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Leveraging Artificial Intelligence to Improve RAM Inspection Analysis

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Discussion Notes

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- Presenters:
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- Agenda
  - Introduction
  - Problem/Challenges
  - Computer Vision Overview
  - Computer Vision Application
  - Impact
  - Summary and Path Forward

Introduction

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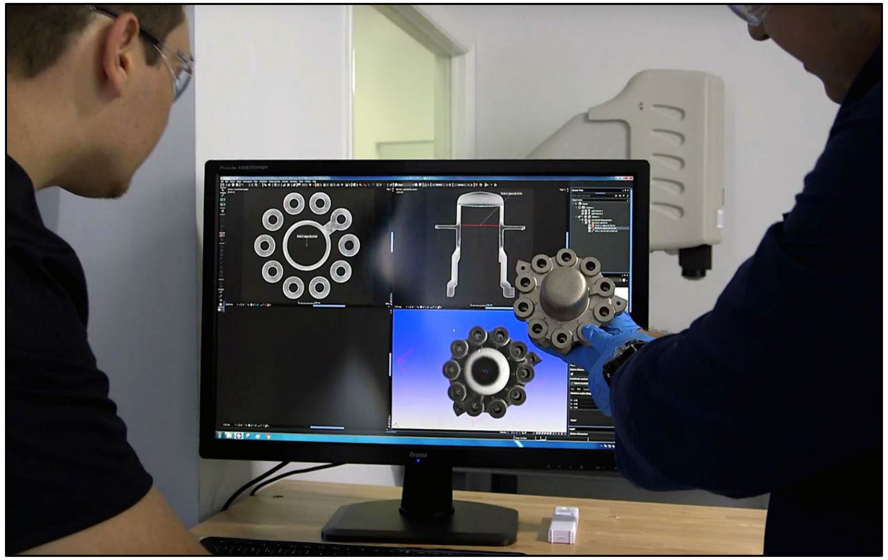
- RAM ensure defenses systems are high quality, affordable, supportable, and effective to sustain
- Nondestructive testing (NDT) is a set analysis techniques used to evaluate the properties of a material, component or system without causing damage
  - X-Ray and CT technology are two common NDT techniques used to:
    - Detect surface and subsurface defects
    - Ensure items were built to design standards
    - Detect internal anomalies (cracks, voids, missing parts, wire breaks, manufacturing defects etc.)
    - Identify Corrosion



Courtesy of EngineerLIve.com

While NDT has improved RAM analysis, with imaging fidelity continuing to increase, the resulting efficiency of the analysis has stifled its benefits

Challenges

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- RAM inspection analysis of manufactured components is difficult because most noted defects are challenging to accurately and consistently characterize
  - The shape, size, and material of the manufactured components can compound the difficulty of the defect identification
  - The fidelity of some RAM inspection methods are vital to the accuracy of its analysis with many current methods not sufficient for critical manufactured components
- Conclusive performance consequences of certain component defects are unknown, so consistent and reliable analysis is critical to accurately distinguish potential use
  - A commonly-employed human review and analysis process is <u>extensive and time consuming (weeks)</u>

<u>Human Analysis Problems:</u>

- Human Error
- Time Consuming, Expensive Review Process
- Limited Qualified Supporting Radiographers
- Real Defects vs. Mimics are Subjective
- Defects Span 3D, Scans in 2D
- Process Unsustainable for Increased Production Rates

The commonly-implemented human analysis of the component CT scans is slow, expensive, subjective and prone to errors expected to result in significant downstream issues

