



Machine Learning and Artificial Intelligence Algorithm for Defect Characterization and Diagnosis

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Aluminum Casting Performance Initiative
(ACPI)

AMC Technology Review

June 24-25, 2026





A horizontal timeline diagram with a green bar. The bar is divided into three segments by vertical lines. The first segment is labeled '1', the second '2', and the third '3'. Below the first segment is a box labeled 'YEAR'. The word 'DURATION' is written in white text across the middle of the green bar.

Overview

- **Needs and Benefits**

- Problem: Misdiagnosis of A356 Defects
- Objective: Develop image based defect diagnosis system
- Technology: AI/ML Cloud hosted algorithm

- **Progress**

- Casting Matrix
- Gold Standard Castings
- Algorithm/Website Host Development

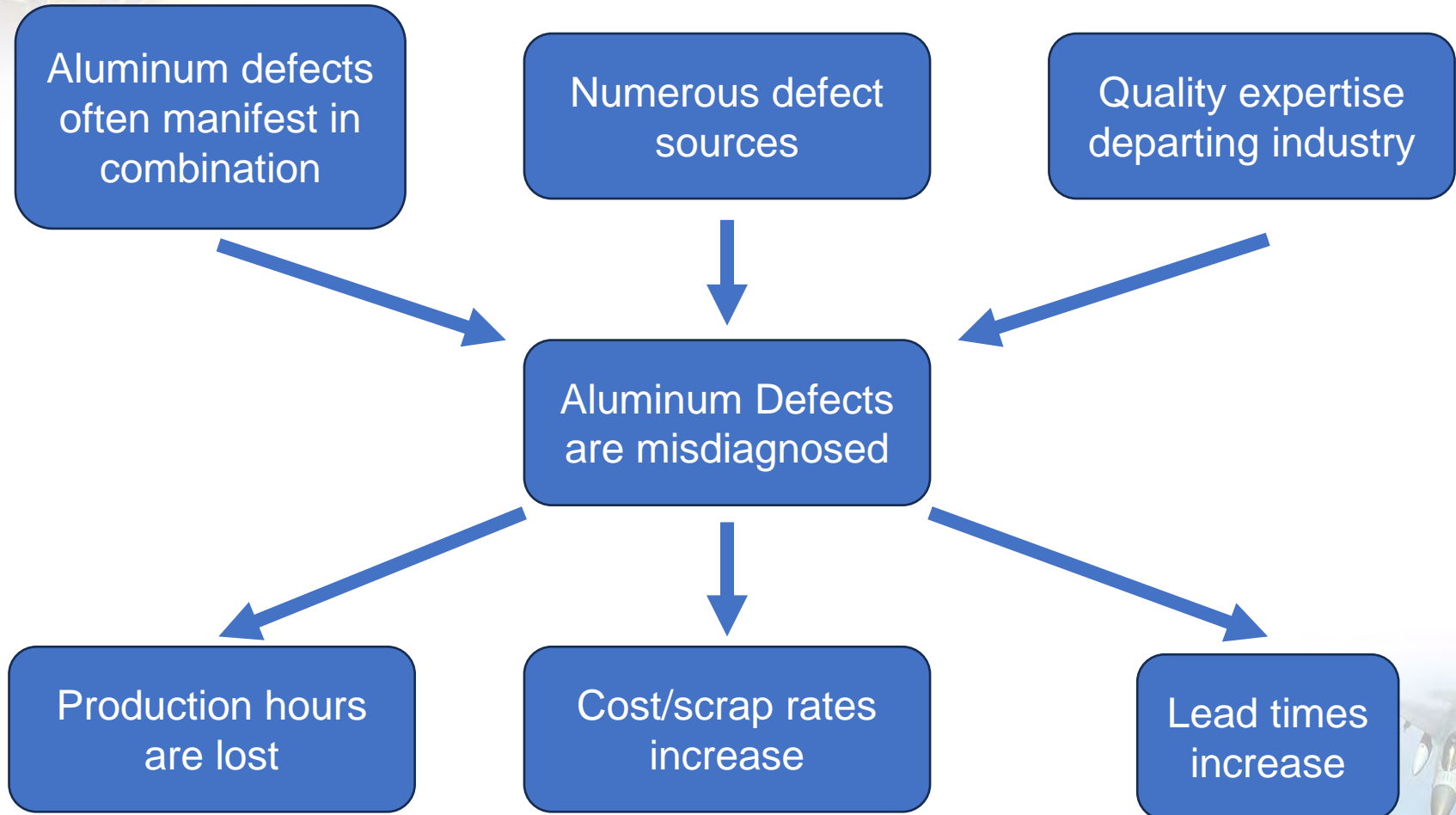
- **Transition**

- Webinars, Publications, and Division Meetings

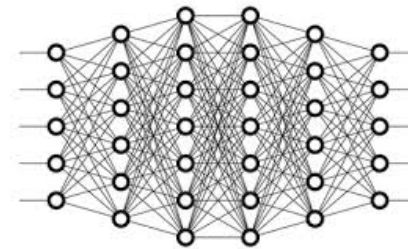
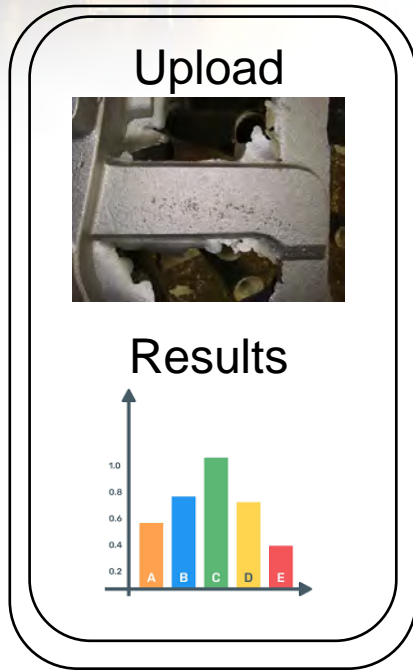
- **Cost Share Provided**

- \$184,696 provided to date out of \$453,393 proposed

Needs – Problem



Needs – Objective



Gold Standard Defect Training Images - UCI, supported by AFS

Cloud-stored AI Image Diagnosis System—Adjacency ML, supported by AFS



Industry Training Images – AFS Member Foundries or other consenting parties

Interface and Web application – Objective Inc, supported by Adjacency ML and AFS

Benefits

- Improvements in corrective action effectiveness would:
 - Decrease lead times
 - Lower scrap rates
 - Reduce quoted cost per part
- Long term
 - Apply trained AI directly to 357 or 359 alloys
 - Train similar AI to other aluminum alloys or even steel/iron/titanium



From “Apache” to “Zumwalt”
A356 is the most common
aluminum casting alloy





Benefits

“I think the defect/ diagnosis project is vital to helping reduce lead time and scrap directly impacting costly delays to USN projects. This impacts both new builds and aftermarket orders.”

