AML™

REIMAGINING THE MAGNET TECHNOLOGY THAT DRIVES THE WORLD

Scaling Domestic Supply of Permanents Magnets

"Innovative Technology to Solve Performance Challenges of Today and Unleash Performance Capabilities of Tomorrow"

Advanced Magnet Lab, Inc. (AML)
Melbourne, Florida USA

May 2024

Introduction

Advanced Magnet Lab, Inc. (AML)

Melbourne, Florida

- ✓ Headquarters - Corporate, Operations, Engineering, R&D, Machine Shop, Prototyping
- ✓ Manufacturing – Non-Sintered and Sintered Magnet Manufacturing, Metal Alloys Development

Company History

1995-2008: Superconducting magnets for particle accelerators and colliders

2009-2014: Superconducting electrical machines R&D for offshore wind turbine generators (DOE) and turbo-electric aero propulsion (NASA)

2015 to Present: R&D for permanent magnets technology platform (DOE, DOD, U.S. Industry)

PM-Wire™ - AML's Permanent Magnet Technology Platform

A novel solution for the design, manufacture of magnets which improve the performance and lower the cost of the end-use products

Magnets & Manufacturing Innovation

- ✓ Unique and state-of-art. Production is high-rate, high-yield, high-quality, less labor and lower CapEx

Materials Innovation – Impact on Rare Earth Elements (REE)

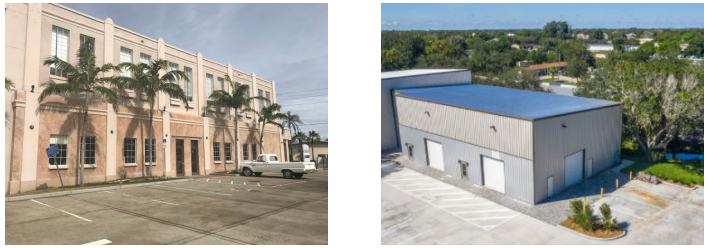
- ✓ Improves end-use performance of existing materials and enables new materials including less critical and Non-REEs

Magnet End-Use Product Innovation – Electrical Machines

- ✓ Unique magnet shapes, magnetization and motor topologies results in optimized performance and cost of end-use product

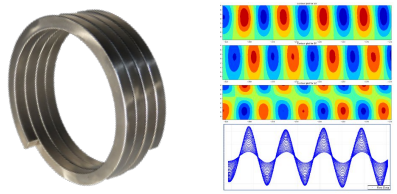
Strategic Partnerships

U.S. Department of Defense | U.S. Department of Energy | U.S. Navy | Oak Ridge National Laboratory | U.S. Defense & Aerospace Companies | Heavy Industries Company | more…



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

MITUS PM-Wire™ manufacturing pilot line funded by the U.S. Department of Defense



Left: PM-Wire™ - Single-Piece Non-Sintered Halbach Array
Right: 3D Field Map Validating a Sinusoidal Magnetic Field Distribution

Creating A New & Stable Magnet Supply Chain

AML

Problem Statement

Magnets are at the heart of manufacturing, consumer products, transportation and defense

China dominates the Rare Earth Magnet Industry (REMI) producing > 85% of the world's supply

China's vertical integration of cheap labor, raw materials and unsafe environmental standards have resulted in a "high-barrier to market-entry" for competitors Worldwide

Historically, U.S. companies entering the REMI could not compete and sustain their business

Solution – Innovative Technologies

Breaking China's stronghold requires downstream innovation for enabling a sustainable REMI supply chain to reinvent technology and transform the industry

AML has developed PM-Wire™. A novel solution for the design, manufacture of magnets which improve the performance and lower the cost of the end-use products

AML has REINVENTED the Magnet Supply Chain. Materials, Magnets, Manufacturing and Electrical Machines

Decommoditizing the magnet industry

Supply Chain – Oxide and Alloys

AML has established relationships with U.S. and European oxide producers including magnet recyclers

AML has in house capabilities for developing alloy from metals at lab-scale

AML has established relationship with a U.S. company for alloy production

Strategic Funding

U.S. Department of Defense | U.S. Department of Energy | U.S. Defense & Aerospace Companies | more…

Magnets are the heart of Motors & Generators

Motors & Generators are what enable electricity, manufacturing, industrial processing, construction, transportation…

Wind Energy

Medical

Consumer

EV

UAV

Aircraft

Marine

Defense

U.S. DEPARTMENT OF ENERGY

Technology Impact

PM-Wire™ unlocks the REE supply chain outside of China

Less Dependency on REE

Enables less critical sintered REE alloys (Mischmetal-NdFeB)

Enables non-sintered alloys (NdFeB, SmFeN)

Enables non-REE and non-sintered alloys (FeN, MnBi)

Magnet Demand

Magnets are at the heart of manufacturing, consumer products, transportation and defense

Colossal Market - Global permanent magnets market in 2022: 20.58 billion (Source: Global Newswire)

Today's market for motors are REE rich sintered magnets with conventional iron-based motor topologies in which critical REEs are used to achieve required performance and prevent demagnetization caused by high operating temperatures

Sector / End-Use Applications / Customers

PM-Wire™ enables equivalent or improved performance with less or non-REE materials

- ✓ Defense & Aerospace – drones, UAVs, ships, aircraft
- ✓ Energy – generators, wind turbines
- ✓ Transportation – cars, trucks, rail, marine, aviation
- ✓ Manufacturing – industrial motors, robots
- ✓ Consumer – power tools, utility equipment

Customer Profiles

Sintered magnets for U.S. defense companies

Non-sintered magnets for plug-and-play replacement of sintered magnets

New applications for customers to achieve specific performance objectives that are not feasible or outcompete conventional permanent magnets

Exploit existing relationships with non-sintered magnet powder manufactures where AML opens new and large electrical machine markets

Colossal Magnet Market

The global permanent magnets market in 2022:
20.58 billion

The electric motor market is expected to hit
$249.6 billion
by 2032
Source: Global Newswire

Expected growth
8.6% CAGR
(compound annual growth rate) annually from 2023 to 2030.
Source: Grandview Research

AML **Case Study** OAK RIDGE National Laboratory
Non-Sintered vs. Sintered

PM-Wire™ - Electric Vehicle Motor Using Using Non-Sintered Alloy

Solution

- ✓ Retrofit solution replacing **~2,750** NdFeB high-grade sintered magnets with **8 PM-Wire™ rings**

AML Performance

- ✓ Equivalent torque and efficiency
- ✓ Eliminate the need to actively cool the motor rotor
- ✓ Significantly reduce part count and complexity of assembly
- ✓ A fraction of the cost compared to sintered complex Halbach array design

AML

Reimagining the Magnet Technology that Drives the World

Magnet Innovation

Reinventing the design and manufacturing of magnets

Today – Magnet manufacturing is archaic

AML

Conventional Approach - The China Approach

Low-yield, low-quality, limited in size, single magnetization direction, high energy cost manufacturing

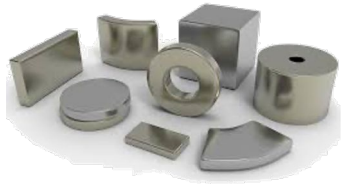
Conventional magnets and assemblies are expensive and limit optimum performance of the end-use products such as motors

- ✓ Magnets are produced in blocks. Cut to shape. Sold as a COMMODITY
- ✓ Magnets are RESTRICTED in shapes, small sizes and single-direction magnetization
- ✓ Motors require dozens, hundreds, sometimes thousands of magnets in an assembly
- ✓ Magnets have strong fields and RESIST going where you want them to go

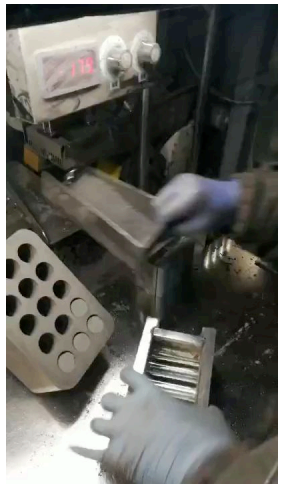
Mining

Processing

REE Materials



Conventional Sintered "Me-Too" Magnets



PM-Wire™ - A Technology Platform

Technology

PM-Wire™ - A unique process for the design, manufacturing and application of permanent magnets

Enabling Configurations – long-length, rings, helixes and more

Enabling Magnetization / Topologies – magnetic flux distribution optimized for the application

High-Rate Manufacturing – mass produced / high yield - >98%

Value Proposition

Improves performance and lowers the cost of end-use products (e.g., motors)

