AML

Reimagining the Magnet Technology that Drives the World

PM-Wire™ Magnets: Thinking Outside the Block!

Advanced Magnetics & Manufacturing

Rare Earth Mines, Magnets & Motors 2025

Find us on social media

Wade Senti

President of AML

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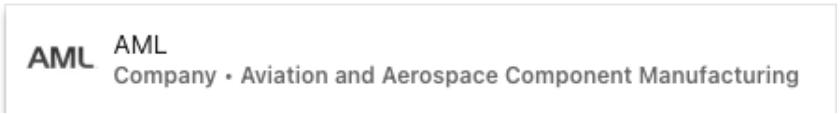


Our Company

World-Class Magnet Technologies

AML was founded on principle of developing world-class magnet technologies that solve complex application needs.

- ✓ Significant IP and software portfolio, trade secrets, and knowhow for designing and producing permanent magnets.

AML facilities located on Florida's Space Coast Melbourne, Florida

Magnet Technologies + Advanced Manufacturing

AML combines its magnet innovation with advanced manufacturing capabilities.

- ✓ AML's team has decades of experience with advanced manufacturing solutions, including leading significant growth transitions.

AML expansion plans include additional facilities in Florida and co-location with strategic partners

Funded to Scale – $15M to date

AML has contributed $8.5M along with $1M from strategic sources combined with $5.5M from the U.S. federal government towards commercialization.

- ✓ AML has drawn significant interest from the REE supply chain, private investors, and the federal government to solve the magnet problem.

Leadership

Management

Wade Senti, President, Director

- Lead all of AML's major transactions and supported $10M + strategic capital to date, responsible for corporate, financial, customer relationships, and strategic affairs.
- 15+ years of experience in finance, transactions, and business strategy.
- Bachelor of Science in Accounting (BSAc) from the University of Florida.

Philippe Masson, Chief Technology Officer

- Co-inventor of most of AML's game-changing permanent magnet technologies and responsible for leading AML technology development and customer programs.
- 20+ years of experience developing superconducting applications and permanent magnet technologies.
- Ph.D. in Electrical Engineering from the Université Henri Poincare, Nancy, France.

Board of Directors

Mark Jensen

- Entrepreneur and businessperson who has founded several companies.
- Chairman and CEO of American Resources Corporation (NASDAQ: AREC) a next generation producer of raw materials.
- Mr. Jensen previously held positions in the financial services and investment sector.

Bill McCollum

- Dentons, Partner - Public Policy and Regulation.
- Former Florida Attorney General.
- Retired U.S. Congressman.
- Retired commander in the U.S. Naval Reserves.

Raj Gutta

- Serial entrepreneur, investor, and medical doctor.
- University of Michigan undergrad and medicine.

Tom Turner

- 40+ years developing, operating and exiting high-tech businesses.
- Companies included Wang Canada Limited, Datamax Corp. and Itronix.
- Currently active in a number of early-state companies and a partner / developer of a new sustainable City in Costa Rica.

Marshall Heard

- The Boeing Company (ret.), Ran a $4B Division.
- Engineering, product development, and operations.
- Air Force Strategic Air and Systems Command.

Vernon Prince

- 30 + years, entrepreneur, executive
- Multiple advanced manufacturing operations
- Luminar Technologies, JDS Uniphase
- Founded/Exited - OPA

Recent Strategic Engagements

U.S. Defense & Aerospace Company

- ✓ **2020 – 2021:** Provided funding for expanded development work with AML's magnet technology and partnered on application development.
- ✓ Development work led to magnets with "continuously changing magnetization direction" (single-piece Halbach array) using bonded NdFeB material compositions.

U.S. Department of Defense / Defense Innovation Unit

- ✓ **2020 – 2022:** Provided funding for the design, build and commissioning of innovative Pilot Manufacturing Process.
- ✓ Program objective – design, build and initial commissioning of an advanced PM-Wire™ Pilot Manufacturing Line for production of non-sintered magnets

U.S. Department of Defense / Defense Logistics Agency

- ✓ **2022 – 2025:** Project Title: "Development and Qualification of Domestically Sintered Neodymium Iron Boron (NdFeB) Magnets for Weapons Platforms."
- ✓ The objective was to qualify sintered PM-Wire™ magnets and to design, build and commission advanced manufacturing for sintered PM-Wire™.
- ✓ Program objective – develop sintered PM-Wire™ magnet configurations using NdFeB compositions – acquisition of equipment and facilities upgrades.

U.S. Department of Energy / ARPA-E ASCEND

- ✓ **2021 – 2025:** Project Title: "High Power Density Dual-Rotor Permanent Magnet Motor with Integrated Cooling and Drive for Aircraft Propulsion."
- ✓ Patented dual-rotor based on non-sintered PM-Wire™. Specifications provided by large U.S. aerospace and defense company.
- ✓ Program objective – a development collaboration with Florida State University and AML for the design and proof of concept.

U.S. Navy Nuclear Laboratory

- ✓ **2021 - Present:** Designed, commissioned and tested and superconducting / permanent magnet bearing system and other work and projects related to permanent magnets applications and sourcing/qualification.

Our Customer Base

Applications development – We've done 100s of design studies to date

Motor and Generator Applications

AML is working with major motor and generator firms to unlock new performance value and smart supply chain strategies.

Consumer Electronic Applications

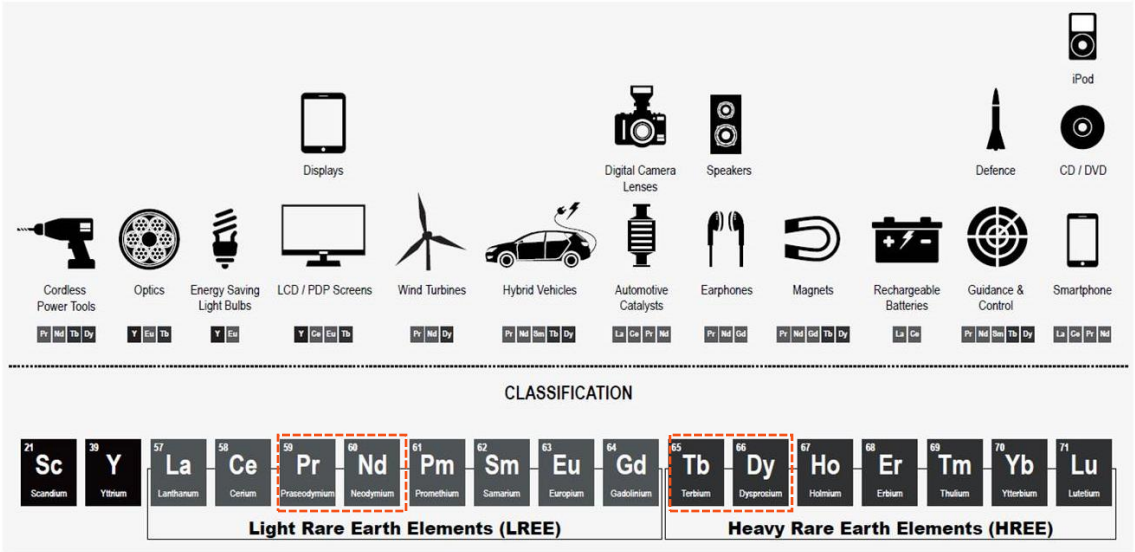
Data storage and other emerging applications are driven by the AI and quantum revolution – need for alternatives is a rapidly growing market.