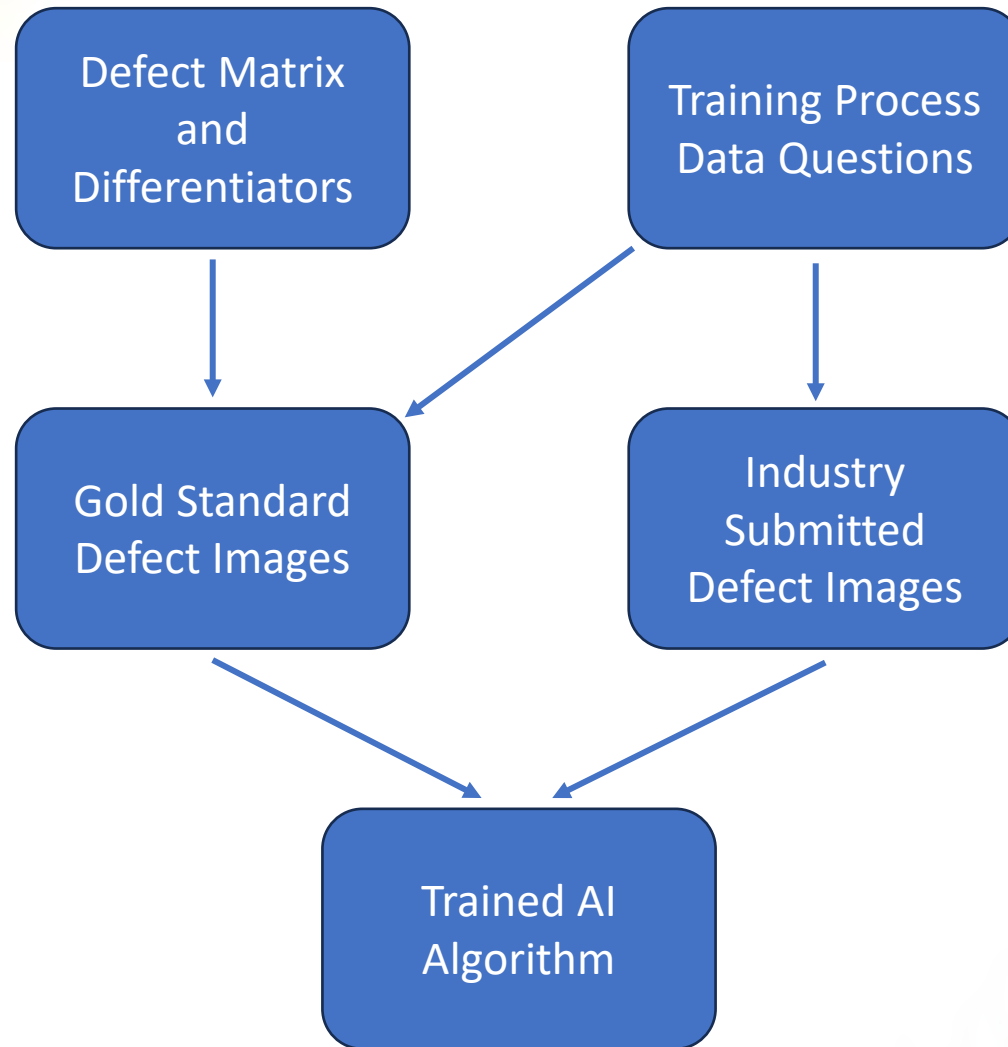
Luke Schimmel
Director of Materials Engineering
Fairbanks Morse Defense



Milestones/Tasks

- In Progress
 - Develop gold standard casting matrix plan
 - Create gold standard castings and images
 - Create ML/AI defect diagnosis algorithm
 - Create integration of algorithm into web browser
- Planned
 - Collect and classify industry defect images
 - Complete case study using completed model

Technical Progress – First Steps



Technical Progress – First Steps

- Defect matrix
 - Common visually observable defects
 - Other testing methods to verify defect

<u>Defect Type</u>
Hydrogen (soluble gas)
Grain Size Microshrink
Volumetric Shrink
Old Oxides
New Oxides
Gas (insoluble)
Eutectic Shrink
Molding Media
Sludge (TiBor)
Intermetallics

<u>Defect Differentiators</u>
H level (HYCAL)
Specific Gravity
Thermal Analysis
K Mold
OES (A356)
Ti Target (%)
B Target (PPM)
Sr level (PPM)
Degas/Upgas
Flux (Y/N)
Grain Refiner (Y/N)
Sr Modification (Y/N)

Technical Progress – First Steps Con't.

- Training data process questions
 - Process questions that assist in characterization of defects
 - Integrated survey-like system

QUESTION 17

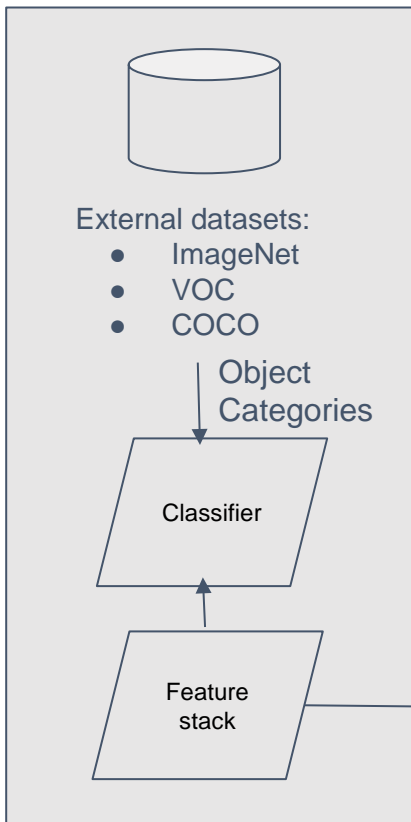
What do you think the defect is?
(select all that apply)

- Hydrogen (soluble gas)
- Grain Size Microshrink
- Volumetric Shrink
- Old Oxides
- New Oxides
- Gas (insoluble)
- Eutectic Shrink
- Molding Media
- Sludge (TiBor)
- Other