Performance – higher efficiency, lighter, smaller, higher temperature operation

Enables Less Critical and Non-REEs – end-use product performance equivalent

Enables Non-Sintered Solutions – performance equivalent to higher cost materials

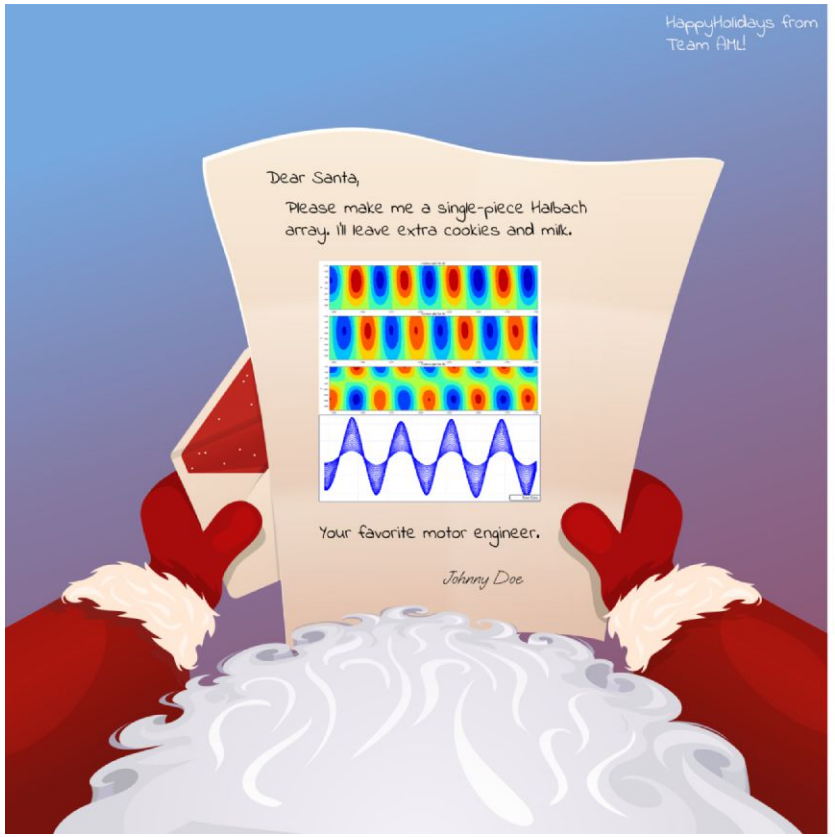
Manufacturing Ease and Safety – less magnets, simplified assembly into end-use products

Sustainable Business – does not compete in existing commoditized market

PM-Wire Impact Example

Electric Vehicle Motor

- ✓ Collaboration with the Oak Ridge National Laboratory
- ✓ Replace **~2,750** magnet Halbach array with **8** PM-360™ rings
- ✓ Eliminate need for active cooling of rotor
- ✓ Using a Non-sintered magnet alloy



- What motor engineers dream about -
"Single-piece Halbach array"

PM-Wire™ Enables Non-Sintered Magnets

AML's Non-Sintered Magnets

Non-sintered magnets are made from anisotropic bonded materials (NdFeB, SmFeN, FeN, MnBi)

PM-Wire™ eliminates the need for bonding agents which results in a higher performance. This combined with unique magnetization and motor topologies enables non-sintered magnets to replace sintered magnets

Magnets are sized, shaped and magnetized to optimize performance / cost of end-use product

Performance – higher efficiency, lighter, smaller, higher temperature operation

Enables Less Critical and Non-REE – enabling supply chain security

Enables Non-Sintered Solutions – high-yield, high-recyclability, environmentally stable

Manufacturing Ease and Safety – less magnets, simplified assembly, reduced mfg. costs

Sustainable Business – breakthrough technology replacing low-grade commodity products

PM-Wire™ - Single-Piece Non-Sintered Halbach Array

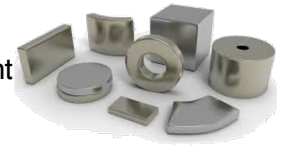
Conventional Sintered Magnets

Conventional magnets and assemblies are expensive and limit optimum performance of the end-use products such as electrical motors

- ✓ Magnets are produced in blocks. Cut to shape. Sold as a COMMODITY
- ✓ Magnets are RESTRICTED in shapes, small sizes and single-direction magnetization
- ✓ Motors require dozens, hundreds, sometimes thousands of magnets in an assembly
- ✓ Magnets have strong fields and RESIST going where you want them to go

Conventional magnet block manufacturing requires:

- ✓ Milling alloys into powder, make green molds and sintering – all in an inert environment
- ✓ Sintering ovens consume energy, gases and take greater than 12 hours to process
- ✓ After sintering, the magnet blocks require cutting / grinding to final shape
- ✓ Shaped magnets are plated to protect from corrosion / oxidation
- ✓ Sintered magnets are brittle, difficult and dangerous to handle



Conventional Sintered Magnets

Industry Expert – Stan Trout on Non-Sintered PM-Wire™
June 18, 2018

Has the potential to overcome a significant inefficiency in the current method of producing rare earth permanent magnets, namely the waste generated by slicing and grinding magnets to achieve their ultimate dimensions and tolerances. This single step wastes on the order of 20% of the material processed, depending on the size of the magnet. It is by far the least efficient step in the process of making magnets.

There also appears to be an additional benefit of being able to control the direction of orientation within the magnet with fewer limitations and constraints. This could be beneficial in allowing here-to-fore unachievable types of permanent magnets that could be used in Halbach configurations as a single piece, for example.

This development could revolutionize the design and production of electric motors

U.S. Defense Contractor – Impact of Non-Sintered PM-Wire™
March 2024

It is the most impactful development in Hard Magnetics since the development of NdFeB magnets.

In our Hard Magnetic Trade Studies, we looked at:

- **Hard Magnetic Materials, Optimization of Hard Magnet Shape and Quantity, Flux Focusing**

We also addressed the common issues facing Hard Magnetics:

- **Structural Integrity, Corrosion, Demagnetization, Thermal Limitations**

What if it were possible to address all of these concerns with a single revolutionary new product?

- **A single product that not only advances the state of the art in motor design, but also disrupts the magnet supply chain and breaks China's stronghold on the Rare Earth Magnet Industry.**
- **Advanced Magnet Lab has done this with the PM- Wire™ magnet technology.**

PM-Wire™ Products

PM-UNIFORM™

Straight, curved, ring or helical magnets with Transverse or Radial magnetization

Single-Piece Magnets
Straight up to 1 m
Curved up 1 m arc
Rings up to 320 mm dia.
Helical (given by dia.)

Lower Cost Assemblies
Reduced part count

PM-UNIFORM™

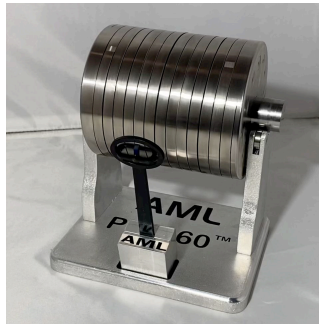
PM-360™ - "Single-piece Halbach Array"

Straight, ring or helical magnets with "Continuously Changing Magnetization Direction"

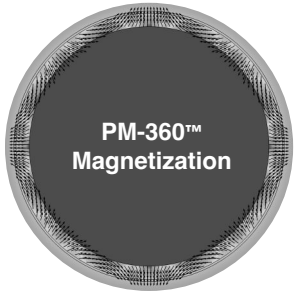
Increased Performance
Halbach Array Performance

Reduced Weight
Iron Free

Lower Cost Assemblies
Reduced part count
Ease to assemble



PM-360™ - Helical



PM-360™ - Magnetization

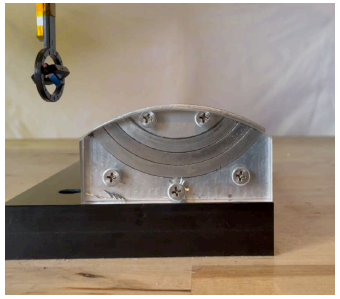
PM-AXIAL™

Curved magnets with Axial magnetization allows rotor topologies having breakthrough benefits

Increased Performance
Halbach Array Performance
Higher Temperature
Reduced Overwrap

Reduced Weight
Iron Free

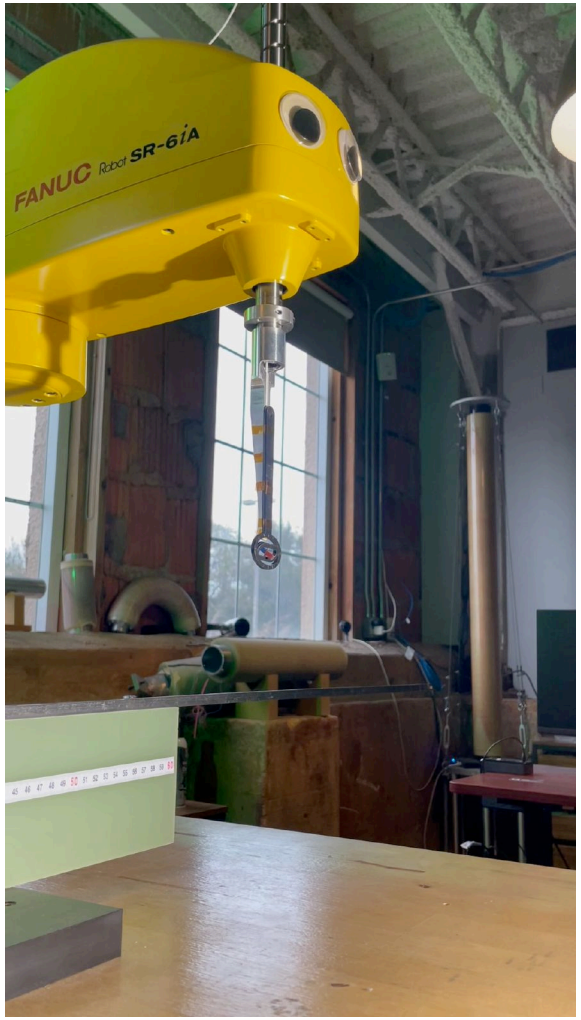
Lower Cost Assemblies
Reduced part count
Ease to assemble
Lower grade metal alloys