Computer Vision

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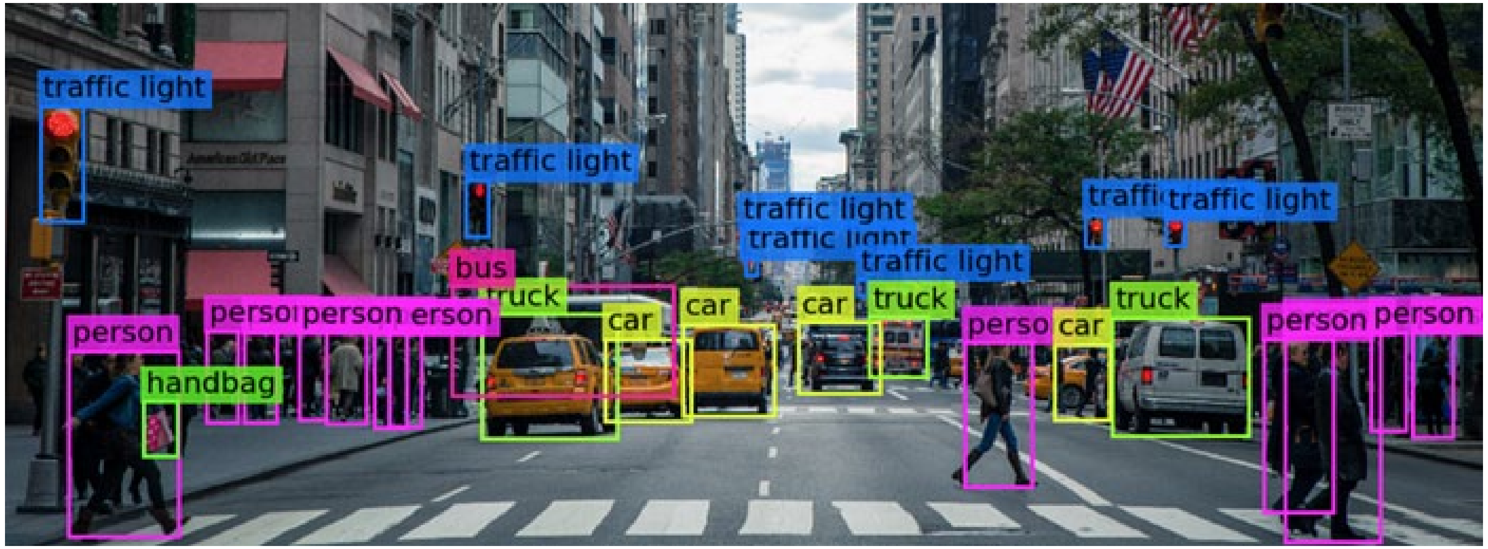
- Artificial Intelligence (AI) is increasingly becoming an integral aspect of society, transforming how we live, work, and interact with the world
  - The effective use and implementation of AI is helping to drive innovation and efficiency in a multitude of industries, ranging from finance and retail to education, entertainment and defense
- Computer Vision (CV) is a field within AI that focuses on enabling computers to analyze and understand visual information, much like humans