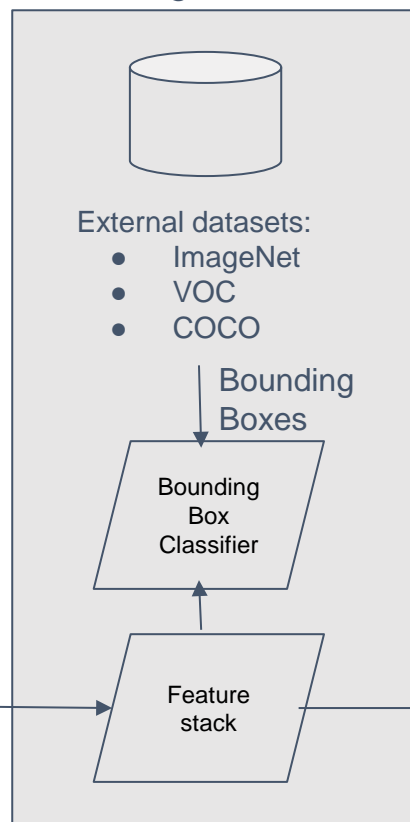
Process Questions	
What is the aluminum casting alloy?	What is the grain refinement method used? (Check all that apply)
What is the molding method?	Eutectic Modification? (Check all that apply)
If cores are used, how are the cores manufactured?	Do you use filters (Check all that apply)?
What is the pouring temperature rounded to nearest whole number?(1250- 1550F)(676 - 843C)	Do you use a parting agent?
What is the process used for degassing?	Mold media (if in sand)
What process controls are in place for hydrogen testing?	What is the flux procedure?
What post casting processing was performed? (check all that apply)	What do you think the defect is? (select all that apply)
Where was the defect located? (Check all that apply)	Feeding aids in proximity (within 1") w/ defect?
Titanium (Ti) levels	

