



SUSTAINMENT MANAGEMENT SYSTEM (SMS) SUMMIT 2026

September 1st-2nd, 2026
Starting 0800 Central



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US Army Corps
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ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER





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2026 Sustainment Management System (SMS) Virtual Summit

Hosted by the Sustainment Management
Technical Center of Expertise (**SMS-TCX**)





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Meeting Format/Logistics:

- Attendees are muted by default
- If you have a question, use the “raise hand” feature
- Once you are “brought on-screen” unmute yourself and turn on camera if desired
- Alternatively, you can pose questions using the Chat feature with attendees and presenters
- Interactive polls at different points during the discussion

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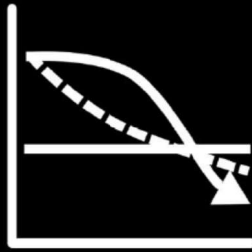




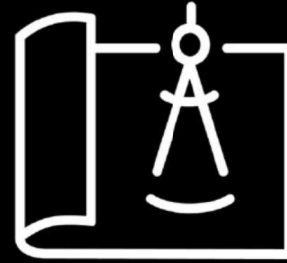
INVENTORY



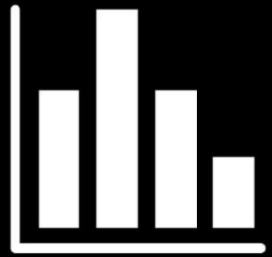
ASSESS



FORECAST



PLAN



ANALYZE



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SMS SUMMIT: DAY 1 AGENDA



- 0800 – 0830** Welcome and Agenda Overview
- 0830 – 0930** Development Update and Brief E-SMS Demo
- 0930 – 1000** Break
- 1000 – 1100** Keynote: Mr. Mark Sinder
- 1100 – 1200** Buildings Migration Lessons / Status
- 1200 – 1300** Lunch
- 1300 – 1400** Utilities Domain Demonstration
- 1400 – 1430** Break
- 1430 – 1530** Rail / Fuels / WCS Demonstration Assessment

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SMS SUMMIT: DAY 2 AGENDA



- 0800 – 0830** Day 1 Recap / Day 2 Agenda Intro
- 0830 – 0900** ORTT PLA Session
- 0900 – 0930** Break
- 0930 – 1030** Third-party Integration Framework
- 1030 – 1100** Break
- 1100 – 1200** FSRM Optimization Update and Demonstration
- 1200 – 1330** Lunch
- 1330 – 1430** Leveraging AI for Assessor Training
- 1430 – 1530** SMS Innovations Lab

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E-SMS DEVELOPMENT UPDATES

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E-SMS Published Releases since August 2025 – 36 (.609 to .644)

Features – 90

Bugs – 621

Changes – 226

<https://support.sms.erd.c.dren.mil/news/e-sms-release-notes>

The screenshot displays the E-SMS Enterprise System interface. On the left is a navigation sidebar with options like Home, Inventory, Organizations, Sites, Assets, Components, Groups, Assess, Work, Catalog, Reference Books, and Administration. The main area shows 'Asset Search | 249 Results' with a map and a table of assets.

RPUD	Asset Number	Asset Name
10087556	3214	FUEL TANK A
	37872	LITTLE FORK DAM
100893484	21018	SOLID WASTE REPOSITORY
200952216	22	BARRACKS 22
90038149	3368	MAINTENANCE BUILDING
100967794	4262	GEOTHERMAL HEAT PLANT BU
90058558	3242	RUNWAY LIGHTING
100818792	1012	TRAINING RANGE W
100812290	1006	TRAINING RANGE C
90040858	3606	RAIL MAINTENANCE SHOP
20088724	1226	WATER WELL

Overlaid on the bottom right is a 'Component Search' window for 'ROOF W [In-Service]' showing details for a specific asset. Another window titled 'E-SMS Release Notes' is overlaid on the bottom right, showing a list of releases with dates, versions, and authors.

E-SMS Release Notes

- JUL 7 2026** E-SMS Sandbox 1.10.643 1.10.644 Release Notes (Brandon Athey)
- JUN 2 2026** E-SMS Sandbox 1.10.642 Release Notes (Brandon Athey)
- MAY 5 2026** E-SMS Sandbox 1.10.639 - 1.10.641 Release Notes (Brandon Athey)



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DEVELOPMENT UPDATES

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E-SMS Field App Validation Events –

Locations: CERL (3x), USACE Ft. Worth, Ft. Lee, Camp Ashland

Attendees from: DHA, AMC, USACE, ARNG, USAR, MILDEP Representatives

Outcomes: Numerous feature enhancements, bugs identified/fixed, and efficiency gains

