Advanced Manufacturing Research Lab (AMRL)

The amount of raw material needed to fabricate a large assortment of repair parts is much too large to be logistically supportable.

AM provides a solution because the raw material is in powder or wire form.

- Thus, we can deposit any geometry if we carry the alloy or non-metallic material in powder or wire.
- The logistical footprint is greatly diminished while the capability is greatly increased.

The AMRL will give AVTB and MARCORSYSCOM the most advanced organic manufacturing capabilities that will:

- Support testing of new and fielded equipment.
  - The Research Lab will facilitate rapid manufacturing of material solutions developed by PdMs, PMs, and equipment users.
    » AVTB is a one-stop shop perfectly situated to design, manufacture, develop and conduct testing, report test results, and conduct follow-on actions required to support Portfolio and Program Managers and their initiatives.
    » Portfolio and Program Managers also face challenges with low demand repair parts that industry will not manufacture or charge too much due to small batch production cost.
- Enable the development of advanced expeditionary manufacturing capabilities that will compliment the supply system that supports the MAGTF.
  - Manufacturing on the Move (MotM)
  - Just In Time (JIT) supply strategy

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The AMRL will occupy spaces at AVTB that currently serve as the machine and weld shop. No new facilities are required. The 5 axis mill and multi-axis mill turn come with custom concrete footings and electrical installation.
Intro to Hybrid

• The metal additive manufacturing (AM) market is growing fast, leaving a $1B mark last year with expectation of $6B by 2026.
  – The two most common technologies are Powder Bed Fusion (PBF), whereby layers of powder are sequentially deposited on a build platform and locally melted by laser or electron beams, and Direct Energy Deposition (DED), whereby a nozzle ejects feedstock which is consolidated under a variety of forms of energy.
  – Both technologies enable near-net shape manufacturing, although they are both plagued by poor surface finish and the need to remove complex support structures. These issues are generally solved by finishing via subtractive technologies, e.g. CNC milling or lathe turning.
  – Hybrid manufacturing is a technology that has emerged in the past 5 years, which consolidates DED with SM methods (CNC machining) in a single piece of equipment. The result is the fastest and largest capable metal 3D printing technology featuring superior material properties, precision, and surface finish.

• Pairing AM and SM, AVTB will be able to leverage the latest technologies together with post manufacturing equipment to provide an organic manufacturing capability that will allow: the manufacturing of OEM compliant parts, fabrication of test support equipment, and participation in the development of expeditionary manufacturing capabilities.
Three AM Deposition Technologies

- **Wire-Arc**
  - 3D Hybrid Solution Inc’s patent pending wire-arc tool is built upon a sophisticated electrical discharge technology that is enhanced for long duration, controlled additive manufacturing processes in a CNC machine. Wire-arc technology enables printing a wide variety of feed-stock alloys in wire form. Integral to the wire-arc technologies’ success is the mechanism that results in low heat input. It is available for integration to CNC machines in two forms, as a manual tool change tool and a parallel mounted automatic tool changed deposition head.
  - The wire-arc process offers a variety of printable metal alloys including many steels, nickel based alloys, and non-ferrous metals.

- **Laser-Powder Fed**
  - The laser-powder deposition technology is a common metal additive manufacturing technology also used for processing a wide range of metal alloys. The laser-powder tool will be able to process a variety of metal feedstocks that are available in powder form. Alloys include: steel, stainless steel, nickel super, stellite (cobalt chrome), and many others. In addition to offering a metal additive manufacturing capability, the technology is matured for advanced coatings and laser surface hardening of shafts and journal ways.
  - The laser-powder deposition technology will be equipped with multiple beam profiles for advanced processing capability in different beam track-widths. This added capability will enable printing fine features that might be required in smaller geometries but also bulk deposition capability for high rate additive manufacturing.

- **Cold Spray**
  - Particles are projected at supersonic speeds in a carrier gas (nitrogen, air, or helium) and impact the surface, relying on kinetic energy to deform upon impact. Since there is no melting, this process lends itself to utilization of several alloys that fail from the melting-solidifying phase changing process. The reasons from failure are commonly associated with over-stressing the material and air-contamination by oxygen and nitrogen.