Defense and Aerospace Applications

AML is engaged with firms developing motor and generator applications for defense.

Other Applications

Medical, robotics, automotive, and others.



Source: China Water Risk report, "Rare Earths: Shades Of Grey – Can China continue to fuel our clean and smart future?" (June 2016)

We are working to remove the constraints of a Neodymium, Praseodymium, Terbium and Dysprosium driven magnet supply chain.

Our Competitive Difference

What separates AML from the rest?

To compete in the United States with global market – you must be able to produce high volume, cost-competitively, and add product value. ***AML can do all three.***

Ideal magnetic distribution, single-piece “Halbach Arrays”, long-lengths with the ability to design in shapes and curvatures that provide applications expanded benefits, including building a magnet around less REE (or non-REE) material attributes.

	AML	Other Magnet Mfg’s
Magnet design	Shapes, sizes, lengths, different magnetizations	Block magnets, magnetized in one direction
Equipment & Capabilities	Automated by design, incorporating standard equipment	Standard equipment for sintered manufacturing with some automation
Manufacturing Processes	High-rate, high yield, automated by design, flexible, and lower capex	Laborious, rigid, non-interchangeable, higher capex
Supply Chain	All magnet materials REE, Non-critical REE, REE-Free	REE - Neodymium Iron Boron REE – Samarium Cobalt

AML PM Magnets

Conventional Sintered Magnets

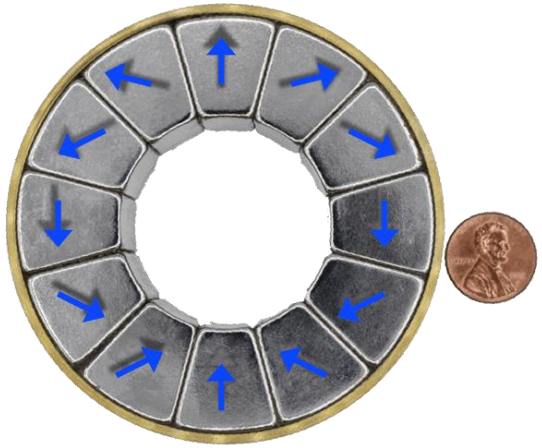
NdFeB Sintered Magnets

AML

NdFeB are usually produced as uniformly magnetized blocks.

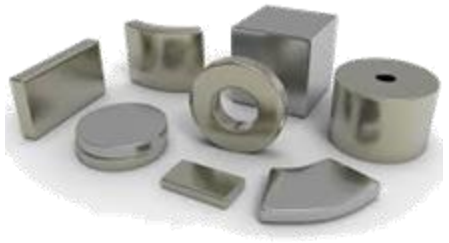
- ✓ Magnets need to be cut from blocks
- ✓ Designers are limited to small magnets with single magnetization directions
  - Design space constraints for the applications
  - Need to combine multiple magnets to achieve variable magnetization directions (expensive tooling)
  - Need high-grade magnets to prevent demagnetization
- ✓ “Single size” fits all approach

Magnet blocks during manufacturing



Halbach array composed of uniformly magnetized blocks

Synchronous motor rotor with surface-mounted magnets



COTS magnets

PM-Wire™ Manufacturing Process – Powder-In-Tube Process

(1) Powder is placed in a cylindrical or square tube

(2) Powder is pre-aligned using a magnetic field

(3) Filled tube is sized, leading to compression and cross-section reduction

(4) Swaging, rolling to further reduce cross-section, increase density, and obtain the desired shape

(5) Sintering-Annealing-Aging
cutting, grinding, coating

(6) Final magnetization

PM-Wire™ Manufacturing

AML

PM-Wire Magnet Manufacturing

Example of High-Rate Magnets Production Line
Partially funded by U.S. Department of Defense / Defense Innovation Unit

Sintering furnace

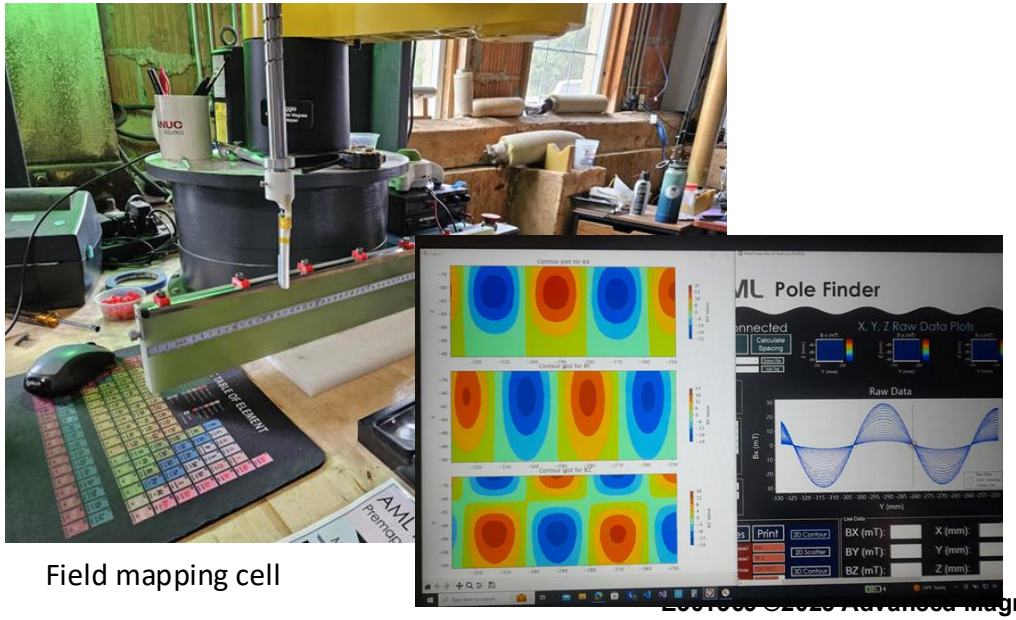
Automated Tube filling in inert environment
Partially funded by U.S. Department of Defense / Defense Logistics Agency