Technical Progress – Algorithm Training

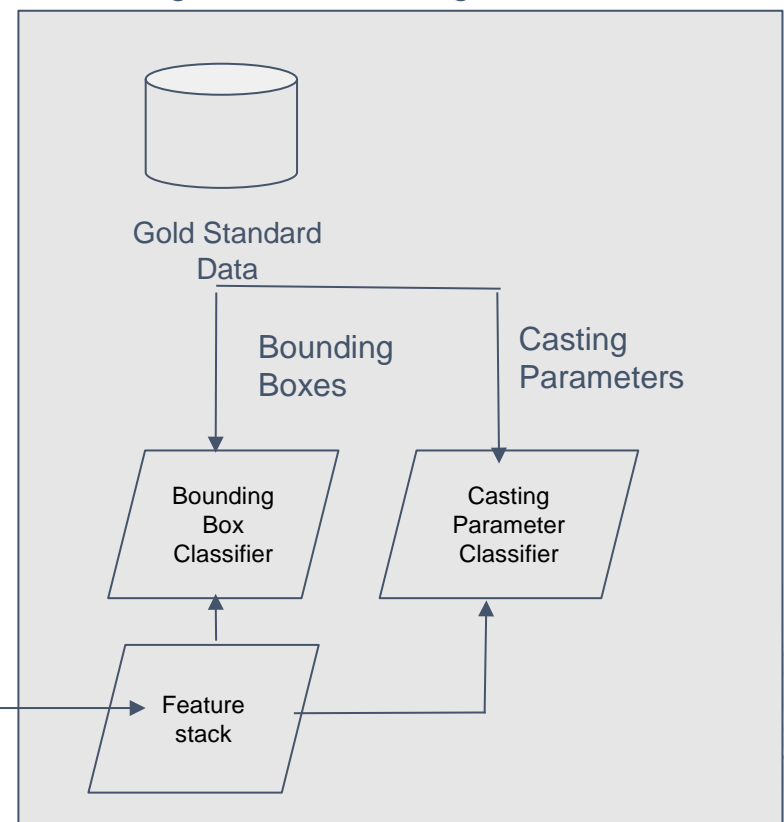
Pretraining: Classification



Pretraining: Bounding Boxes



Task Training: Bounding Boxes + Casting Parameters

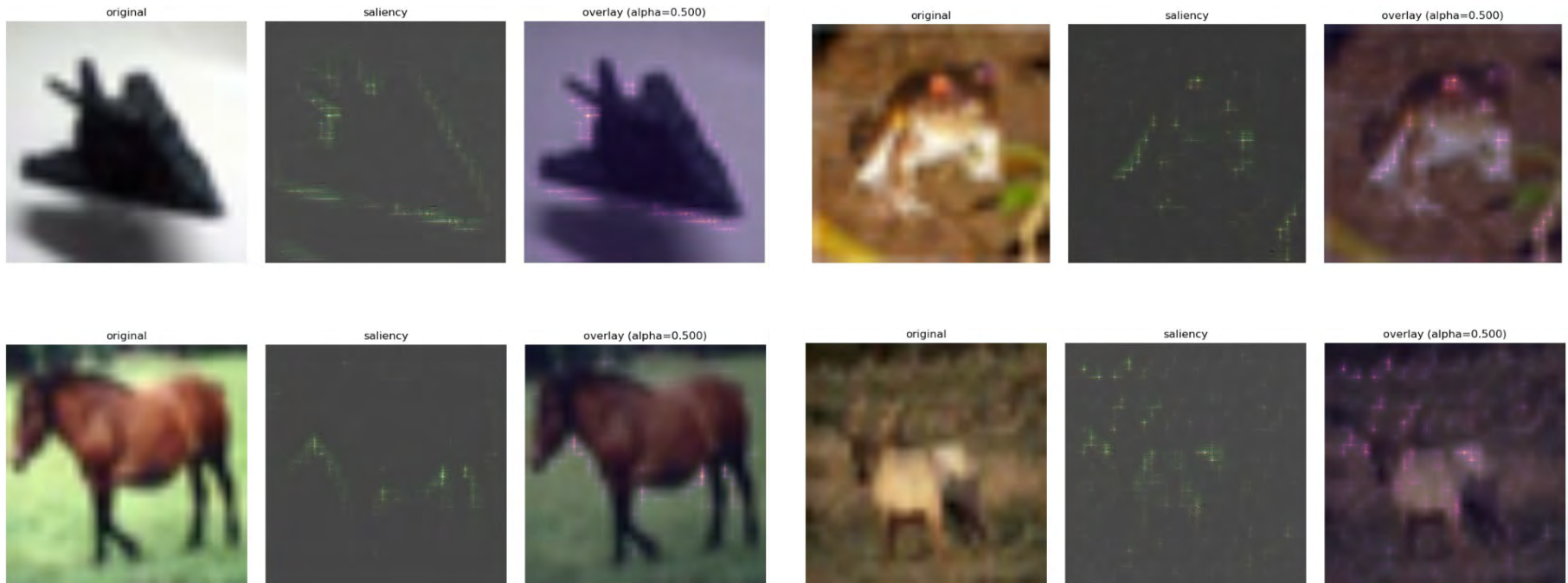


Technical Progress – Algorithm Training

- Base of Deep Convolutional Model
 - Features
 - YOLOv2 - Bounding Box Loss Function
 - AutoAugment – Data Augmentation
 - Mixed Task Training – Training Function
 - Guided Back Propagation – Visualization Function

Technical Progress – Algorithm Training

- Guided Back Propagation
 - Allows us to see what the algorithm is using to classify