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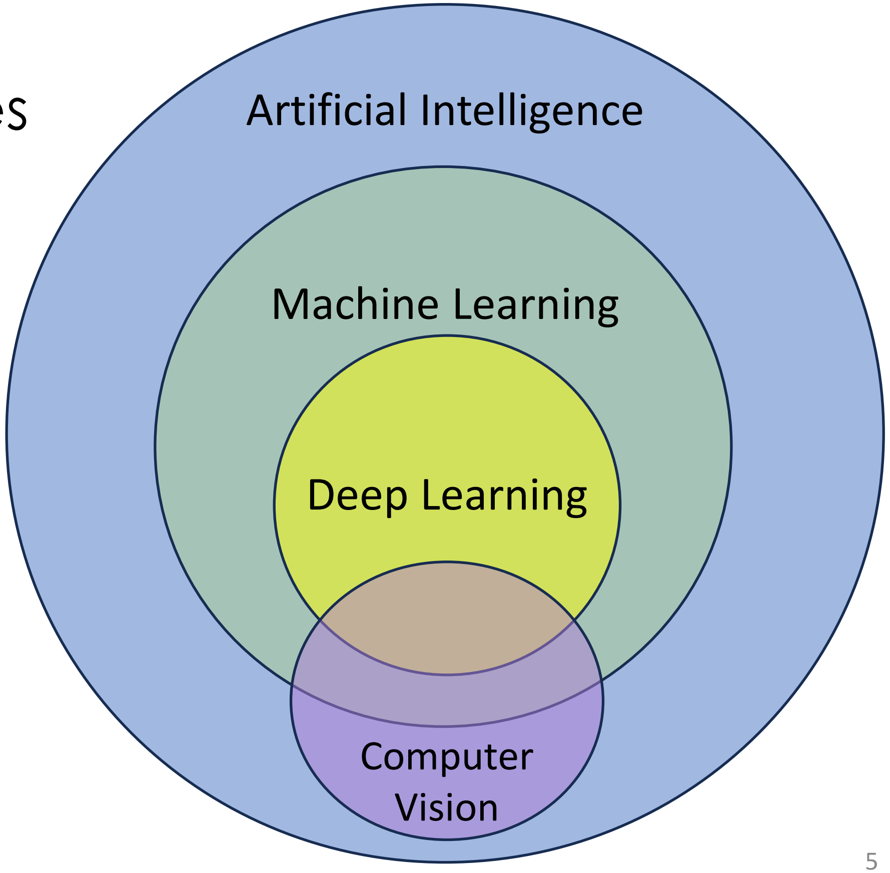
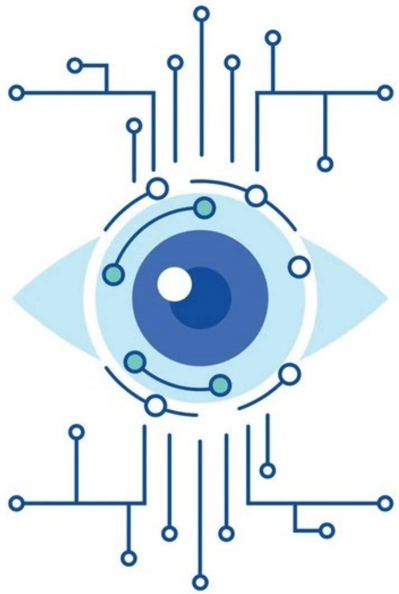


Traditional Computer Vision

- Computer Vision (CV) seeks to extract high-dimensional data from real-world visual data to produce numerical or symbolic information, typically in the form of a decision
  - The classical CV problem is to determine if some specific object, feature, or activity is present within an image



Computer Vision Implementation Expectations

Task Complexity	Task Description	Training Requirements	Training Time	Required Hardware
Low	Detect simple patterns and features	10 - 1000 Images	Hours	Consumer-Grade GPU Hardware
Medium	Detect objects in varied environments	10,000+ Images	Days	Mid/High Consumer-Grade GPU Hardware
High	Detect objects and features in diverse and cluttered environments	100,000+ Images	Weeks	Larger, Server-Grade Hardware