Sintered Magnets Lab
Partially funded by U.S. Department of Defense / Defense Logistics Agency

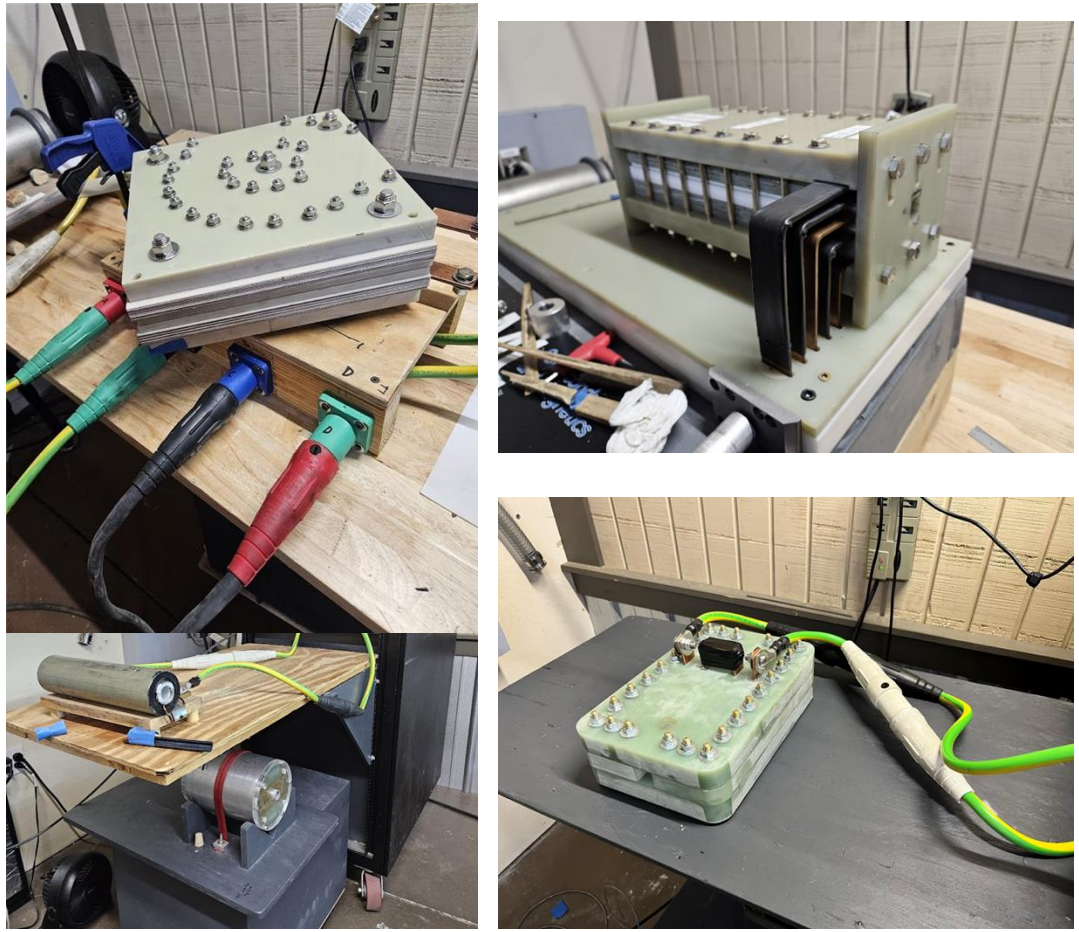
Magnetization

AML has developed custom pre-alignment and magnetization fixtures to achieve useful magnetization configurations

- ✓ Axial for straight and curved magnets
- ✓ Radial for rings and curved magnets
- ✓ Uniform for long straight magnets and large blocks
- ✓ PM-360 (single piece multipole)
  - Radial inward and outward flux
  - Axial flux



Field mapping cell



Example of custom magnetization fixtures

PM-Wire™ Process for Sintered Magnets

AML

Only 1 step requires an inert environment

Flexible shapes

- ✓ Long straight magnets
- ✓ Curved magnets

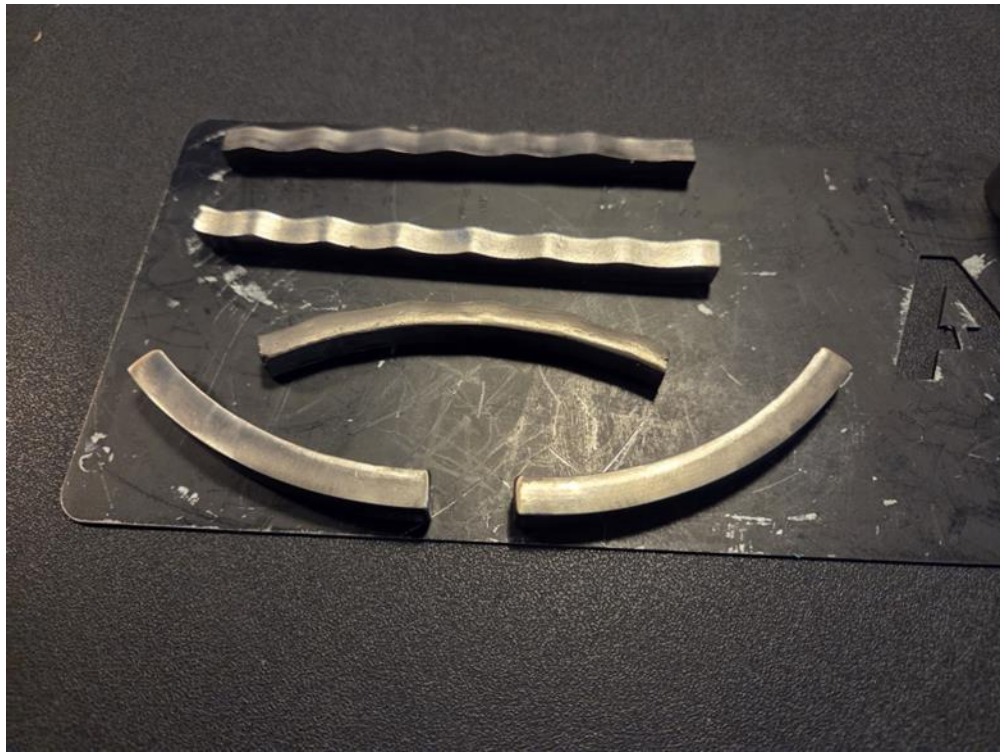
Flexible magnetization directions

- ✓ Radial
- ✓ Axial
- ✓ Continuously changing (**PM-360™**)