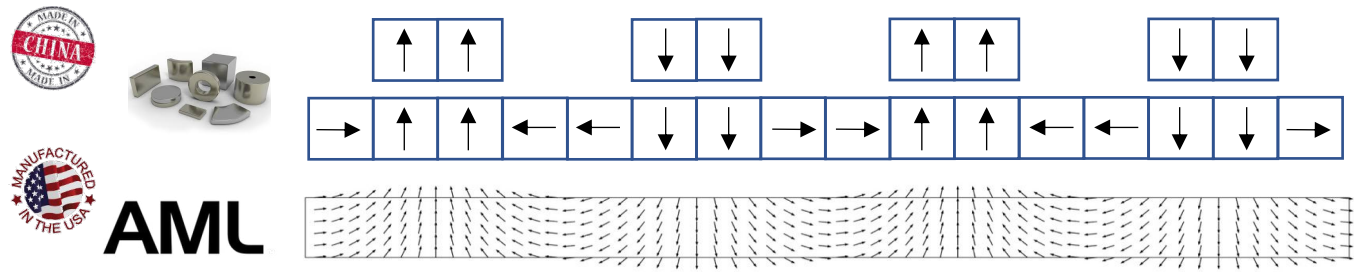
PM-AXIAL™

Straight PM-360™

Ideal magnetic field distribution, Single-piece “Halbach Array”, Long-lengths



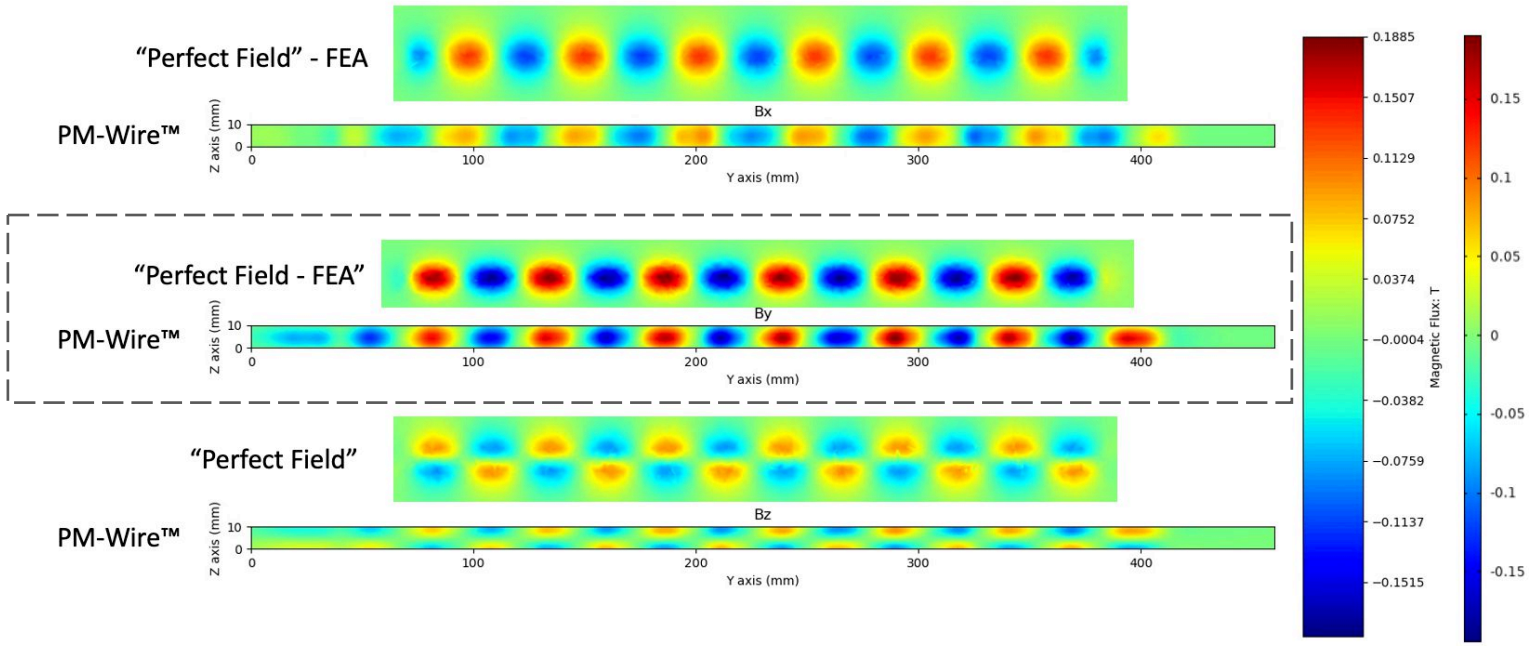
Video



North – South Magnetization

90 Degree Halbach Array

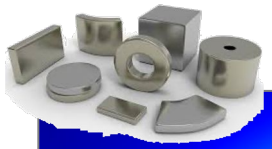
Continuously Changing Flux Direction

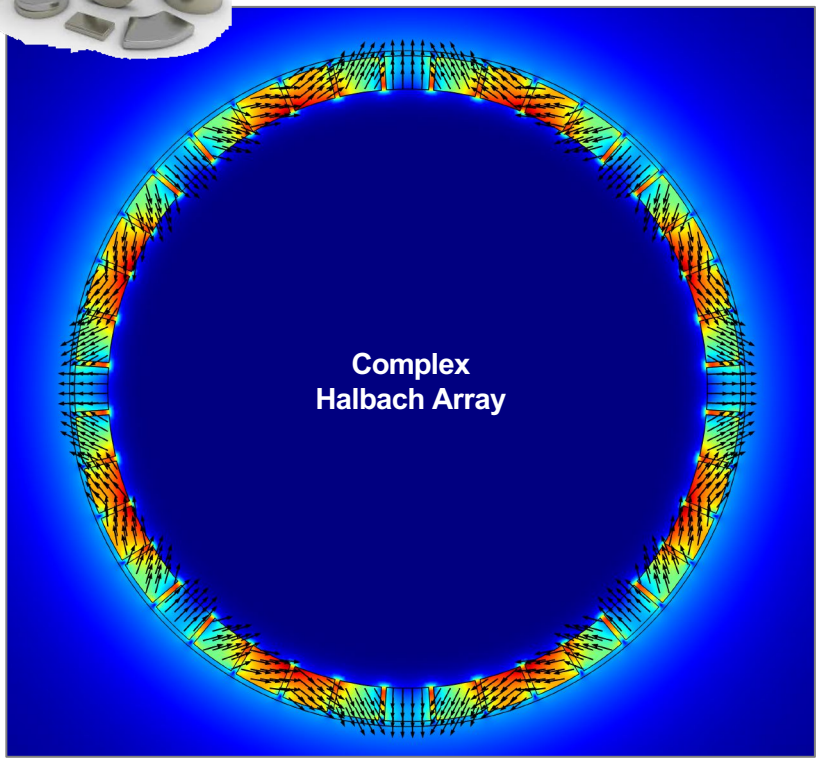


Circular PM-Wire™ - PM-360™

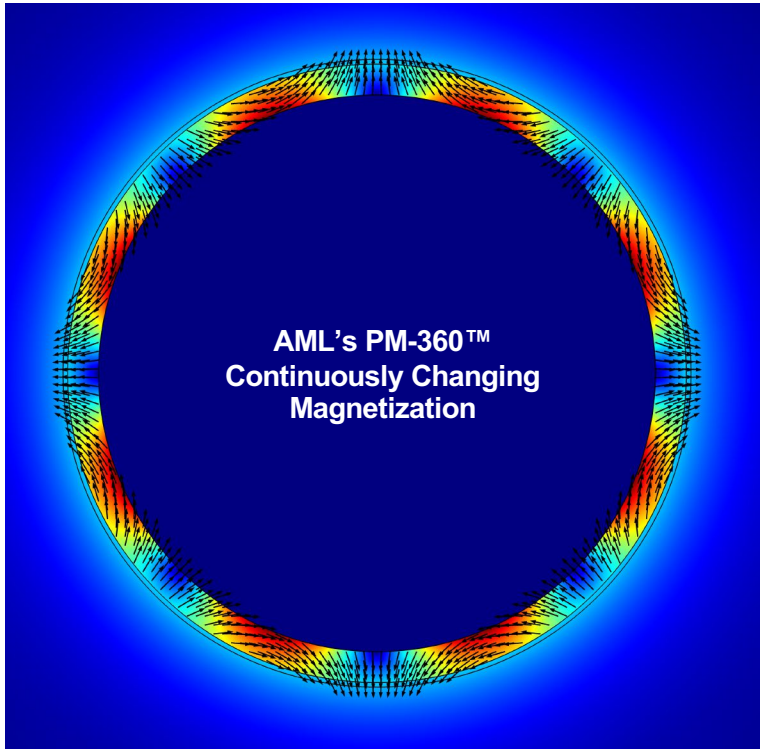
Single-piece, ring and helix “Halbach Array”