Component Search **ROOF W [In-Service]**

No images yet
Tap to add a photo

Uniformat
D304008

Last Assessment
3/11/22

Installation Date
1/1/90

Repair Date
None

Design Life
None (Specification)

Specification
Air Handling Unit, Central Station, 5000 CFM, VAV

CI
100

Age
None

Effective Age
None

Remaining Design Life
None

Description
None

Replacement Value
\$0.00

Remaining Service Life
None

Quantity
1 Each

Comments

Section Details

Assessments

Work Items

Child Components

Asset Details

Name	Assessment Template	Assessment Date	Score	Sample Count
Legacy BUILDER Inspection	Direct Condition Rating	2022-03-11	88	1



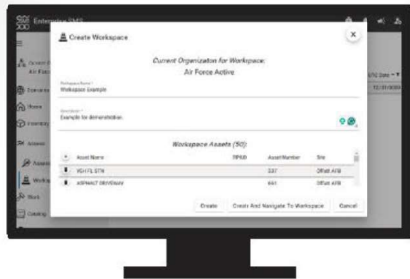




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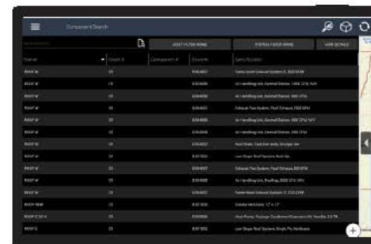
E-SMS FIELD APP WORKFLOW

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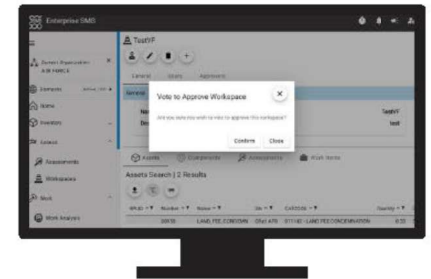
Planning

1



Inventory & Assess

3



Work Acceptance

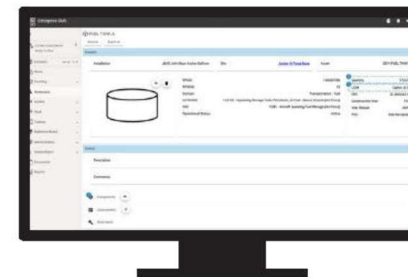
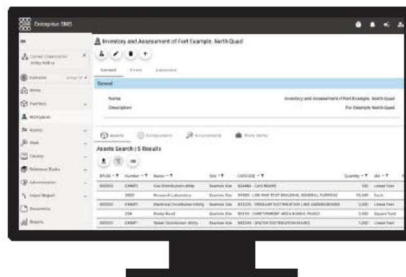
5

Delegating

2

QA/QC

4



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DEVELOPMENT UPDATES – E-SMS AND AI

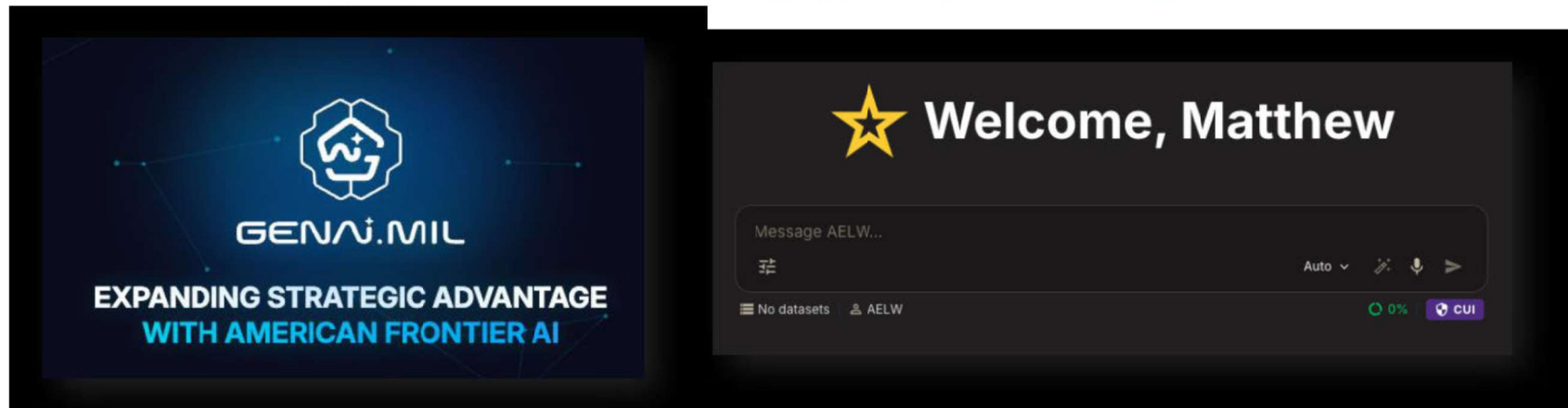
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E-SMS Development with Agentic AI (GenAI, Ask Sage)