Opens the design space for applications

- ✓ Applications no longer constrained to small uniformly magnetized block magnets

6-pole single-piece NdFeB magnet (PM-360™)

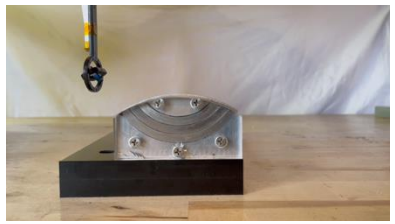


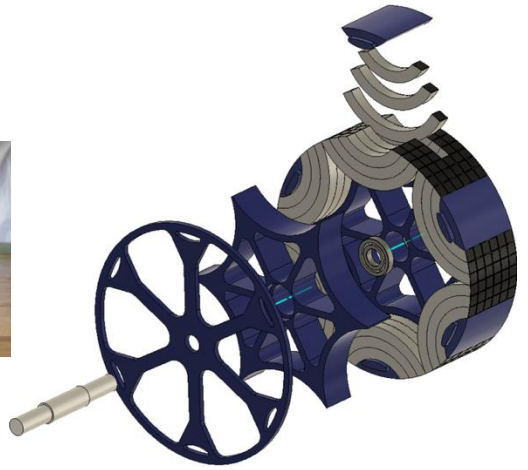
Examples of axially magnetized wound magnets (PM-Axial™) and multipole magnets PM-360™)

Why PM-Wire Magnets Matter?

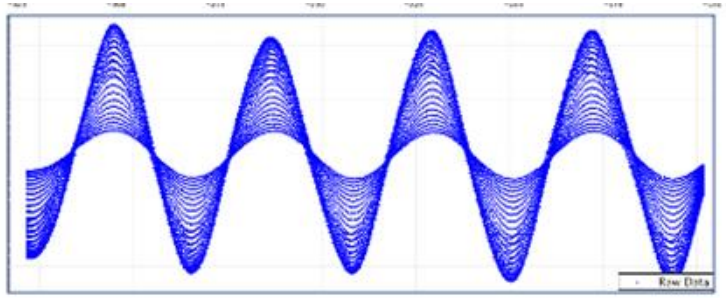
Flexibility in magnet shape and magnetization direction opens the design space for the applications and <u>smart design</u>:

- ✓ Minimize demagnetization
  - Allows operation at higher temperatures
  - Enables the use of lower coercivity magnets (**<u>less REEs, nor Heavy REEs</u>**)
  - Enables new designs and topologies
- ✓ Generate multiple poles from single magnets
  - Significantly reduce the number of parts/magnets
  - Simplify assembly: no tooling needed
  - Enhance the field magnitude
  - Produce sinusoidal fields (no space harmonics)
  - Enable the use of lower Br magnets

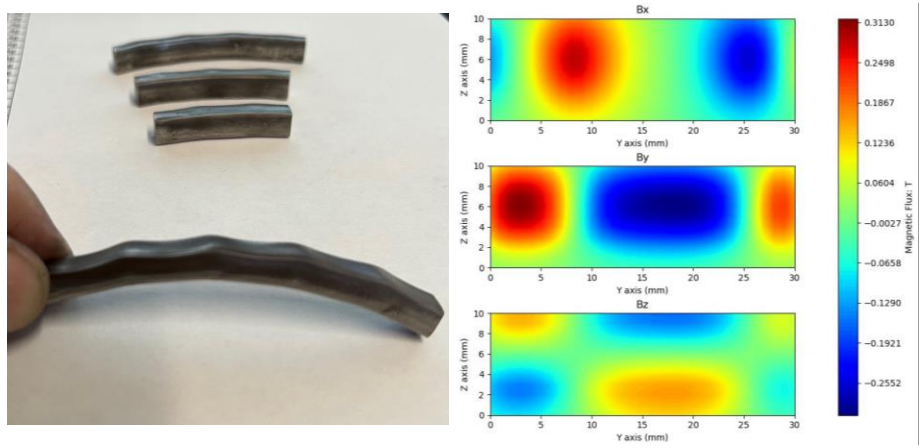




PM-Axial rotor configuration: demagnetization field < 0.15 T in the rotor magnets!



Magnetic field measurements of the field produced by a PM-360™ magnet



Example of curved sintered PM-360™ magnets

Example of Use of PM-Axial™ Magnets – Global Electrical Machine Manufacturer AML

Baseline Design

Torque - 311 Nm; Efficiency - 98.6%; Power - 375 kW; RPM - 11,500

Magnet Material: N48SH NdFeB

Maximum Operating Temperature: 100 C

Critical REEs: NdPr and Dysprosium

PM-AXIAL™ Impact – Significant Improvement In Performance

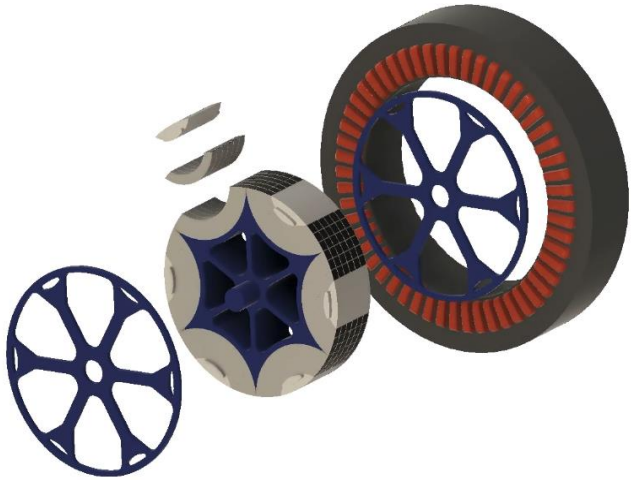
Solution

- ✓ Retrofit solution replaced conventional surface-mounted magnets topology with PM-AXIAL™
- ✓ No change to stator
- ✓ Same magnet N48SH NdFeB alloy