Computer Vision Applications

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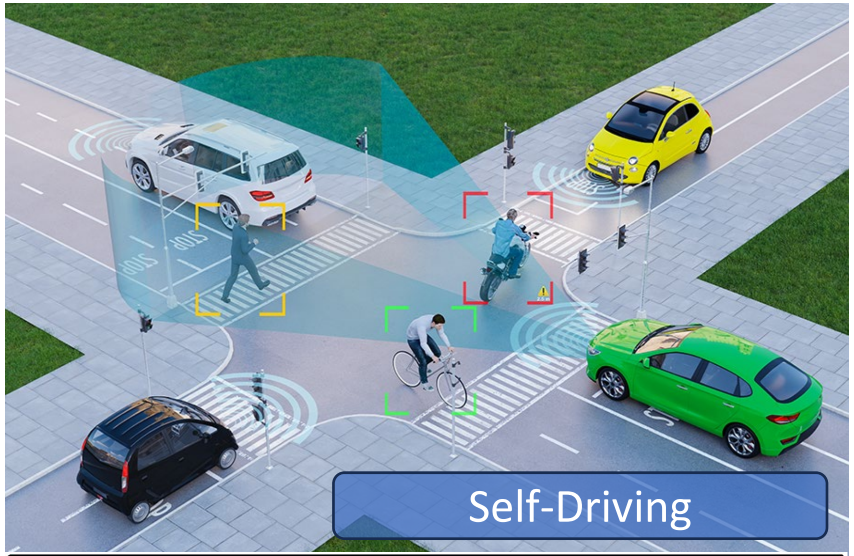
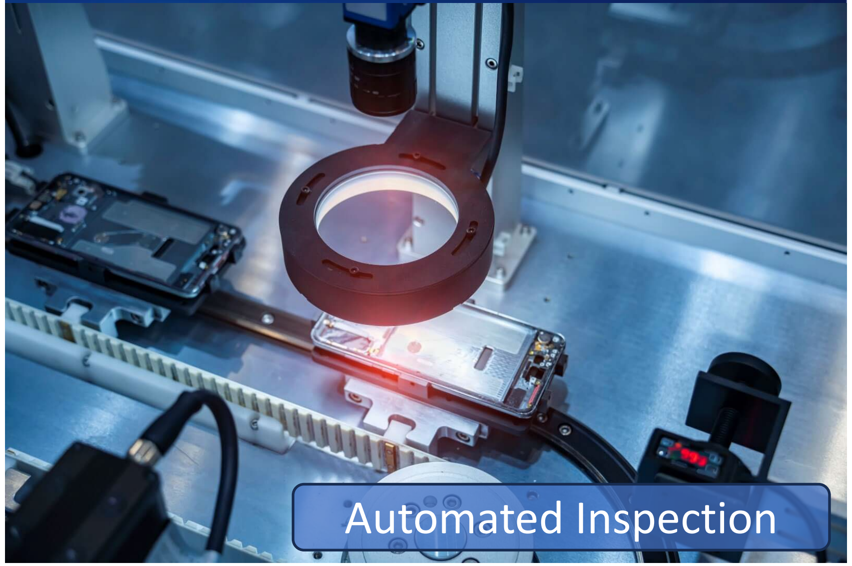
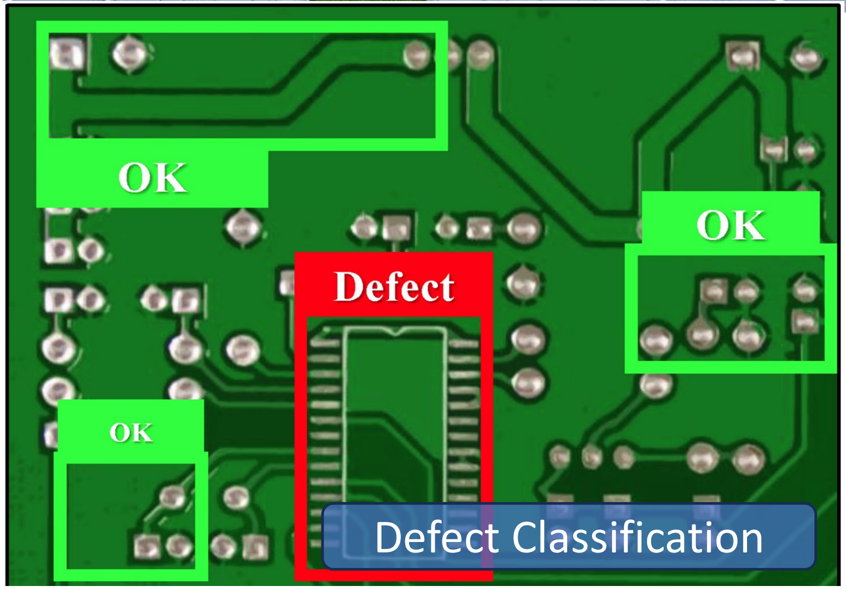
Courtesy of TechCody.com

Courtesy of Edge-AI-Vision.com





Courtesy of ElectronicsWeekly.com



Courtesy of MDPI.com

Solution: Implementation

- Solution - a hybrid, multi-model architecture
  - Base layer for detecting a broad array of objects within various X-ray and CT images
    - Handles object detection and determines object location within imagery
    - Does not require additional training to learn new components
  - Specialized layer for precise defect detection
    - Tailored to specific components
    - Learns the "ideal" component structure