- **Laser-Assisted Cold Spray**
  - The laser-assisted cold spray process is much the same but with an addition of a laser in front of the cold spray head. The laser softens the base material to alloy the impacting particles to more easily join. This increases the efficiency of the process by both increasing particle attachment and enabling lower pressure processing (lower gas consumption). For the long term goal of a mobilized capability, this is promising because nitrogen can be extracted with nitrogen generators.
  - There are some metal alloys that resist printing from a phase changing melting process like wire-arc and laser-powder fed; this is where the laser-assisted cold spray additive manufacturing process can fulfill and achieve great material flexibility. The system is based on a gas-efficient low pressure cold spray technology coupled with a laser assist. The laser assist is what enables a lower pressure cold spray head to effectively reduce the operating costs from gas consumption and increase the material varieties in materials that are unable to impact and deform from high brittle cracking. The lower pressure head also enables CNC integration because of the smaller size.
Equipment

- 5 axis Vertical Mill
  - Hermle C650
  - 35.4” diameter x 23.6” height x 3306 lbs workpiece
  - X, Y, Z axis travel: 31.5” x 45.2” x 29.5”
  - A axis travel: ±120°
  - C axis travel: 360 °
  - 18,000 rpm spindle
  - 42 tool automatic tool changer
  - Made in Germany
  - Comes with 3 year warranty and one spindle replacement
  - Comes with cement foundation, electrical installation, training, and setup
  - Wire-Arc Deposition
  - Laser-Powder Fed Deposition
  - Laser-Assisted Cold Spray Deposition

- 5 axis Mill-Turn
  - Doosan PUMA SMX 2600 ST w/ lower turret
  - 25.9” diameter x 60.6” length workpiece
  - 4,000 rpm lathe spindle
  - 12,000 rpm mill spindle
  - 80 tool automatic tool changer
  - Made in South Korea
  - Comes with 3 year warranty and one spindle replacement
  - Comes with cement foundation, electrical installation, training, and setup
  - Wire-Arc Deposition
  - Laser-Powder Fed Deposition
Equipment

• Ancillary Equipment
  – Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) software
    • PowerMill for SM on the 5 axis mill and AM on the 5 axis mill and mill turn machine.
    • FeatureCAM for SM on the mill turn machine.
  – Laptop Computers optimized for 3D model rendering and handling complex tool paths.
  – Computer Server to handle networking of machines and to serve as storage for manufacturing files.
  – EROWA Workholding System reduces job setup time and increases repeatability.
  – REGO-FIX Tool Holder System allows for quick changing of cutters via a press collet system that is superior to conventional and thermal set tool holders.
  – Tooling and other work holding – carbide cutters in all shapes and sizes to handle the hardest metal and produce the finest finishes. Hard and soft jaws are required to hold complex geometries with the rigidity required for aerospace tolerances.

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Equipment

- Post-manufacturing equipment
  - Industrial Ovens for heat treating metal alloys are used to attain the required material properties. Aluminum requires a drop tank included in the heat treating cycle. Other metals can be heated all the way to their upper critical temperature if needed using a dual furnace with multi-step control. Some material properties are attained through liquid baths and tempering in a tempering oven.
Equipment

• Inspection Equipment
  – High quality precision measuring equipment are required to inspect parts to validate set-up and geometries.
  – T-SCAN 20 - SCAN laser scanner is a complete solution, achieving a new dimension in coordinate measuring technology. Tracking camera, hand-held scanner and touch probe system offers maximum flexibility for many different applications. Ensures a consistently efficient and project-oriented workflow during the entire measuring process.
  – GEOMAGIC – This is a portable 3D scanner that will be used to fabricate test support equipment and manufacturing efforts not tied to programs of record.
  – Hardness Testers are used to immediately identify material properties prior to qualification testing.
Equipment

• Thermoplastic and advanced nylon AM
  – (6) Prusa i3 MK2 3D
    • Prints any thermoplastic including PETG, PLA, soluble support, nylon and polycarbonate with multi-material head. 9.8” x 8.3” x 8.3” build volume. These machines will be used for geometry verification and for applications that are not related to programs of record.
  – (3) Markforged X7 3D
    • The X7 delivers breakthrough quality and precision in 3D printing. The top-of-the-line industrial grade platform features a strengthened dual nozzle print system that supports Onyx, Tough Nylon, Fiberglass, Continuous Carbon Fiber and Kevlar reinforcement. Laser inspection scans parts mid-print to ensure dimensional accuracy for the most critical tolerances. 13” x 10.6” x 7.9” build volume. It is capable of printing parts stronger than machined aluminum for a fraction of the cost, the X7 delivers unparalleled surface finish, build size, and reliability.
Personnel Required