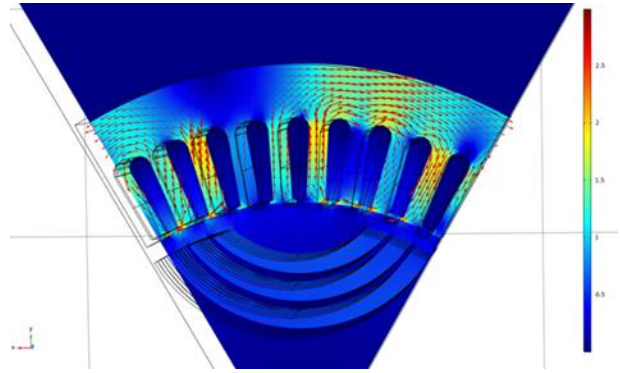
PM-Axial™ Performance Improvement

- ✓ Field enhancement
- ✓ Increase in operating temperature to over 150 C
- ✓ Reduction in rotor overwrap thickness
- ✓ 20% reduction in mass by removing the iron

Baseline Design – Conventional north-south pole rotor configuration



PM-AXIAL™ - Provides very-low demagnetization field (~ 1/10 of conventional north-south pole configuration)



Magnetic field distribution in 1 pole of the motor

Example of Use of PM-Axial™ Magnets – Global Electrical Machine Manufacturer AML

PM-AXIAL™ Impact – Reduced Critical REE

Solution

- ✓ Retrofit solution replaced north-south rotor pole topology with PM-AXIAL™
- ✓ No change to the stator
- ✓ **(Mischmetal / NdPr) NdFeB** alloy
  - Br and Hci (@ 120 C) = 1.01 T and 2.85 kGauss

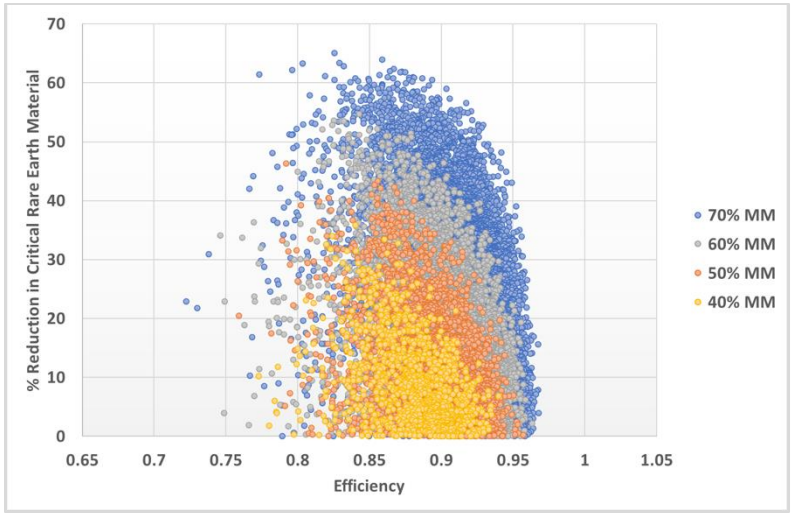
PM-Axial™ Performance

- ✓ Equivalent torque and efficiency
- ✓ 37% reduction in critical REE (**NdPr**) and **no dysprosium**
- ✓ 11% reduction in active mass

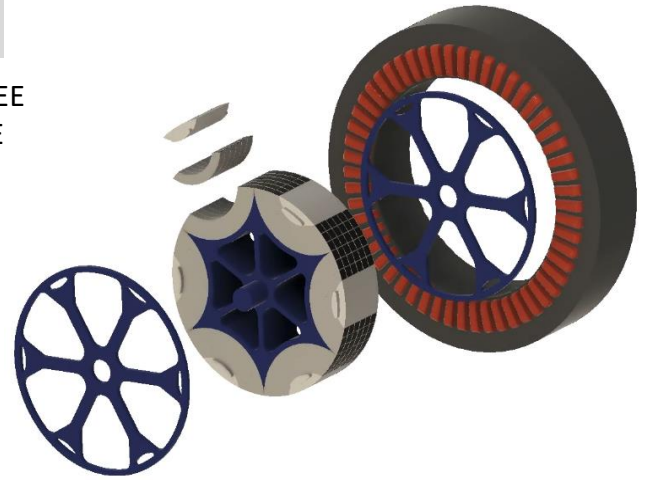
NdPr - ~ $70 per kilogram

Mischmetal - $lower per kg
(Cerium, Lanthanum, Neodymium, Praseodymium)

Mischmetal reduces the cost of REE separation and can provides REE provenance of NdPr oxides



Example of Reduction in critical REE materials vs. efficiency



PM-AXIAL™ - Provides very-low demagnetization field (~ 1/10 of conventional north-south pole configuration)