Solution Goals

- ✓ Reduce training requirements and costs
- ✓ Reduce inspection workload
- ✓ Increase inspection throughput without removing human input in the inspection process
- ✓ Allow new component models to be added quickly and at low cost

Multi-Model Implementation Simplifies the Training Process For New Components

Solution: Training Requirements

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Base Layer

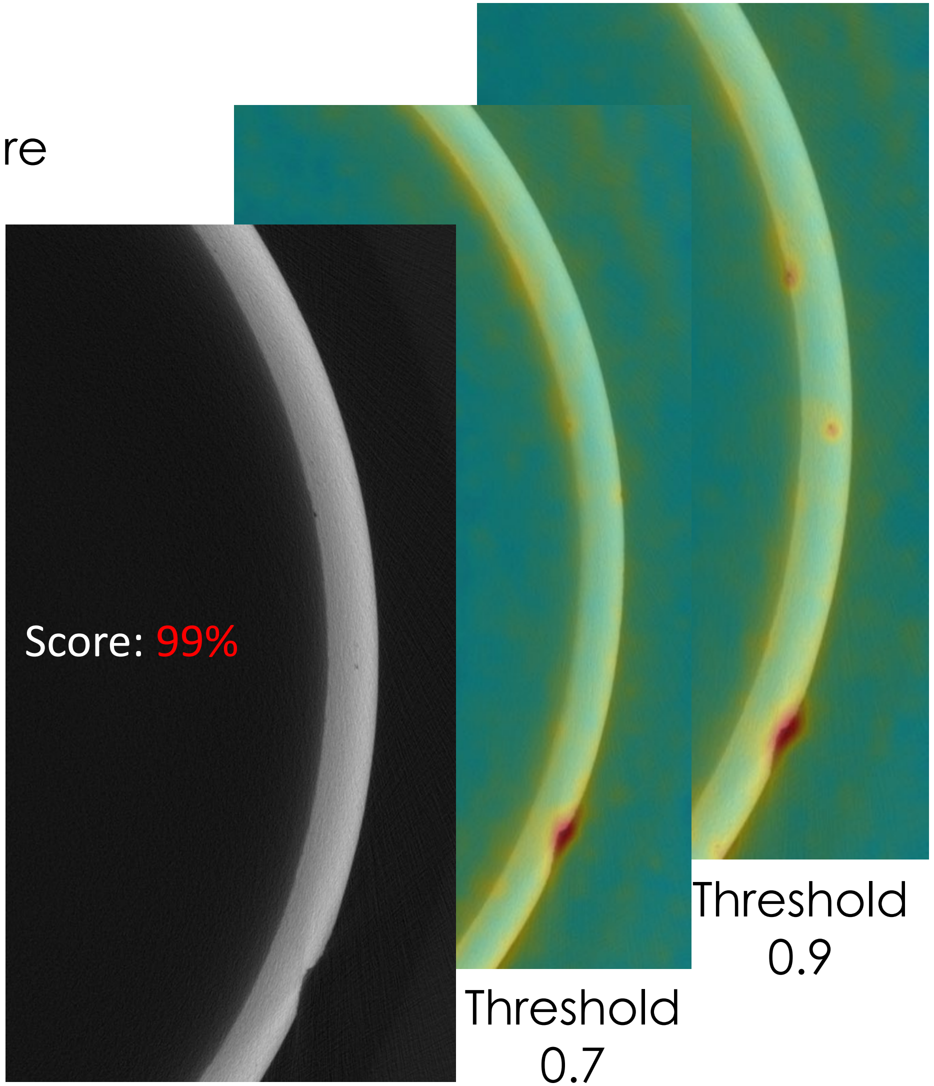
- Built using a large Convolutional Neural Network (CNN)
- Trained on a wide array of X-ray and CT images to extract objects of interest
    - Trained using ~20,000 images
    - Requires days of runtime and specialized hardware
- Allows the specialized model layer to be relatively simple in comparison
- Does not attempt to classify or label detected objects
- Does not need to be retrained to learn new objects