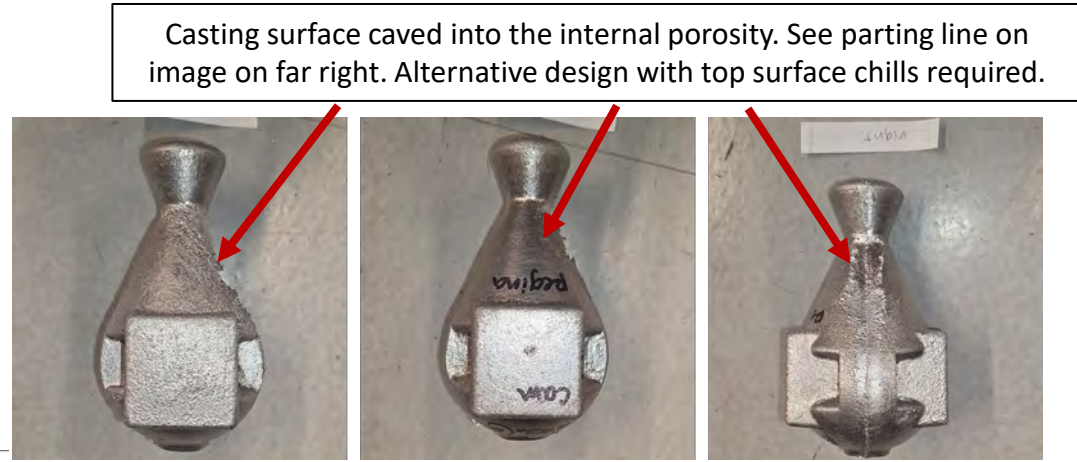
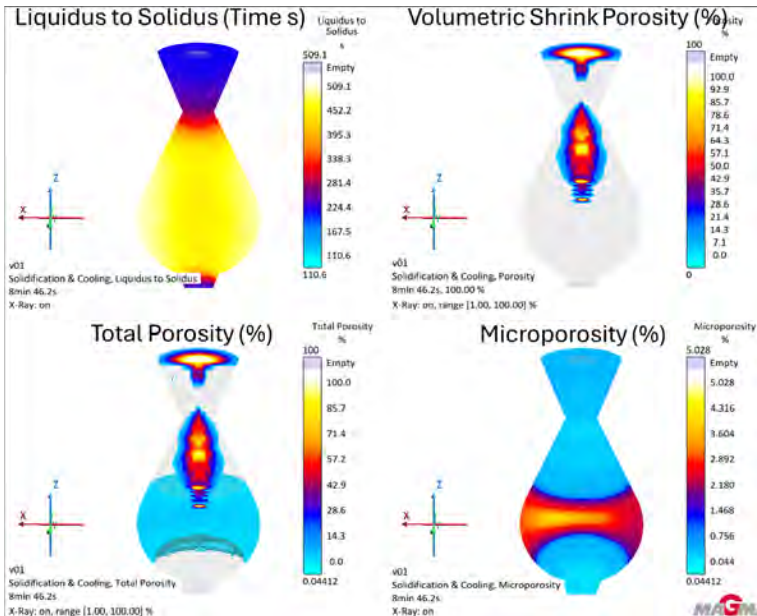


Technical Progress – VSP Convex Mold



Smaller riser/feeder compared to the previous design to prevent feeding.

Simulation of Porosity Distribution



Casting surface caved into the internal porosity. See parting line on image on far right. Alternative design with top surface chills required.

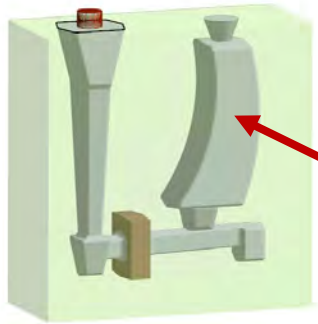
600 grit SiC paper

Higher magnification resolves porosity well. Less impact of light reflection.

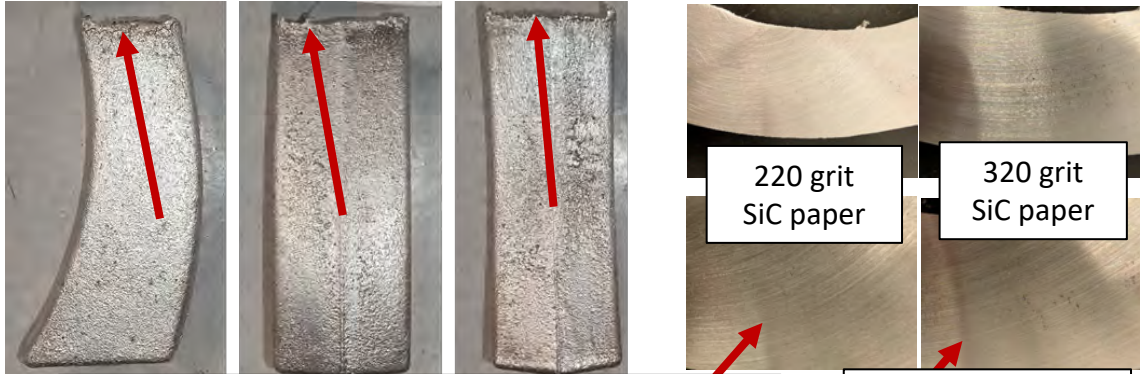


Greater polish of surface exaggerates the light reflection in sample. What are required light conditions?