AML's Other Sintered Magnets

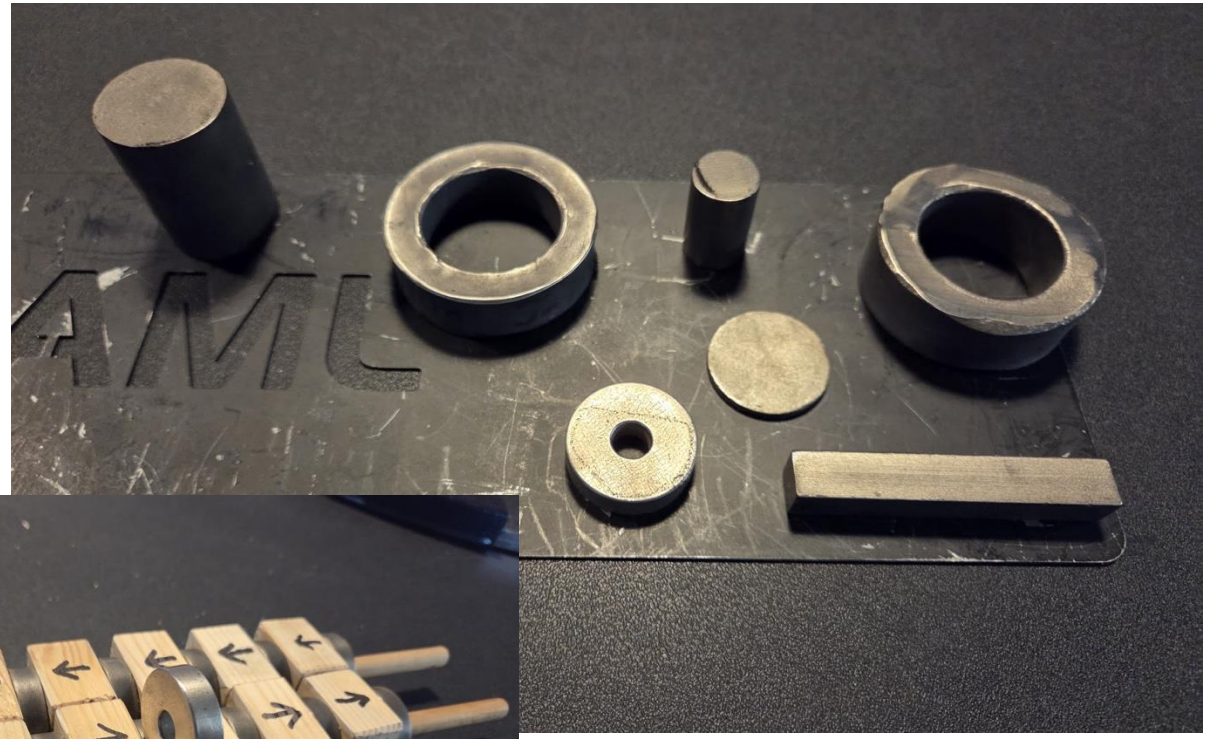
Conventional magnet shapes

- ✓ Blocks, cylinders, "donuts", rings

Uniform magnetization

- ✓ Radial
- ✓ Axial
- ✓ Transverse

Produced in long lengths close to final cross-section or close to final shape



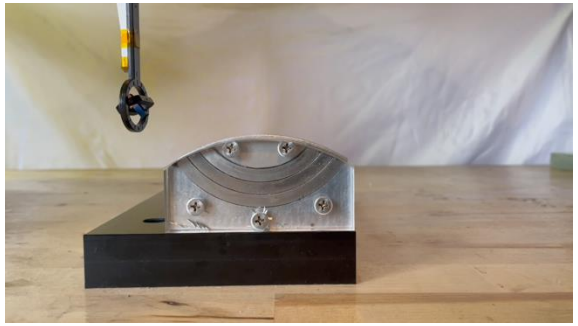
Example of different sizes and shapes NdFeB magnets produced at AML

Example of NdFeB magnets produced at AML

PM-Wire™ - Material Enabler

Materials

- ✓ SmFeN
- ✓ NdFeB
- ✓ MnBi
- ✓ MnAlC
- ✓ FeN
- ✓ Other



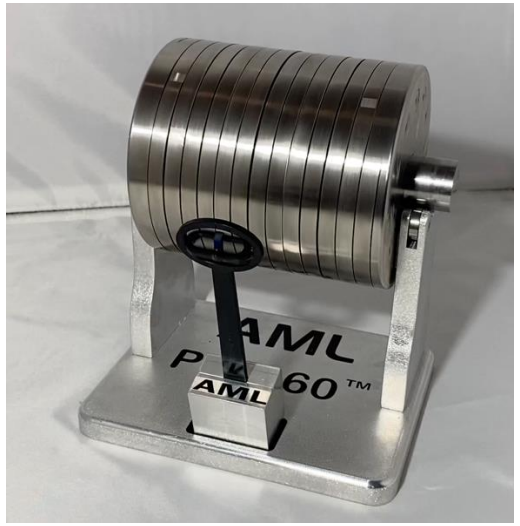
PM-AXIAL™ Magnets

PM-UNIFORM™ Magnets

PM-360™ Magnets

Engineering magnets

- ✓ Custom shapes
- ✓ Custom magnetization direction
- ✓ Strong: strength of Stainless steel
- ✓ No cracking, no chipping
- ✓ No corrosion (magnets sealed in jacket)



PM-360™ Radial Flux Rotor

PM-360™ Outrunner Rotor

PM-360™ Axial Magnetization

Example of PM-360™ Applications in Motors

Motor Specifications

Collaboration with the Oak Ridge National Laboratory

U.S. Department of Energy: Power - 58 kW; RPM - 20,000

PM-360™ Impact – EV Motor With Non-Sintered Alloy

Solution

- ✓ Retrofit solution replacing Halbach rotor topology with PM-360™
- ✓ Replacing **~2,750** NdFeB thin sintered magnets with **8 PM-360™ rings**
- ✓ **SmFeN**
  - Br and Hci (@ 80 C) = 0.9 T and 14 kOe

PM-360™ Performance

- ✓ Equivalent torque and efficiency
- ✓ Significantly reduce part count and complexity of assembly
- ✓ Lower eddy current losses
- ✓ A fraction of the cost compared to sintered complex Halbach array design

PM-360™

Halbach Array

PM-360™ Impact – Enable the use of SmFeN

Torque - 311 Nm; Efficiency - 98.6%; Power - 375 kW; RPM - 11,500

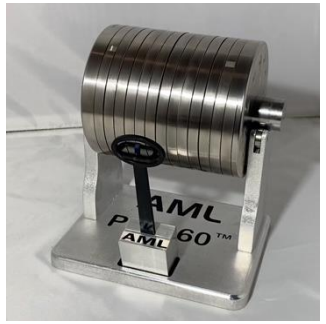
Maximum Operating Temperature: 100 C

Solution

- ✓ Retrofit solution replaced north-south rotor pole topology with PM-360™
- ✓ No change to motor stator
- ✓ **No Critical REE - Samarium Iron Nitride (SmFeN)** alloy
  - Br and Hci (@120C) = 0.88T and 11.5 kGauss @120C
- ✓ Replace 168 sintered N48SH magnets with **10 PM-360™ rings**

PM-360™ Performance

- ✓ Equivalent torque and efficiency
- ✓ 10% reduction in active mass
- ✓ No NdPr or Dy



PM-360™ - Helical

PM-360™ - Ten (10) Helical Rings replacing 168 sintered magnets

Qualification of “Non-Sintered” PM-360™

PM-360™ - “Single-piece Halbach Array”

Straight, ring or helical magnets with “Continuously Changing Magnetization Direction”

Materials

NdFeB – NeoMagnequench, Aichi Metals
SmFeN – Sumitomo Metal Mining, Nichia
MnBi - AML

Lower Cost Assemblies

Reduced part count
Easy to assemble

Stability

Tube filled in an inert environment: the powder is sealed in tubes before compaction: → No Corrosion
Mechanical strength of Stainless Steel
Magnets can deform without cracking or breaking
Magnets cannot chip
PM-Wire process ideal for mass production

Example of PM-360™ Magnet assembly for axial flux motor.