Specialized Layer

- Built using a much smaller CNN
- Training is tailored to a specific component
    - New models are required per component to be analyzed
- Much smaller training data requirements
    - Only 500-1,000 images per model
    - Training images do not need to be labeled or annotated
    - Training images should be of "ideal" components, which passed a human inspection
    - Can be training in under 1 hour on consumer grade hardware

Solution: Performance

- Inference - running of the trained model
  - Far less resource intensive than training
  - Analyzes 1 - 5 images per second on consumer hardware
    - Tested with NVIDIA 3080 and 4090
- Provides an adjustable detection threshold
  - Used to increase or decrease detection sensitivity
  - Higher sensitivity will increase runtime
    - Does not necessarily increase detection precision
    - Does increase the ability to find smaller defects
- Each resulting image is given an overall detection score
  - This score is the likelihood that an image contains at least one defect
  - Any detected defects will be highlighted for the analyst
  - Images can be filtered from the analyst's results based on detection score



Threshold 0.9

Threshold 0.7

Solution: Limitations

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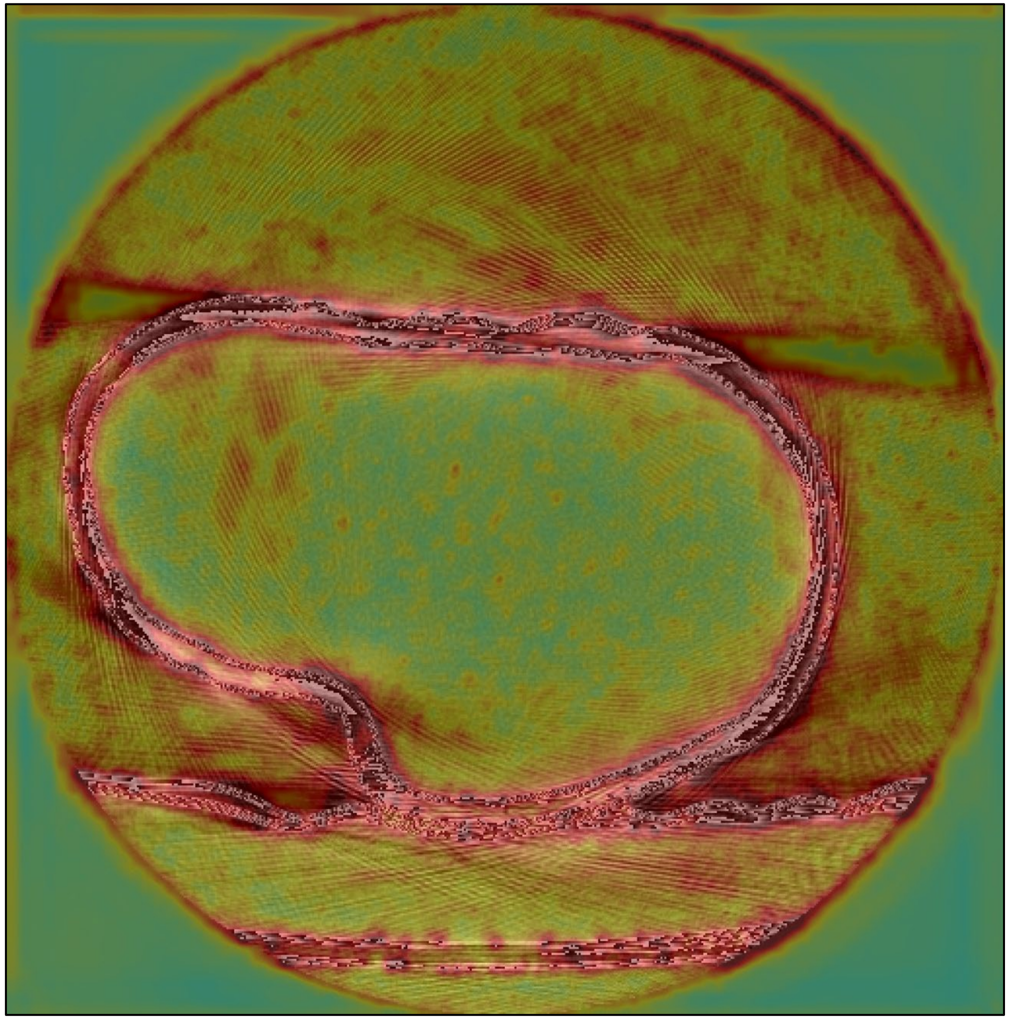
- Nominal, non-defective images are required for training
- All training images must fit within GPU memory during training.
- New components, alterations to existing components, and alternative scan angles require new models
- Component orientation is limited to ~10-12 degrees to maintain accuracy