Technical Progress – VSP Concave Mold



Convex and concave surface with undersized riser/feeder



220 grit SiC paper

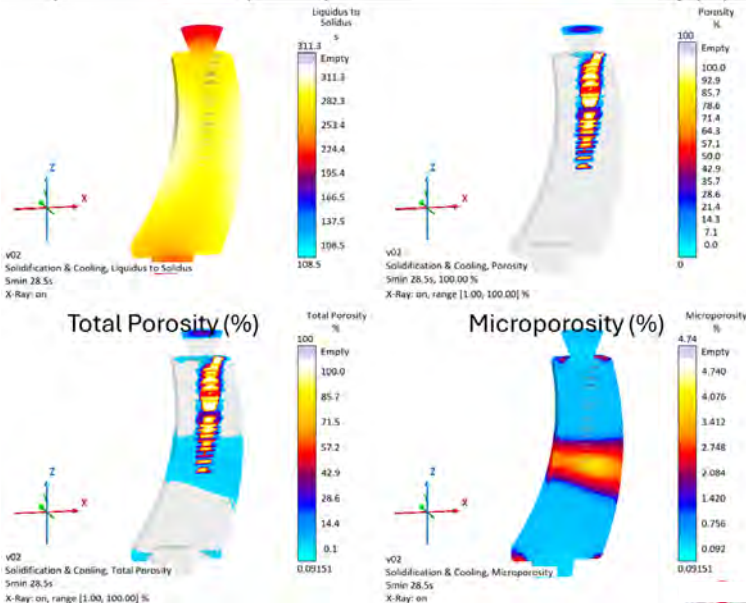
320 grit SiC paper

Simulation of Porosity Distribution

Top of casting surface slightly caved into the internal porosity. This is partly predicted by simulation.

Smaller porosity requires at least a 320 grit polish to resolve porosity.

Liquidus to Solidus (Time s) Volumetric Shrink Porosity (%)



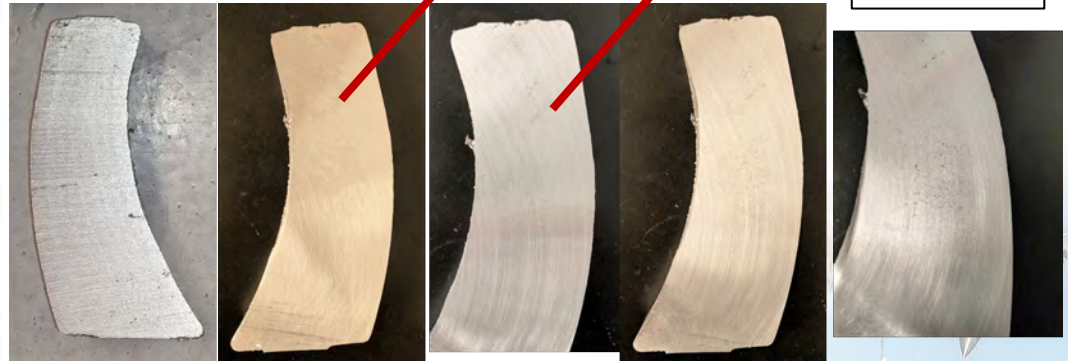
Band saw

220 grit SiC paper

320 grit SiC paper

400 grit SiC paper

600 grit SiC paper



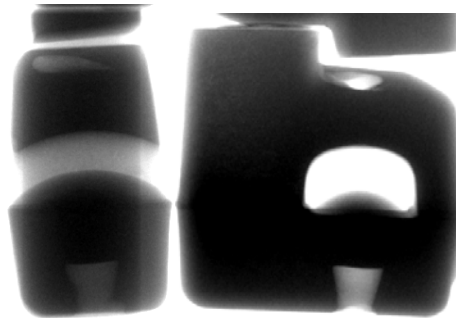
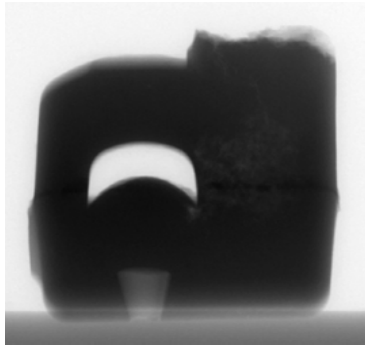
Rough

Smooth

Technical Progress – New VSP **AMC** Molds

AMERICAN METALCASTING CONSORTIUM

Insoluble gas defect molds



Volumetric shrink molds



DISTRIBUTION A. Approved for public release.