PM-360™ Motor during testing

Supply Chain

NdFeB (sintered)

- ✓ Produced at AML (Oxides to magnets)
- ✓ AML has relationships with domestic (US) suppliers for oxides and metals
  - ReElement, Phoenix Tailings, RER, LCM

MnBi

- ✓ Produced at AML (currently R&D only)
- ✓ AML has a relationship with Mn and Bi suppliers

AML
MnBi material processing

FORTUNE MINERALS LIMITED
Bismuth mine

SmFeN

- ✓ Mainly produced in Japan – NICHIA and Sumitomo
- ✓ AML has a relationship with both suppliers

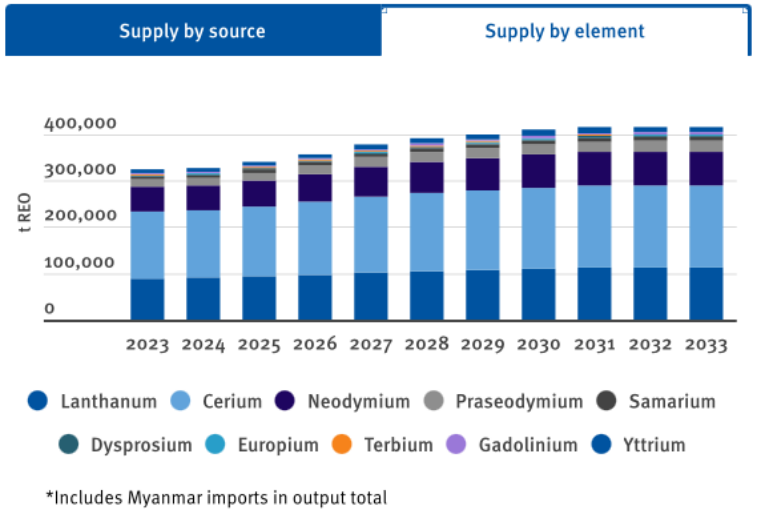
NdFeB (anisotropic powder)

- ✓ Produced in Japan: AICHI Metals, and China: NeoMagnequench
- ✓ AML has a relationship with both suppliers

AML invites new opportunities for strategic relationships for sourcing oxides, metals, and alloys.

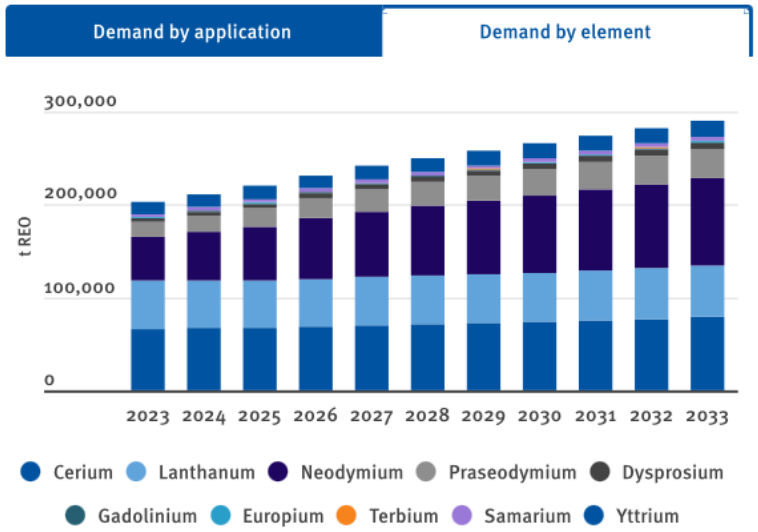
Sm Supply Chain

Forecast rare-earth supply 2023 – 2033



*Includes Myanmar imports in output total

Forecast rare-earth demand 2022 – 2033



Common Uses:

- Military systems
- Computer disk drives
- Headphones
- Speakers
- Hybrid car motors
- Specialized aircraft

SmCo magnets < 5% of total permanent magnet market

- Large portion of Samarium (Sm) and Samarium metals are sourced from China today – which is due to separation, processing, and refining. The demand for Samarium is not enough to incentivize building remainder of supply chain outside of China.
- Samarium Cobalt (SmCo) magnets represent the largest existing use of Samarium for magnet-based applications. SmCo magnet producers exist outside of China. These magnet producers likely source their metals from China.
- The estimated total reserves of rare earth oxides (REOs) globally is approximately 120 million metric tons, with Samarium consisting of approximately .50 – 1% of a given REO deposit (rough math).

"Samarium is better suited for magnet supply chain than NdPr" – Multinational SmFeN producer.

Sm Supply Chain

Examples of Existing AML Supply Chain

- NdPr, along with Dysprosium (Dy) and Terbium (Tb), are highly in demand, especially for permanent magnets used in electric vehicles and wind turbines.
- Compared to other in-demand REEs like Nd and Pr, the prices of more abundant REEs such as Cerium (Ce) have been flat or even decreased.
- AML foresees a similar trend for Samarium, despite less in ground content as compared to more abundant REEs contained within deposits.
- Samarium may have significant 'above-ground' stockpiles and unaccounted for supply due to being under separated / processed in mining operations.
- AML PM-Wire manufacturing for PM-360 could expand demand for Samarium and incentivize new industry participants to develop the supply chain ex-China.

Samarium metal

Factors to consider with large scale demand for Samarium:

- Supply chain investment in the separation and metallization of Samarium for supporting potential upswing in demand.
- Unknown or new demands that could impact pricing for Samarium based upon AML success with scaling commercial access to SmFeN.
- SmFeN producers may invest in and support supply chain efforts for supporting stability and continuity within REEs input supply chains.

Our Plans

AML "Warp Speed Expansion"

Existing Footprint

10,000 square feet – Alloys and Magnets < 1,000 MTPY

- ✓ Low-rate production, advanced applications prototyping, materials & magnet R&D.
- ✓ Strategic sourcing with suppliers of REOs, alloys, and magnet materials.