PM-360™

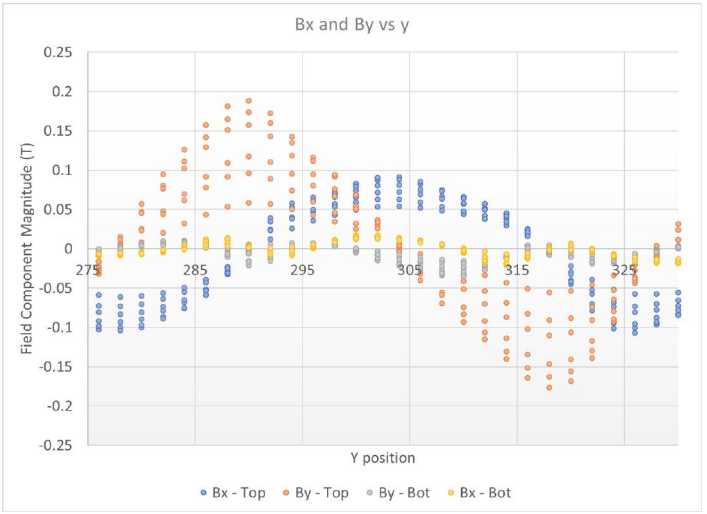




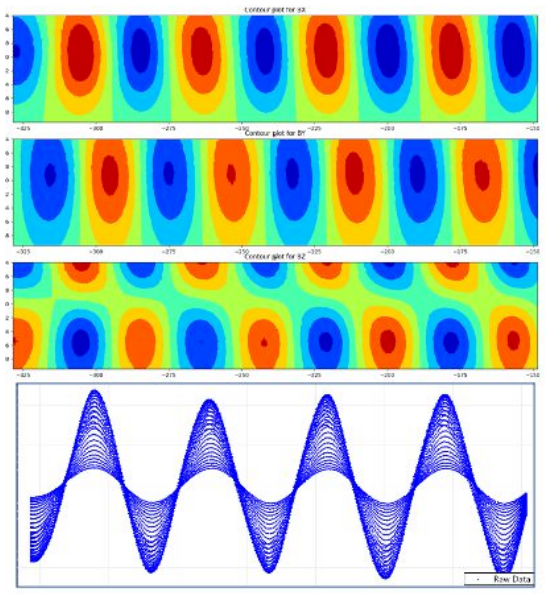
Conventional Magnets



PM-Wire™

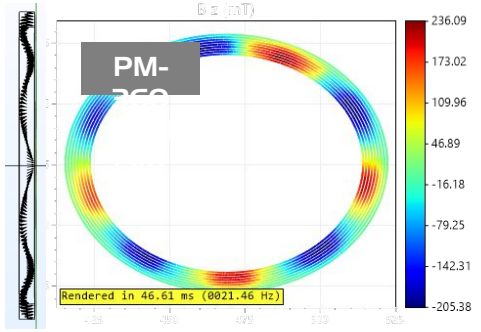


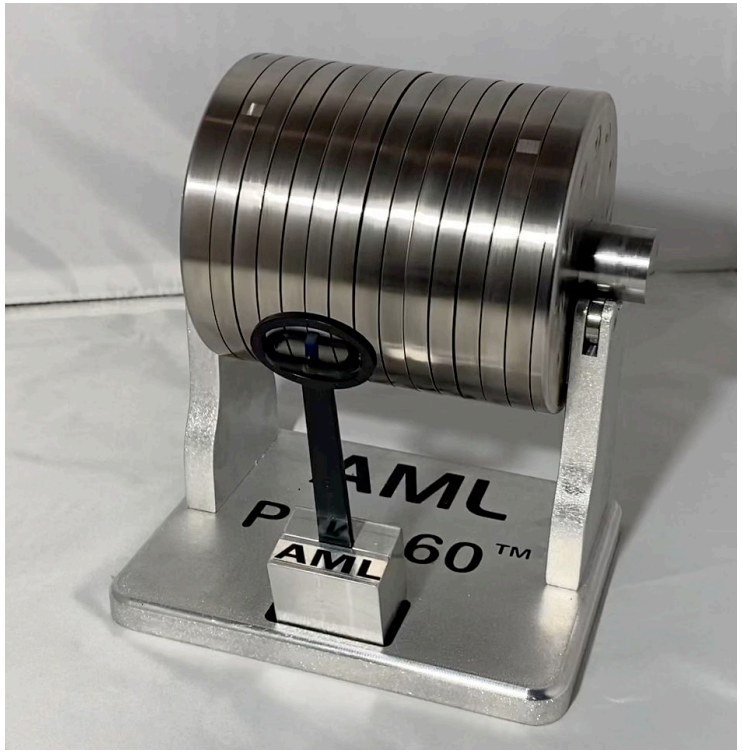
PM-360™ 3D Field Map Example



PM-360™ - Motor Rotor Magnets

Single-piece, ring and helix “Halbach Array” rotors for electrical machines





PM-360™ Radial Flux Rotor

PM-360™ Outrunner Rotor

PM-360™ Axial Magnetization

PM-Wire™ – Lower REE and Non-REE – Sintered and Non-Sintered

PM-AXIAL™ Magnets

Improves the performance of existing alloys

Enables a motor topology which is well suited for low coercivity alloys

- ✓ Provides very low demagnetization field enabling the use of low coercivity alloys including less critical REE and non-REE materials

Additional Features and Benefits

Optimized Performance

- ✓ Halbach Array like performance
- ✓ Higher Temperature Operation
- ✓ Enables lower grade / cost alloys with performance equal to higher grade alloys
- ✓ Significantly reduces or eliminates overwrap (magnet containment)

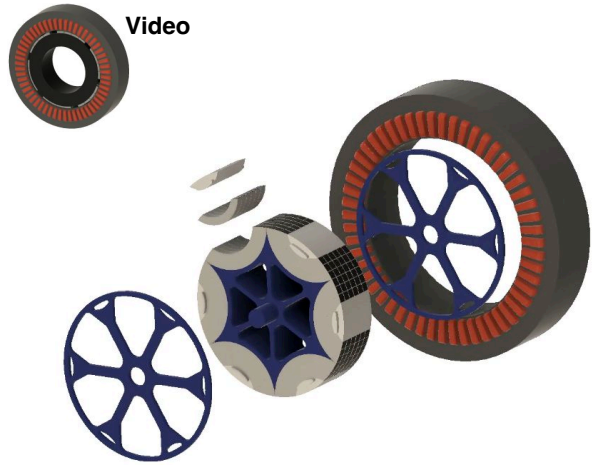
Reduced Weight

- ✓ No need for iron at the rotor

Ease of manufacturing and assembly

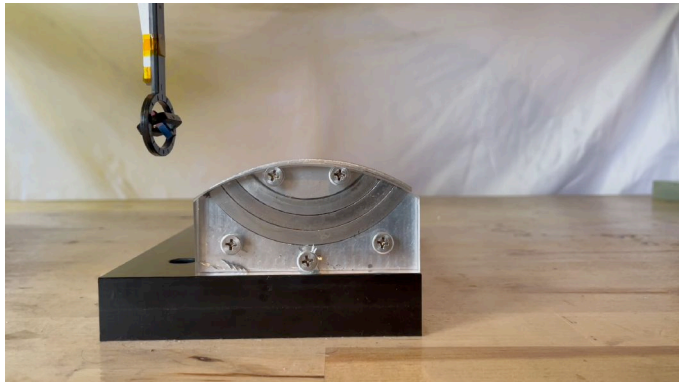
- ✓ All the segments can be mass-produced at low cost
- ✓ The magnetic flux is contained within the magnets making it easy and safe during assembly