Project Plans

- Prepare Gold Standard Casting Images
 - Volumetric Shrink Porosity (In Progress)
 - Insoluble Gas Porosity (Just Started)
 - Soluble Gas Porosity
- Finish Single Defect List
- Plan for defect combinations
- Continue Algorithm Training
 - Classifier Pretraining
 - Bounding Box Pretraining
 - Integrate GSC Images into Multitask Training

Transition Plan For Industry

Events



Website/Webinars



Publications

International
**Journal
of
Metalcasting**



Committees



Leveraging

- AFS Technical Committees – ALM Division
 - Valued input from metalcasters, casting designers, and buyers in defense and commercial applications
- Relevant AFS Projects
 - AFS Funded – 20-21 #02 Quantifying Aluminum Casting Quality Through H Gas
 - AFS Funded – 20-051 Quantifying Casting Quality Through Filling Conditions
 - EMCS - Surface Defects Project
 - EMCS - Virtual Knowledge Transfer
- Cost Share – \$184,696 of \$453,393 required

Project Metrics

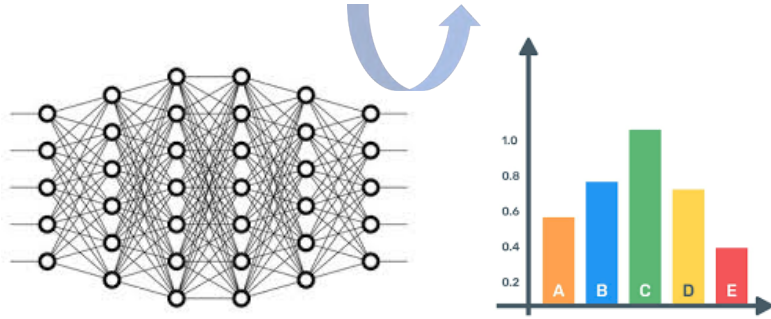
Description	Baseline	Threshold	Goal	How Measured	Target Date	Progress	How Demonstrated
Algorithm Accuracy	No similar algorithm currently exists	mAP 80%	mAP 90%	Classification for datasets, differentiators for defects	May 2028	Bounding Box Pretraining in progress	Internal verification testing and training tools
Initial Industry Submitted Image Dataset	No industry database exists	500	1000	Website Metrics	3-4 Months before end of training (Est. 08/2027)	Not Started	# of unique image submissions
Initial Gold Standard Image Dataset	No gold standard database exists	3000	6000	UCI Generated Images	3-4 Months before end of training (Est. 08/2027)	5%	# of unique defect image uploads
Usage Metrics	No website exists	50 Inquiries for Diagnosis	100 Inquiries for Diagnosis	Website Metrics	May 2028	Not Started	# of unique defect inquiries
Review w/ AFS Technical Committees	Review on other projects 3/year	2/year	3/year	Attendance and Participation	Ongoing until May 2028	On Target	Meeting Minutes

Acknowledgements

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Machine Learning and Artificial Intelligence Algorithm for Defect Characterization and Diagnosis

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Problem

- Aluminum defect diagnosis expertise has largely left industry. Defect misdiagnosis causes lost production hours pursuing ineffective solutions

Objectives

- Develop an AI-based defect diagnosis system that characterizes defects in A356 castings from a picture using optical feature recognition

Benefits to Warfighter

- Improved accuracy in diagnosing defects will help minimize lead time, lower costs, and improve quality in aluminum metal castings. Capturing workforce knowledge in an AI algorithm will help transfer to a new generation of metalcasters and DoW casting users

Description of Project

Develop a machine learning based algorithm for A356 alloy systems for rapid, accurate macro defect characterization,

Team: American Foundry Society, ATI, University of California-Irvine, Adjacency ML Analytics LLC, Objective



Milestones / Deliverables

- Finalize matrix of castings for gold standard images
- Develop gold standard images of defects and incorporate industry supplied defect images
- Complete working algorithm for ML/AI interpretation of defects
- Complete interface for defect characterization algorithm
- Complete case study using developed model
- Final report and industrial presentations