• Personnel
  – AMRL Chief
    • Metallurgical testing and qualification
    • Can operate all equipment
    • Responsible for the quality of parts manufactured in the AMRL
  – 5 Axis CNC Programmer and Operator
    • Responsible for the programming, operation, and care of the 5 axis mill
    • Responsible for conducting post-manufacturing requirements laid out by the AMRL Chief
  – Multi-Axis Mill Turn Programmer and Operator
    • Responsible for the programming, operation, and care of multi-axis mill turn
    • Responsible for conducting post-manufacturing requirements laid out by the AMRL Chief
  – Materials Engineer PhD
    • Process development
    • Qualification of recipes
Phase 1

• This phase begins when the wire-arc deposition is operational on the 5 axis mill. (Approximately 8 weeks after funding)

• Critical repair parts with long lead times will be chosen to focus initial efforts.
  – The alloys for these parts will be ordered from the metal powder and wire manufacturer.
  – Design of Experiments will be conducted to produce samples that will be deposited and heat treated in diverse ways.
    • Qualification Process
      – These samples will be sent to the material analysis lab where the output will be a characteristics data report for each sample.
      – These data reports will then be sent to material engineers who will compare the results of the samples with the required characteristics for the specific alloy to determine if specifications are met.
        » If specifications are met, the deposition and post-manufacturing process for the successful sample will be captured as the “recipe” for that alloy.
        » If specifications are not met, further sample will be produced and the qualification process will begin again until a successful recipe is qualified.

• This phase will be an enduring requirement when new alloys are required for manufacturing.
Phase 2

• This phase begins when a recipe is qualified (Approximately 18 weeks after funding)
• Once a recipe is qualified, the drawing will be converted to a 3D CAD model.
  – CAM software will be used to make the toolpaths and to produce the “G Code” for the mill or mill turn.
  – The operator will load the tools in the machine, prepare the machine, and run the AM and SM program.
• Inspection Process
  – Once a part is finished with the deposition and SM process, post-manufacturing procedures based on the recipe will be carried out.
  – After all manufacturing processes are complete, geometry inspection will be conducted to verify the manufactured part against the engineering drawing for the part using inspection equipment and advanced 3D scanners.
    » If all specifications are met, the manufactured part and a supply system furnished part will be delivered to the end item manager for approval.
    » If specifications are not met, discrepancies will be identified and processes will be modified to correct discrepancies.
• The output of this phase is manufactured parts to exact OEM specifications that are indistinguishable from supply system furnished parts and approved for use by proper authority.
Phase 3

• This phase begins after confidence in the AMRL and the advanced manufacturing process is attained. (Approximately 9-12 months after funding)

• AVTB will qualify all alloys and materials supportable and new alloys that AM technologies unlock for use that were either cost prohibitive or unworkable due to geometric constraints.
  – AVTB will provide all available customers with alloys and materials that can be utilized to manufacture new parts or old parts with new materials and build volume capabilities.

• Machine Learning and Generative Design will fundamentally alter the way new items are designed and engineered.
  – Any given design developed through traditional means is essentially an engineer’s best guess of how to solve a problem.
    » With generative design, you tell the computer: “I don’t know the solution, but I do know how to frame the problem.” You start this process by capturing constraints (such as loads or mounting points) and establishing preferences (such as weight, safety factors, and manufacturing techniques). From there, generative design explores every geometric option, returning hundreds (if not thousands) of options based on materials, manufacturing processes, and performance requirements. You can decide which options make the most sense for your project.
    – Example: Airbus teamed up with AutoDesk to produce cabin partitions that are stronger than the original and half the weight.

• This phase will be an enduring effort based on PdMs, PMs, and equipment users identification of discrepancies that can be solved with material solutions and the AMRL delivering those solutions.
Phase 4

- This phase begins after the AMRL has manufactured a broad assortment of parts, catalogued recipes, and has a thorough understanding of the equipment required to manufacture. (Approximately 14-24 months after funding)

- Manufacturing on the Move (MotM) Labs
  - Four sizes of labs will be proposed.
    - One for navy ships that support the MAGTF. One sized for MEFs. One sized for MEBs. One sized for MEUs.
      - These MotM Labs will be configured to utilize existing bed space and transportation equipment already allocated for fabrication equipment.
        » The equipment required for the labs will be redesigned by the equipment manufacturer IOT ruggedize, miniaturize, and use expeditionary power.

- This phase will end when each size lab’s proposal is submitted for consideration.
Questions