Video



Example of PM-AXIAL™ rotor design

Video



Sample PM-AXIAL™ motor poles made with non-sintered NdFeB alloy

PM-Wire™ and Conventional Sintered

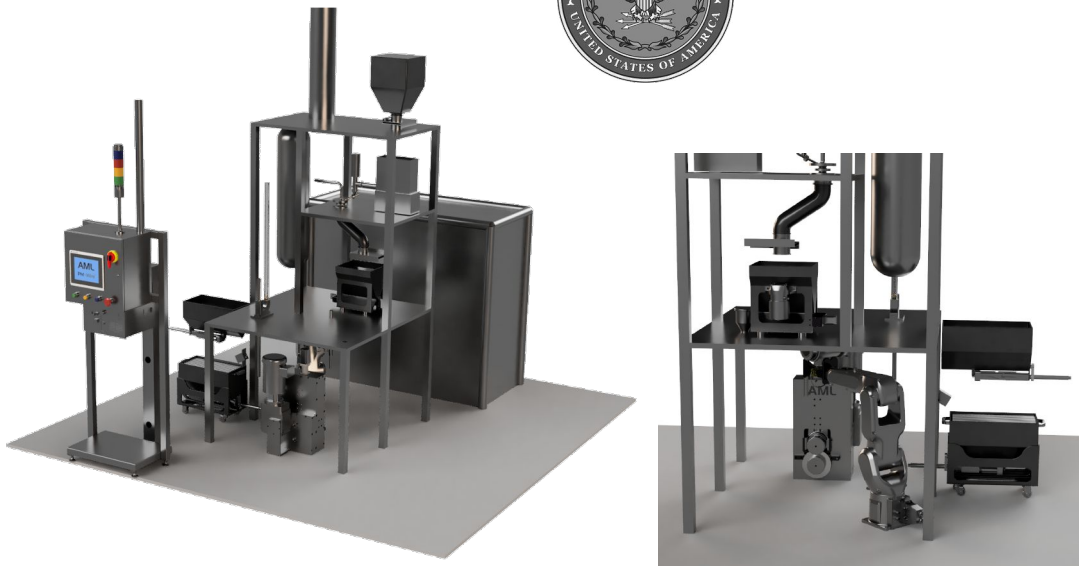
Capabilities for both conventional and PM-Wire™ sintered magnets

Sintered Capacity / Plan

- ✓ 2024 - 1 mt / annum (funded by DoD / DLA)
- ✓ 2026 - DOD / DLA has requested a proposal for scaling to 10 mt / ann um

AML Sintered Magnets

Low-Rate Sintered Magnets Production Facility
Funded by U.S. Department of Defense / Defense Logistics Agency



Sintered Magnet Automaton Development (2024)
Funded by U.S. Department of Defense / Defense Logistics Agency

Manufacturing Innovation

High-rate, high-yield, high-quality and low capex

PM-Wire™ High-Rate Manufacturing

AML

High Volume Manufacturing

3-6 meters / minute / production line

Capacity Potential Scenarios (magnet cross-section dependent)

Single Line Production Capacity - Straight PM-Wire™

High Volume (m/min)	Size by Cross Section	Daily Production (m)	Annual Production (m)	Daily Volume (mt)	Annual Volume (mt)	Capacity Per 6,000 mt of NdPr
4	2 cm x 2 cm	4,536	1,360,800	11	3,320	7 production lines
4	1.5 cm x 1.5 cm	4,536	1,360,800	6	1,868	11 production lines
4	1 cm x 1 cm	4,536	1,360,800	3	830	25 production lines

Production Parameters

Days Per Year	300
Hours Per Day	21
Line Utilization	90%

Production Capacity Comparison

NdPr Deposit	NdPr Supply	Potential Magnet Capacity (mtpa)	Planned Magnet Capacity (mt)
Mountan Pass Mine	6,000	20,000	1,000

AML capacity scenarios for producing 20,000 mt per year

Mount Pass Mine has an expected production capacity of 6,000 metric tons of NdPr rare earths which equates to ~20,000 metric tons of magnets

MP Material's 200,000 sq ft production facility will have the capacity to produce approximately 1,000 metric tons of magnets per year

MP Materials; Gabelli Funds 46th Annual Auto Symposium – October 31, 2022

Project MITUS - PM-Wire™ Pilot Line
Funded by the U.S. Department of Defense

Materials Innovation

Improving performance of existing and enabling less critical REE, non-sintered and non-REE alloys for electrical machines

PM-Wire™ Impact

Magnet Materials Impact for Electrical Machines

- ✓ Improved end-use product performance of existing sintered alloy compositions
- ✓ Enable non-sintered alloys
- ✓ Enable lower critical REE alloys
- ✓ Enable non-REE alloys

End-Use Product Impact

Improving the performance and lowering the cost of the end-use product

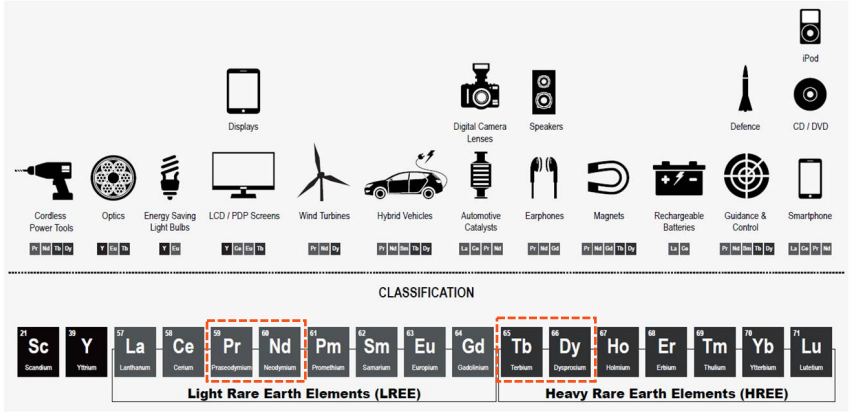
PM-Wire™ magnets can replace conventional north-south pole rotor topologies

- ✓ Unique magnet shapes
- ✓ Unique magnetization
- ✓ Unique motor topologies

End-Use Impact Examples

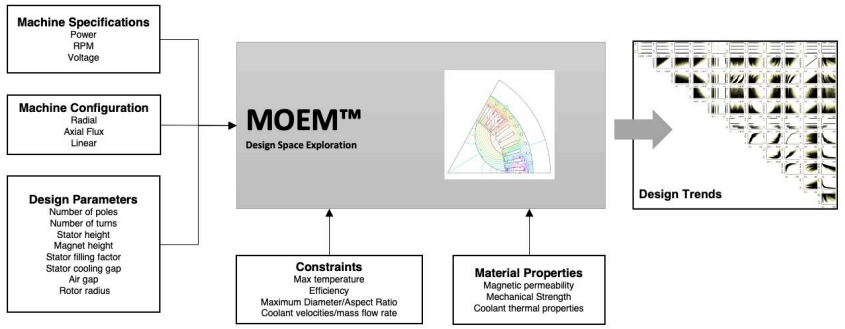
AML has unique software and experience for the optimization of electrical machines

- ✓ PM-AXIAL™ - Industrial Motor With Significant Improvement In Performance (NdFeB)
- ✓ PM-AXIAL™ - Industrial Motor Using Reduced Critical REE Alloy (Mischmetal-NdFeB)
- ✓ PM-360™ - Industrial Motor Using Non-Sintered REE Alloy (NdFeB)
- ✓ PM-360™ - Electric Vehicle Motor Using Using Non-Sintered REE Alloy (NdFeB)
- ✓ PM-360 ™ - Electric Vehicle Motor Using No Critical REE Alloy (SmFeN)
- ✓ PM-AXIAL™ - Electric Vehicle Motor Using Non-REE Alloy (FeN)
- ✓ PM-360™ - Electric Vehicle Motor Using Non-Sintered and Non-REE Alloy (MnBi)



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

Critical REEs - Praseodymium, Neodymium, Terbium and Dysprosium



AML Electrical Machine Optimization

Proprietary software and unique experience used for electrical machine optimization

Process flow: 1st Order Design Study (no charge) → Preliminary Design → Detailed Design → Prototyping → Optimized Product

Industrial Motor – Global Electrical Machine Manufacturer

Baseline Design

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

Magnet Material: N48SH NdFeB

Operating Temperature: 100 C

Critical REEs: NdPr and Dysprosium

Baseline Design – Conventional north-south pole rotor configuration

Example 1

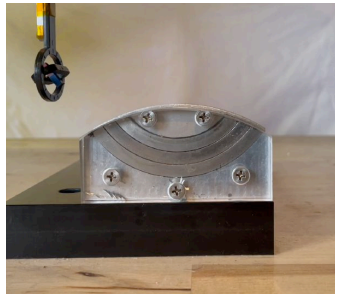
PM-AXIAL™ Impact – Significant Improvement In Performance

Solution

- ✓ Retrofit solution replaced north-south rotor pole topology with PM-AXIAL™
- ✓ No change to motor stator
- ✓ Same magnet N48SH NdFeB alloy

AML Performance Improvement

- ✓ Halbach array performance
- ✓ 50% increase in operating temperature (150 C)
- ✓ 50% reduction in rotor overwrap thickness
- ✓ 20% reduction in mass by removing the iron
- ✓ Modification of motor stator would result in additional increase in performance



PM-AXIAL™

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

Industrial Motor – Global Electrical Machine Manufacturer

Example 2

PM-AXIAL™ Impact – Reduced Critical REE

Solution

- ✓ Retrofit solution replaced north-south rotor pole topology with PM-AXIAL™
- ✓ No change to motor stator
- ✓ **Mischmetal (40%) / NdPr (60%) NdFeB** alloy
  - Br and Hci (@ 120 C) = 1.01 T and 1.850 kGauss