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Impact

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- The implementation of Computer Vision within RAM analysis can provide an increase in detection accuracy and significantly reduce time/cost
  - Estimated 86% Effort Reduction – using an example effort
  - Some anomalies found in structures using Computer Vision were not noticeable by human team

Manual (Current) Review Approach				
Step	**Task Description**	**# of Individuals Involved**	**Hours Estimate (each)**	**Total Hours Estimate**
1	Individual Reviews	4	8	32
2	Group Review	15	2	30
3	In-Depth Flagged-Item Analysis	8	4	32
4	Designation Confirmation Meeting	8	2	16
			Total Hours Estimate	**110**

Computer Vision Approach				
Step	**Task Description**	**# of Individuals Involved**	**Hours Estimate (each)**	**Total Hours Estimate**
1a	Algorithm Multi-Image Analysis (X-Axis)	0	1	1
1b	Algorithm Multi-Image Analysis (Y-Axis)	0	1	1
1c	Algorithm Multi-Image Analysis (Z-Axis)	0	1	1
2	Group Review	4	1	4
3	Designation Confirmation Meeting	8	1	8
			Total Hours Estimate	**15**

The integration of Computer Vision within RAM analysis can lead to significant time and effort savings, allowing analysts, engineers, and inspectors to focus on other aspects of the inspection process

Conclusions and Future Work

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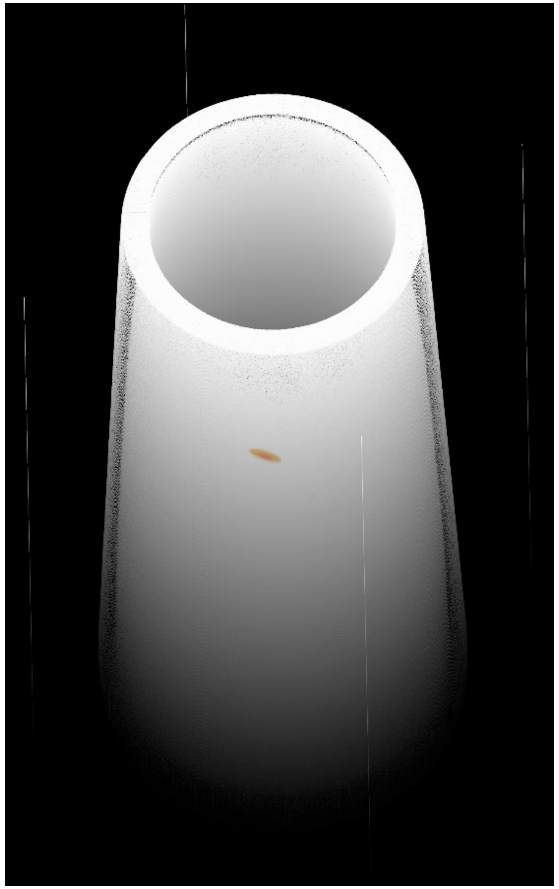
Reliability and maintainability practices can utilize technological innovations in AI and ML to increase detection accuracy, leading to significant time and cost reductions for manufactured component inspection analysis

Future Work (for RAM implementation)

- Reduction of training requirements to increase accessibility and decrease training costs
- Precise reporting and defect classification to aid in the inspection and review processes
- 3D modeling of components and detection locations to allow rapid manual inspection
- CV models to support portable scanners and enable defect detection in the field
- Leveraging CV to utilize optical imaging for microelectronic inspection and analysis



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Questions

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