Stage II and Stage III

50,000 + square feet – Metals, Alloys, and Magnets - Commercial MTPY

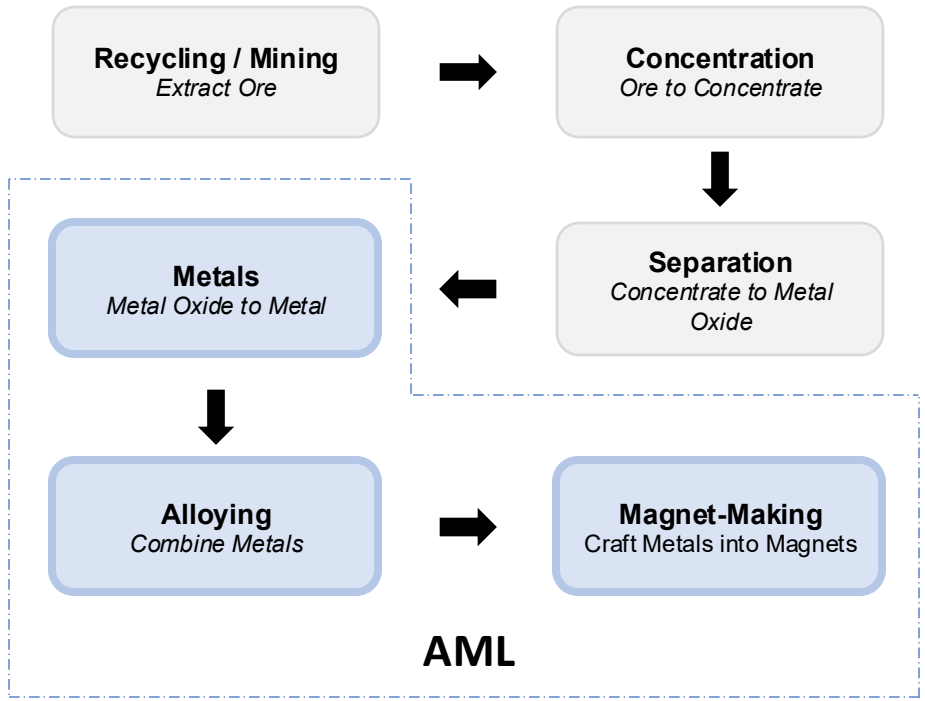
- ✓ Stage II: Scaled magnet manufacturing (DPA Title III proposal blueprint).
- ✓ Stage III: Expansion with metals and alloys production for supporting magnet making.
- ✓ Strategic partnerships with REO suppliers and magnet material producers.

Stage IV – AML 10x

Multiple Sites – Co-Location with Suppliers and Customers

- ✓ Global expansion with AML PM-Wire™ manufacturing partnerships with strategic customers and suppliers.
- ✓ AML will be fully integrating material development and scaled in-house compositions for novel magnet materials as well as NdPr.

"Source to Magnet Supply Chain"



AML intends to expand capabilities organically to scale from metals to magnets.

Our Plans

Team Expansion

Vernon Prince

AML Advanced Manufacturing

- 30 + years, entrepreneur, executive, and developing advanced manufacturing capabilities.
- Co-founded and pioneered automation solutions for fiber optics manufacturing (OPA, acquired by JDS Uniphase).
- Scaled and developed advanced manufacturing at companies such as Luminar Technologies and Infleqtion.
- Shareholder and Board Member of AML.

AML Metals and Alloys

TBA Industry Veteran

- 15 + years experience with developing and scaling casting, powder metallurgy, and materials processing.

AML Existing Team & Expansion

Existing Team

- Engineering – 3 full-time, 2 part-time, 2 contract.
- Science – 2 full-time, 1 contract (pending).

Team Expansion

- Engineering – applications, magnet R&D, and manufacturing.
- Science – material science and magnet R&D.
- Business – chief of staff, business development, and operations / supply chains.

Example DPA Title III – AML Stage II

Product:

- PM-Wire™ - Innovative permanent magnets and magnet manufacturing technology.
- Magnets are needed for energy, transportation, consumer products, and critical component to virtually every instrument, weapon, and vehicles used by the U.S. Department of Defense (DoD).

Starting TRL/MRL: 9/8 Projected Ending TRL/MRL: 9/10

Operational Capability:

- Scaling to full-rate mfg. Capacity of 2,000 mtpa of magnets.
- Build-out of 35,000 sq. ft. existing facility in Melbourne, Florida
- Manufacturing of existing sintered neodymium iron boron (NdFeB), enabling less-critical REE mischmetal neodymium iron boron (MM/NdFeB) magnets, non-sintered NdFeB, critical REE-Free samarium iron nitride (SmFeN), REE-Free manganese bismuth (MnBi) magnets.
- Government agencies benefitting include all DoD branches, DoD and DoE laboratories, NASA and universities.
- Existing partnerships include U.S. REE mines, magnet recyclers, oxide producers, non-REE material producers, and metals / alloy producers, defense and commercial companies.

Proposed Technical Approach:

- Magnets are needed for energy, transportation, consumer products, and critical component to virtually every instrument, weapon, and vehicles used by the DoD.
- PM-Wire is a novel technology for the design and mfg. of magnets that improves performance and lowers cost of the end-use produces like motors and generators.
- PM-Wire replaces rare earth element (REE) magnets with non-critical REE and REE-Free materials.
- Project scales from MRL-9 low-rate to MRL-10 full-rate manufacturing of sintered and non-sintered magnets for DoD and commercial electrical machine manufacturers.

Estimated Cost and Period of Performance:

- Total Cost for Facility Build-Out - $30,000,000

#	Milestones	12-Mon.				18-Mon.	
1	Hire and Train Personnel						
2	Retrofit Facilities						
3	Sintered Production Equipment						
4	Non-Sintered Production Equipment						
5	Start of Expanded Production						

Project Deliverables:

- Deliver a resilient domestic supply of permanent magnets.

Our team has a proven track record of executing on major advanced manufacturing programs.

Proven Execution Track Record

Let's Partner

AML - The Future of Magnetics

REE supply partnerships

Let's build a diversified globally supply chain for value-add magnet products

Let's build better products with magnets

Innovation for improved applications through smart magnet designs

Enabling new magnet materials for a tech revolution

AML is leading the transition to non-REEs and new materials for applications

AML-Enabled.com

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"Magneto"
Making Better Magnets
USA