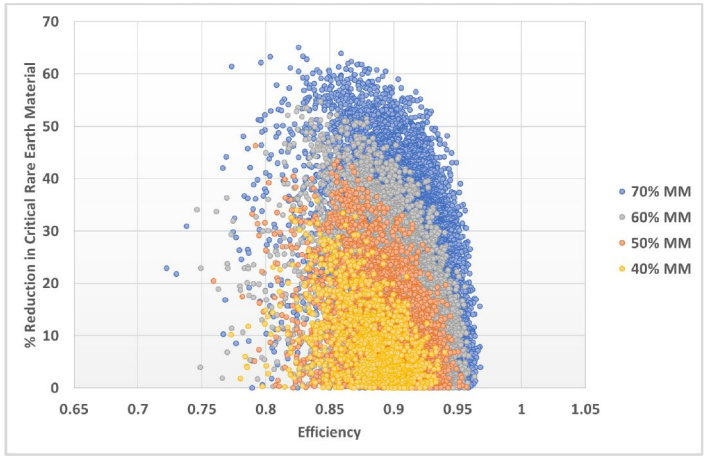
AML Performance

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

NdPr - ~ $90 per kilogram

Mischmetal - $1-$5 per kg
(55% Cerium, 25% Lanthanum, 18%Neodymium, %2 Praseodymium)

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



Reduction in critical REE materials vs. efficiency for a Chevy Bolt EV motor retrofit design

Example 3

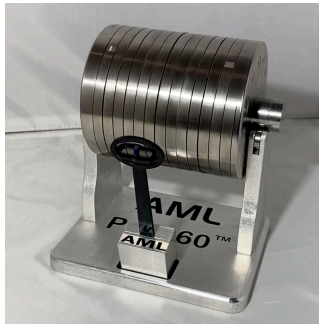
PM-360™ Impact – Enable Non-Sintered Alloy

Solution

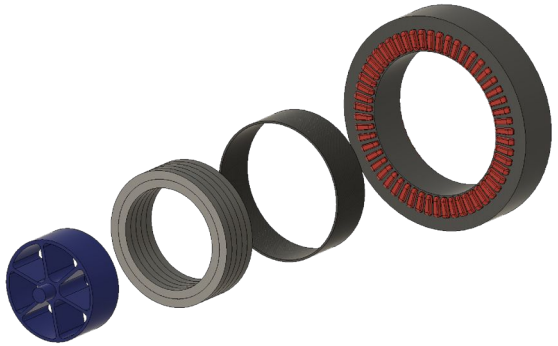
- ✓ Retrofit solution replaced north-south rotor pole topology with PM-360™
- ✓ No change to motor stator
- ✓ **Non-Sintered MF18P** alloy
  - Br and Hci (@ 120 C) = 0.89 T and 9.2 kGauss
- ✓ Replace 168 sintered N48SH magnets with **10 PM-360™ rings**

AML Performance

- ✓ Equivalent torque and efficiency
- ✓ 10% reduction in active mass and and **no dysprosium**



PM-360™ - Helical



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

Electric Vehicle Motors

Motor Specifications

Collaboration with the Oak Ridge National Laboratory

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

Example 4

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

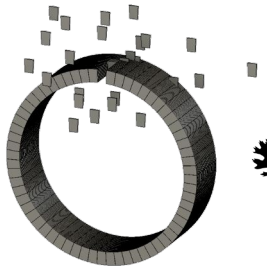
Solution

- ✓ Retrofit solution replacing Halbach rotor topology with PM-360™
- ✓ Replacing ~**2,750** NdFeB thin sintered magnets with **8 PM-360™ rings**
- ✓ **Non-Sintered NdFeB** alloy
  - Br and Hci (@ 80 C) = 0.9 T and 19 kGauss

AML Performance

- ✓ Equivalent torque and efficiency
- ✓ Eliminate the need to actively cool the motor rotor
- ✓ Significantly reduce part count and complexity of assembly
- ✓ A fraction of the cost compared to sintered complex Halbach array design

PM-360™



Halbach Array

Motor Specifications

2022 U.S. Department of Energy Power Density Goal: > 50 kW/L

Power - 300 kW; RPM - 12,000

Example 5

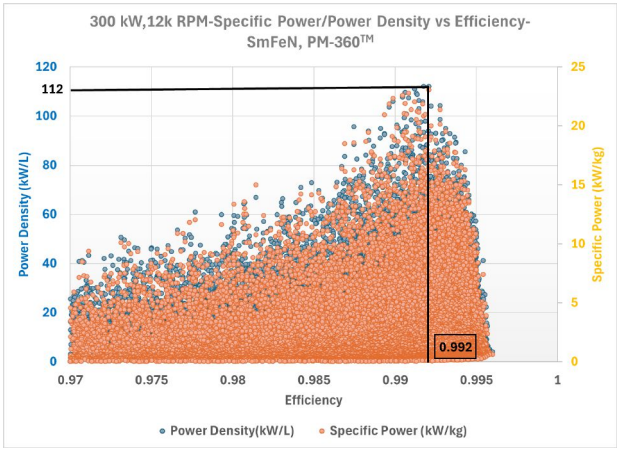
PM-360™ – EV Motor With No Critical REE

Solution

- ✓ New Design (re-design of stator and rotor)
- ✓ **No Critical REE - Samarium Iron Nitride (SmFeN)** alloy
  - Br and Hci (@120C) = 0.88T and 11.5 kGauss @120C

AML Performance

- ✓ Motor Efficiency ~ 99%
- ✓ Motor Power Density ~ **112 kW/L**



Electric Vehicle Motor

Motor Specifications

2022 U.S. Department of Energy Power Density Goal: > 50 kW/L

Power - 300 kW; RPM - 12,000

Example 6

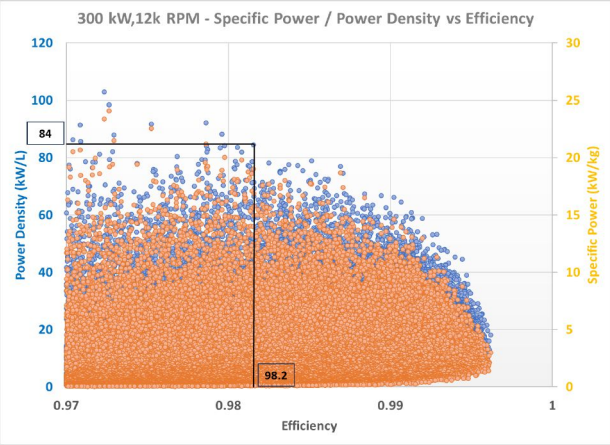
PM-AXIAL™ Impact – EV Motor With Non-Sintered / Non-REE Alloy

Solution

- ✓ New Design (re-design of stator and rotor)
- ✓ **Non-REE - Iron Nitride (FeN)** alloy
  - Br and Hci (@120C) = 0.88T and 3 kGauss

AML Performance

- ✓ Motor Efficiency ~ 98%
- ✓ Motor Power Density ~ **70 kW/L**



Motor Specifications

Power Density: > 30 kW/L

Power - 300 kW; RPM - 12,000

Example 7

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

Solution

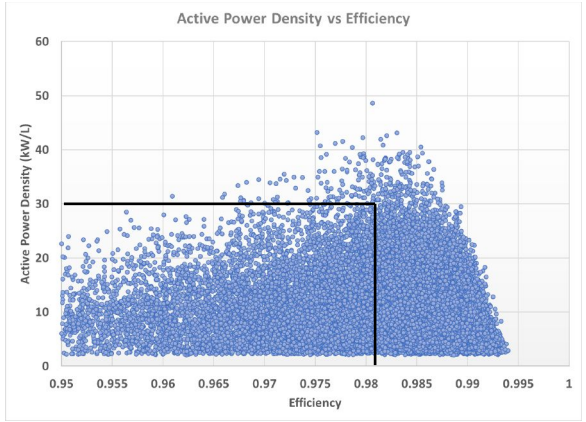
- ✓ New Design (re-design of stator and rotor)
- ✓ **Non-REE - Manganese Bismuth (MnBi)** alloy
  - MnBi @ 120 C, Br = 0.235 T and Hci = 15 kGauss

AML Performance

- ✓ Design Space Exploration shows opportunity for >30 kW/L power densities

"MnBi is being explored as an alternative to the permanent magnets containing REEs, for medium temperature applications due to its unique properties: its coercivity increases with increasing temperature"

U.S. Department of Energy
Quadrennial Technology Review 2015
Technology Assessments for Critical Materials



AML

Reimagining the Magnet Technology that Drives the World

Technology and Business Execution

PM-Wire™ Development, Funding and Timeline

Technology and Business Execution

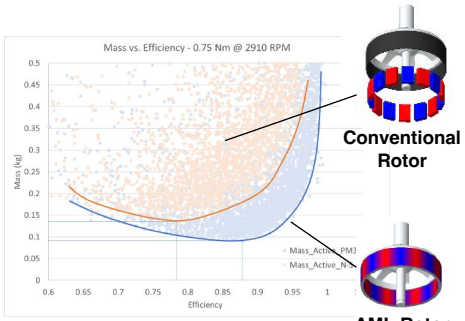
2017-18

Phase 1 - PM-Wire™ R&D

The concept was validated using isotropic non-sintered NdFeB compositions. Magnets having uniform magnetization were produced. Achieved optimum performance

