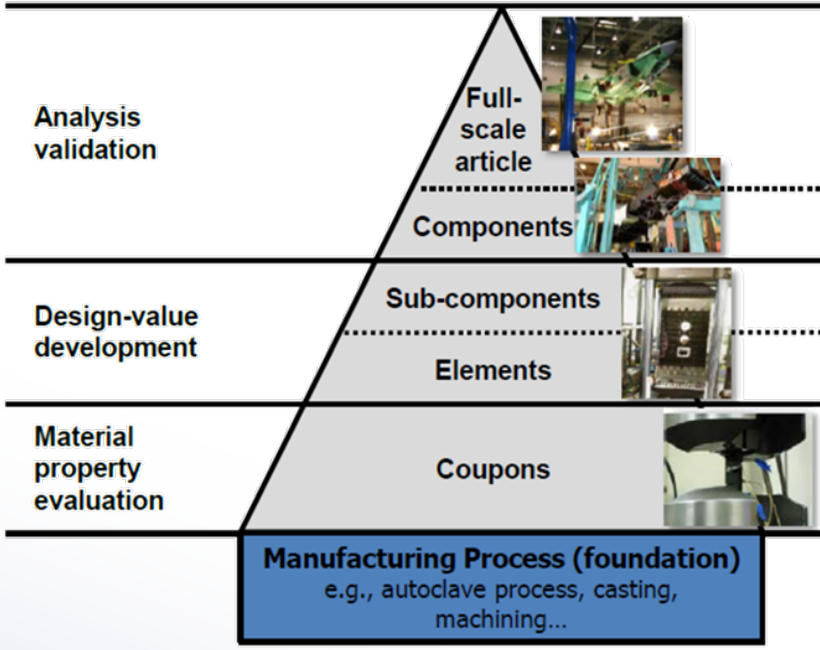


Blending of Materials and Structural Engineering



Major Challenge: Qualification & Certification

- Typical Aircraft Qualification/Certification Path
  - Range is determined by extent of new material, process and technology being introduced; and the amount of iterations.
  - Rotor and UAV platform costs are lower, large transport costs can be higher



	Specimen Count	Cost ($M)	Time (Yrs)
Full-scale article	2-3	100-125	4
Components	10-30	10-20	3
Sub-components	25-50	10-35	3
Elements	2000-5000	10-35	3
Coupons	5000-100,000	8-15	2

Risk of unplanned cost and schedule impacts causes barrier to manufacturing innovation

Ref. Mick Maher, DARPA "Open manufacturing," SAMPE, Nov 13, 2012

Technology Gaps

The following are technology gaps identified in discussion with industry, academic, and other government personnel:

Materials

- Research in emerging AM materials
- Research in existing materials
- Development of AM specific materials
- Multi-material research (material gradients, embedded sensors, etc.)
- Repaired materials

Processes

- Real-time process monitoring
- Equipment control
- Material control
- Modeling
- Integration with other systems (i.e. 3D scanning)

Design

- Design guide for each process
- Printing systems, parts of systems, and assemblies
- Identification of properties that determine when AM should be considered
- AM for design (topology optimization)

Standards and Qualification

- Rapid qualification of parts
- Database of material properties
- Non-destructive evaluation of parts
- Identification of parts that can be made using AM

Data Management

- Database of parts that can be made using AM
- CAD data storage
- Integration of CAD files into COTs software
- Handling of feedback data

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NAVAIR Transformative Goals

- Manufacture and qualify a Flight Critical Component at an FRC with minimal "touch labor"
- Make AM the preferred process for making tools at the FRCs
- Buy AM parts and tooling from DLA and NAVICP
- Manufacture and qualify a flight worthy AM "meta-material" integrating structural and sensor components
- Produce and qualify a rotating component with PHM-capable embedded sensors
- Build an AM printed explosive train with initiating, booster/timing, and main charge elements
- Development cost estimating methodology and should-cost for AM.
- Establish a NAVAIR AM capability for training, prototyping, process development, and standardization of AM.

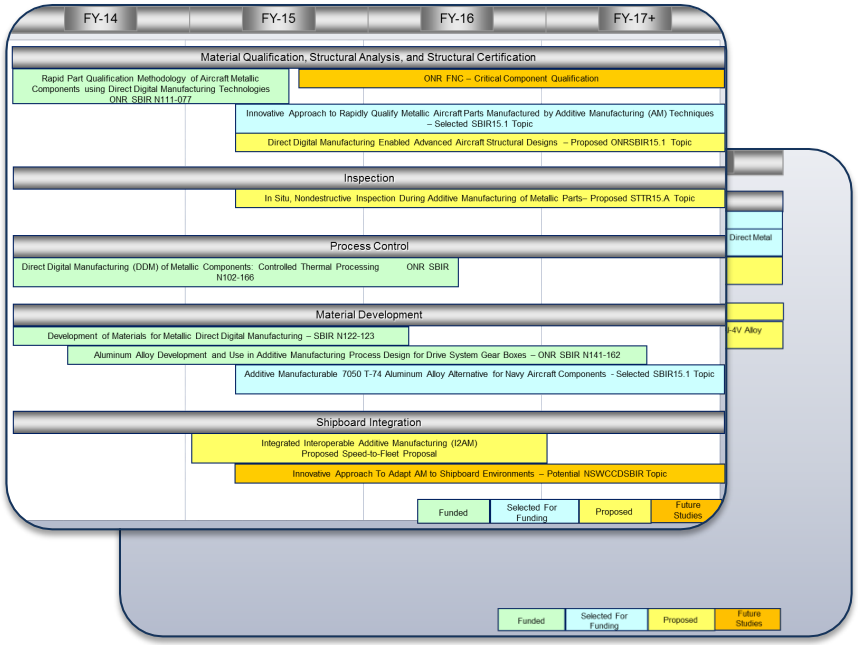
Execute change necessary to rapidly leverage additive manufacturing for delivery of warfighter capability.

Manufacture and qualify a flight critical, non-proprietary component at an FRC with minimal "touch" labor using additive manufacturing.

NAVAIR Initiatives: Additive Manufacturing for Naval Aviation

Portfolio of projects focused on achieving NAVAIR's transformational goals

- Material and Process Qualification
- Structural Analysis, Design and Certification
- NDI
- AM process sensing, control, and modeling
- Digital thread / 3D AM digital environment



Help Needed (What are we asking of Industry)

- Partnerships in achieving NAVAIR's AM goals
  - Align / leverage extant funded work, e.g., IRAD & CRADAs
  - American Makes engagement
- Develop common standards, specifications, and practices, e.g.,
  - Build packages
  - 3D model environment
  - Common acquisition / contracting language.
  - Material allowable database
- AM component realization
  - Part selection, system performance, and ROI assessments
  - Material and process development & characterization
  - Reducing the cost and time of AM part qualification
  - Approaches to reducing sustainment costs
  - Approaches to for optimizing new structural components.

Concluding Remarks

- AM is a disruptive, transformative technology that will profoundly impact NAVAIR.
- We are leaning forward in the implementation of AM in support of naval aviation weapon systems.
- We are more than willing to challenge extant assumptions and paradigms.
- We seek opportunities to partner with you in order to overcome the technical, business, administrative and policy issues limiting AM's full implementation.