Funding Source: AML

Isotropic Magnets



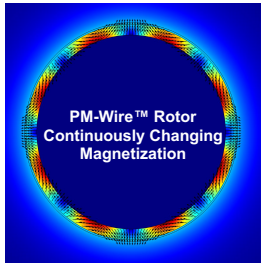
Engaged With Industry
Performed Dozen's of PM-Wire Application Design Studies

2020-21

Phase 2 - PM-Wire™ R&D

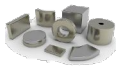
Developed magnets having "continuously changing magnetization" (single-piece Halbach array) using anisotropic bonded NdFeB compositions. Achieved optimum performance

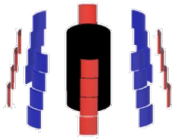
Funding Source: U.S. Aero & Defense Company



Non-Sintered

PM-Wire™
Single Part with ideal, continuously changing magnetization





Conventional - "Me-Too" Magnets
Dozens / hundreds of piece parts with one-direction magnetization

2021-22

Phase 3 - Manufacturing

Design, build and commissioning of an advanced PM-Wire™ Pilot Manufacturing. Line is ready for mass production of non-sintered magnets

Funding Source: U.S. Dept. of Defense / DIU

MITUS Advanced Manufacturing Line

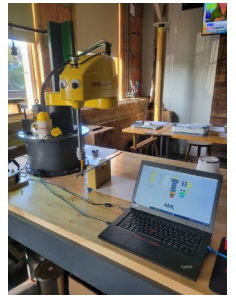
2022-2023

Phase 4 - PM-Wire™ R&D

Develop sintered PM-Wire™ magnet configurations using NdFeB compositions. Majority of funds used for facilities and processing equipment

Funding Source: U.S. Dept. of Defense / DLA

Magnet Processing & Testing Equipment



Technology and Business Execution

2023-24

Phase 5 – Manufacturing

Design, build and commissioning of a pilot automated manufacturing cell and post processing for sintered PM-Wire™

Production Capacity: **1 mt/annum**
Funding Source: U.S. Dept. of Defense / DLA

NdFeB Production for Sintered PM-Wire™ Permanent Magnets

Capacity / Plan

- ✓ 1 mt/annum, Melbourne FL

Sintering Equipment

- ✓ Hydrogen Decrepitation
- ✓ Jet milling
- ✓ Cold Isostatic Pressing
- ✓ PM-Wire Automation Pilot Cell
- ✓ Automated PM-Wire Ring Rolling
- ✓ Pulsers , Pre-alignment and Magnetization Fixtures
- ✓ High Vacuum Furnaces
- ✓ Electrical Discharge Machining
- ✓ Surface Grinding
- ✓ Particle Size Analysis, Simultaneous Thermal Analyzer
- ✓ BH-Looper

Manufacturing Automation Development

Planned 2024 -25

Phase 6 - Manufacturing

Manufacturing automation, processing equipment for production manufacturing of sintered PM-Wire™ conventional magnets

Production Capacity: **10 mt/annum**
Potential Funding Sources: U.S. Dept. of Defense (DLA and DIU)

NdFeB Production for Sintered Permanent Magnets

PM-Wire™ & Conventional

Capacity / Plan

- ✓ 10 mt/annum, Melbourne FL

Sintering Equipment

- ✓ Hydrogen Decrepitation
- ✓ Jet milling
- ✓ Cold Isostatic Pressing
- ✓ PM-Wire Automation Pilot Cell
- ✓ Automated PM-Wire Ring Rolling
- ✓ Pulsers , Pre-alignment and Magnetization Fixtures
- ✓ High Vacuum Furnaces
- ✓ Electrical Discharge Machining
- ✓ Surface Grinding
- ✓ Particle Size Analysis, Simultaneous Thermal Analyzer
- ✓ BH-Looper

Manufacturing Automation Development

2023-24

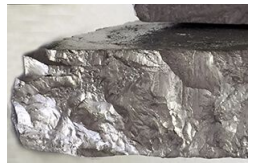
Metal Alloys

Development of lab-scale magnet alloy compositions which are optimized for performance and cost.

Funded by REE supply chain partner. U.S. magnet recycler

REE Pure Oxides

Magnet Metal



Magnet Alloy

2021-Present

PM-Wire™ Product Developments

Co-developing electrical machines for commercial use of PM-Wire™. To include US Dept. of Energy, US Navy, Oak Ridge National Laboratory and Heavy Industries Company

Funding Source: U.S. Dept. of Energy, Customer, AML IR&D Budget

U.S. DEPARTMENT OF ENERGY

U.S. Aerospace & Defense Company

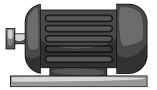
Aircraft

Defense

OAK RIDGE National Laboratory

EV

U.S. Defense Company



Motors for Defense

U.S. Government Relationships

PM-Wire™ Government Relationships / Programs

U.S. Department of Defense / Defense Innovation Unit

- ✓ Provided funding for the design, build and commissioning of an advanced Pilot Manufacturing Line for non-sintered PM-Wire™
- ✓ SBIR Follow On. Contract No.: HQ0845-21-9-100

U.S. Department of Defense / Defense Logistics Agency

- ✓ Project Title: “Development and Qualification of Domestically Sintered Neodymium Iron Boron (NdFeB) Magnets for Weapons Platforms”
- ✓ The objective is to qualify sintered PM-Wire™ magnets and to design, build and commission advanced manufacturing for both conventional and PM-Wire™ sintered magnets
- ✓ SBIR / Contract Number: SP4701-22-P-0018

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

- ✓ 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
- ✓ Award No. : DE-AR0001359

U.S. Department of Energy / Oak Ridge National Laboratory

- ✓ Collaborating on electric vehicle motor development base on PM-Wire™
- ✓ PM-Wire™ solution will replace **~2,750** sintered magnets with **eight (8)** non-sintered magnets
- ✓ Non-sintered PM-Wire™ eliminates the need for high magnet segmentation or active cooling of the motor’s rotor due to higher resistivity
- ✓ A. Ananthanpillai, P. Masson, V. Rallabandi and M. Senti, "Analysis of a Continuous Halbach Array Permanent Magnet Motor for Electric Vehicles," 2023 IEEE International Electric Machines & Drives Conference (IEMDC), San Francisco, CA, USA, 2023, pp. 1-4

U.S. Military Branch

- ✓ Developed and implemented numerical models to compute forces between assemblies of field-cooled superconductors and permanent magnets
- ✓ Designed, commissioned and tested and superconducting / permanent magnet bearing system
- ✓ New Program - Design, commission a “levitated system” to measure and evaluate forces between magnets assemblies
- ✓ New Program (Q3 / 2024) - Qualify AML as a supplier of sintered permanent magnets

U.S. Magnet Companies / Projects

Sintered

Samarium Cobalt (SmCo)

- ✓ Electron Energy Corp

Neodymium Iron Boron (NdFeB)

- ✓ **AML**
- ✓ E-Vac Magnetics (Vacuumschmelze)
- ✓ Noveon
- ✓ MP Materials(NdFeB)
- ✓ U.S. Rare Earth

Mischmetal-NdFeB (Less Critical REE)

- ✓ **AML**

Non-Sintered & Non-REE

Samarium Iron Nitride (SmFeN)

- ✓ **AML**

Manganese Bismuth (MnBi)

- ✓ **AML**

Iron Nitride (FeN)

- ✓ **AML** (Competes with sintered using Niron Magnetics powder)
- ✓ Niron Magnetics

Materials from Recycled Magnets

- ✓ **AML** (Supply Chain: ReElement, Cyclic Materials)
- ✓ Noveon
- ✓ MP Materials
- ✓ Vacuumschmelze

	AML	Others
IMPACT	**NON-SINTERED MAGNETS**	**SINTERED MAGNETS**
National Security		
Domestic Magnet Supply	DFAR Compliant Materials, Domestic Manufacturing, No Dysprosium	No Solution - Materials & Magnets Controlled by China
Sustainable Domestic Magnet Supply		
Magnet Manufacturing	Innovation Breakthrough, Sustainable	Uncompetitive, Unsustainable, with China
Supply Chain	Allows Premium Pricing - Supply Chain Profitability	Commodity Pricing Controlled by China
Environment	Less Mining, Less Extraction	Maximum REE Needed
Energy	Less REE Processing, Lower Energy Manufacturing	High - Sintering & Final Shaping Process
Infrastructure	Fewer Facilities, Scalable & Ease for Co-Locating	Large Infrastructure, Does Not Scale, Cannot Co-Locate
Critical Materials - Less Dependency on REE		
Reduced REE Magnets	Enables Lower Grade Materials Which Use Less REE	No Solution - Requires REE Rich Alloys
Non-REE Magnets	Enables Lower Grade Materials Which Eliminate REE	No Solution - Requires REE Rich Alloys
Economic Development		
New & Sustainable Industry	Does not compete with China	Not Sustainable - Cannot compete with China
New Manufacturing Jobs	New, High Paying, Multiple Regions in the U.S.	Not Sustainable - Cannot compete with China
New Markets	Enabling Sizes, Shapes, Magnetization & Motor Topologies	No Innovation to Spark New Markets
Consumers		
Improved Product Performance	Enabling Sizes, Shapes, Magnetization & Assembly Topologies	Cannot Optimize for Performance and Cost
Lower Cost Products	Enabling Sizes, Shapes, Magnetization & Assembly Topologies	Cannot Optimize for Performance and Cost
Enable New Products	Enabling Sizes, Shapes, Magnetization & Assembly Topologies	Limited Sizes, Shapes, Magnetization & Motor Topologies

TECHNOLOGY	**NON-SINTERED**	**CONVENTIONAL SINTERED**
Supply Chain		
Enables non-REE alloys	Manganese Bismuth (MnBi), Iron Nitride (FeN)	No Solution - Requires REE Rich Alloys
Enables Non-Critical REE alloys	Samarium Iron Nitride (SmFeN)	No Solution - Requires REE Rich Alloys
Enables Non-Sintered Alloys	Neodymium Iron Boron (NdFeB), SmFeN, MnBi, FeN	No Solution - Requires REE Rich Alloys
Manufacturing		
CapEx	Low - Small Footprint, Less Equipment	High - Large Facilities, High Qty. of Equipment, Sintering Ovens
Scaling	Easy to Scale	Does Not Scale Easily
Collocation	Easy to Co-Locate	Cannot Co-Locate
Environment	Ambient	Inert (< 50 ppm Oxygen)
Process Type	Powder-In-Tube	Cold Isostatic Pressing
Process Complexity	Low	High
Throughput Rates	High-Rate with Minimal Equipment	Low Rate - Laborious, Days of Processing
Material Yield (final magnet)	> 95%	70% - 90%
Performance Yield (final magnet)	> 98%	70% - 90%
Magnets		
Shape	Straight, rings, helixes	Small Blocks - Square, concave, wedge
Size (length)	1.5 meter	< 150 centimeter
Magnetization	Uniform, Axial, Single-piece Halbach Array	Uniform
Corrosion Resistance	Sealed in stainless steel jacket	Relies on thin coating of nickel plating
Mechanical Robustness	Virtually Unbreakable	Brittle - Easy to chip or break during handling
Assembly into Products (i.e. motors)	Easy and Safe	Very Difficult & Can Be Dangerous
Magnet Count in Products	Low	High

AML Differentiation – Enable New Material Markets

Market Pathways

Pathways are based on magnet material (alloy) type

Non-Sintered Magnets

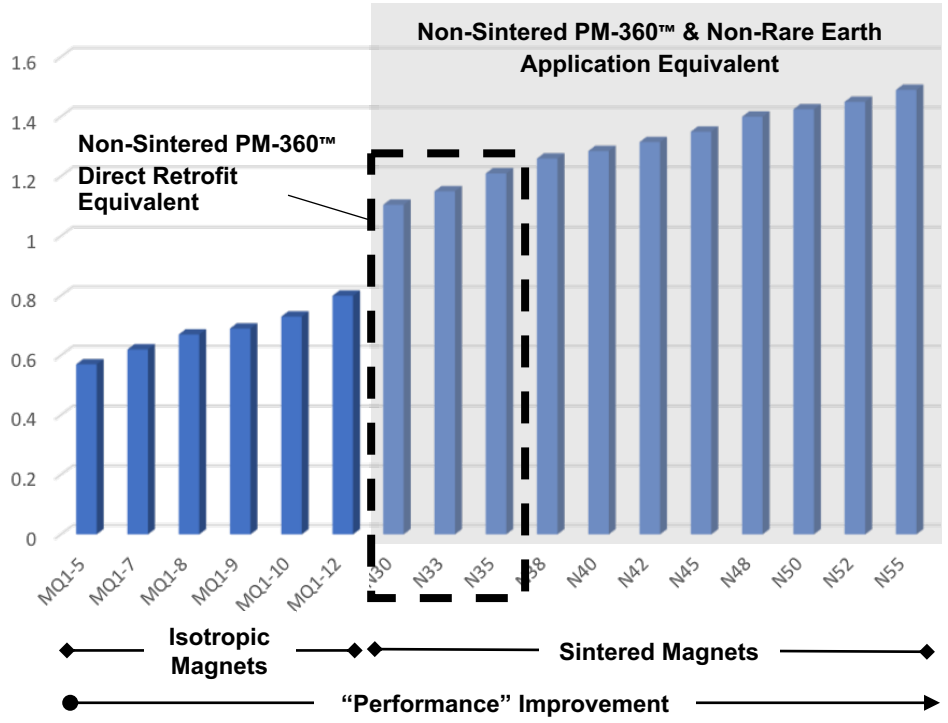
- ✓ PM-Wire™ manufacturing process validated for producing non-sintered NdFeB magnets
- ✓ Ideal for densifying and containing material and eliminates need for a bonding agent
- ✓ Configured as a PM-360™ or PM-AXIAL™ magnets can replace sintered magnets
- ✓ **MITUS Manufacturing Line is ready for Full-Rate Manufacturing**

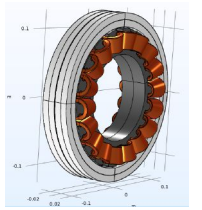
Sintered Magnets

- ✓ PM-Wire™ manufacturing process validated for producing conventional magnets
- ✓ Requires engineering and commissioning Full-Rate Manufacturing automation
- ✓ **Low-rate manufacturing with a focus on defense applications in 2024**

Non-Rare Earth Magnets

- ✓ PM-Wire™ manufacturing process validated for producing non-rare earth magnets
- ✓ Ideal for densifying and containing material and eliminates need for a bonding agent
- ✓ PM-AXIAL™ non-rare earth magnets can replace sintered magnets in motors and generators
- ✓ MITUS Manufacturing Line is ready for Full-Rate Manufacturing
- ✓ **Once materials are commercialization**

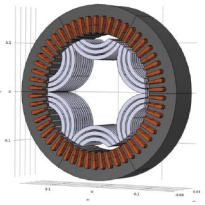




Non-Sintered Validation

OAK RIDGE National Laboratory

EV



Non-Rare Earth Validation

Commercialization Programs

Market Attraction

Gaining attraction for non-sintered magnets

1. Large heavy industries company qualified AML non-sintered magnets and will move forward to test in high RPM rotor in 2024
2. DoE-ARPA-E has approved change from sintered magnets to non-sintered for the ASCEND
3. U.S. defense and aerospace company who is the customer providing the specifications for the ASCEND motor/generator
4. U.S. defense and aerospace company is proposing two projects for motors which us non-sintered magnets
5. U.S. automotive company has an interest in AML's magnets using iron nitride from Niron Magnetics
6. U.S. military branch interested in development of next generation on PM-Wire™ magnet solutions
7. Oak Ridge National Laboratory / DOE project will demonstrate non-sintered magnets can replace sintered magnets for electric vehicles
8. Large Japanese magnet manufacturer has interest in AML magnets which would open new markets for their non-sintered magnets

Market Attraction

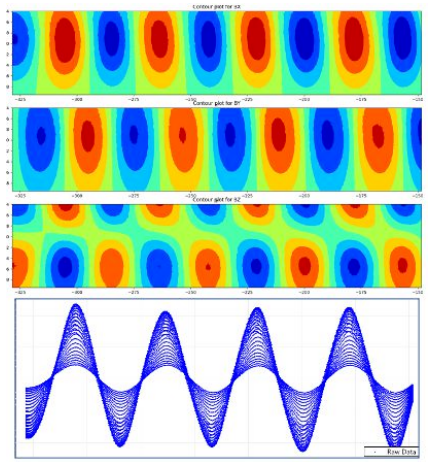
Gaining attraction sintered magnets

1. U.S. Military Branch
2. U.S Defense & Aerospace Companies

Project MITUS - PM-Wire™ Pilot Line
High-Rate Manufacturing of Non-Sintered PM-Wire ™
Funded by the U.S. Department of Defense

Takeaway

Imagine a Magnet Industry Without Limitations



Materials

Enabling less critical rare earth and non rare earth alloys

Magnets & Manufacturing

High-rate, high-yield, high-quality, low CapEx

Magnet End-Use Product

Improving the performance and lowering the cost of the end-use product

Along with our supply chain, governmental and end-use partners,

We are Decommoditizing the Magnet Industry!

Leadership

AML Management

Mark Senti, CEO / Director / Founder

- 30+ years, visionary technology/business innovation leader
- IP, corporate structure, business development, joint ventures
- Cray Research, Founded & Exited – GSMA Systems / robotics

Wade Senti, COO / Director

- 10+ years, corporate accounting, investment banking
- Capital formation, strategic initiatives
- New business development

Dr. Philippe Masson, CTO

- 20+ years, Expert in electrical machines / superconductivity
- Lead electrical machine modeling, development
- AML, Florida State Univ., Univ. of Houston

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

Marshall Heard

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

Raj Gutta

- Medical Doctor
- Entrepreneur
- Investor

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

Bill McCollum

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

Vernon Prince

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

AML

Reimagining the Magnet Technology that Drives the World

AML-Enabled.com

Corporate Address

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Melbourne, FL 32901

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Magneto
Making Better Magnets
USA