- 61 AI issues completed Q2+Q3
 - 54 bugs
 - 22 changes
 - 6 features
 - 4.175 months of work
-
- Frontend technology is heavily documented and thus high usability
 - AI buildout of automated test cases for better regression testing
 - One senior dev utilizing agentic AI for challenging/complex development work





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OVERVIEW OF E-SMS (DEMO)



ENTERPRISE SUSTAINMENT MANAGEMENT SYSTEM

BASEMENT - MECH RM

Create New Component Edit Component Delete Component Weather Impact

General

Installation JBAS Joint Base Archer Sullivan Site [JBAS-AR Archer Air Force Base 12](#) Asset [2703 BUILDING 2703 90050347](#)

Click to Add Image

Component Name	BASEMENT - MECH RM	Year Installed	1995	CI	65
Number	NONE	Year Repaired	NONE	RSL	7
Alternate ID	NONE	Replacement Value (Computed)	\$13,974.00	RDL	2
Component Type	Hydronic Unit Heater	Quantity	1 SF	Design Life	30 (Service Life Book)
Component Type Domain	Facility - Building				
Specification	Hydronic Unit Heater, 100 MB				
Uniformat Classification	D305002 - UNIT HEATER				
Operational Status	Active				

Details

Description

Comments

Component Search: ROOF W [In-Service]

No images yet
Tap to add a photo

Uniformat	D304008	Specification	Air Handling Unit, Central Station, 5000 CFM, VAV	Description	None
Last Assessment	3/11/22	Q	108	Replacement Value	\$0.00
Installation Date	1/1/99	Age	None	Remaining Service Life	None
Repair Date	None	Effective Age	None	Quantity	1 Each
Design Life	None (Specification)	Remaining Design Life	None		

Comments	Section Details	Assessments	Work Items	Child Components	Asset Details
Name	Assessment Template	Assessment Date	Score	Sample Count	
Legacy BUILDER Inspection	Direct Condition Rating	2022-03-11	88	1	

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MR. MARK SINDER

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Deputy Assistant Secretary of War for Infrastructure Modernization & Resilience

Mr. Sinder is currently serving as Deputy Assistant Secretary of Defense for Infrastructure Modernization and Resilience. In this role, he is charged with ensuring strategic alignment of DoD's physical infrastructure with warfighter requirements, to include development and execution of policies, guidance, and procedures for basing, real property management, geospatial information and services, and the construction, operations, maintenance and repair of DoD's worldwide infrastructure portfolio.

Prior to this assignment Mr. Sinder served as the Director, Installations Division (OPNAV N4I) under the Deputy, Chief of Naval Operations for Fleet Readiness and Logistics. From 2020-2023, Mr. Sinder served as the Director of Operations (N3) for Commander, Navy Installations Command.

Prior to this appointment, from 2019-2020, Mr. Sinder served as the Executive Director for Naval District Washington (NDW).

Mr. Sinder began working in the Department of Defense environment in 2003 in variety of positions principally on Chief of Naval Operations staff and for Commander, Navy Installations Command.

Mr. Sinder is a native of Champaign, IL and graduated from the College of William and Mary with a Bachelor of Arts in Economics and Political Science.

<https://www.acq.osd.mil/eie/leadership/mark-sinder.html>

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BUILDINGS MIGRATIONS STATUS / LESSONS



- Pilot migrations underway
 - Multiple migration sites for independent verification; single production site for DoW
 - Planning for production migration beginning October 2026

Internal Pre-Production Effort

- E-SMS Migration Sandbox
 - US Army, USAF, USMC, DoWEA, DeCA, WHS, DLA, MDA
 - 356.4K Assets
 - 7.81M Components
 - 11.09M Assessments
 - 2,782,198 Images migrated
- Whole DoW Rollup – ~6 hours

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BUILDINGS MIGRATIONS – DATA PRE-WORK



- Facilities with missing or duplicate RPUIDs as well as those with missing category codes or construction years.
- Organization with missing locations, inflation books, policy sequences, or priority schemes.
- Sections with zero quantities, missing build dates, missing service life records, or invalid material category codes.
- Duplicate sections and inspections.
- Inspections with missing inspector names, future dates, or missing component indexes.
- Elimination of duplicate data due to data sharing across different agencies.
- Reconciliation of mismatched category codes between different agencies.
- Update and removal of images that were mismatched, removed, or duplicated.
- Consolidation of user accounts across multiple agencies.

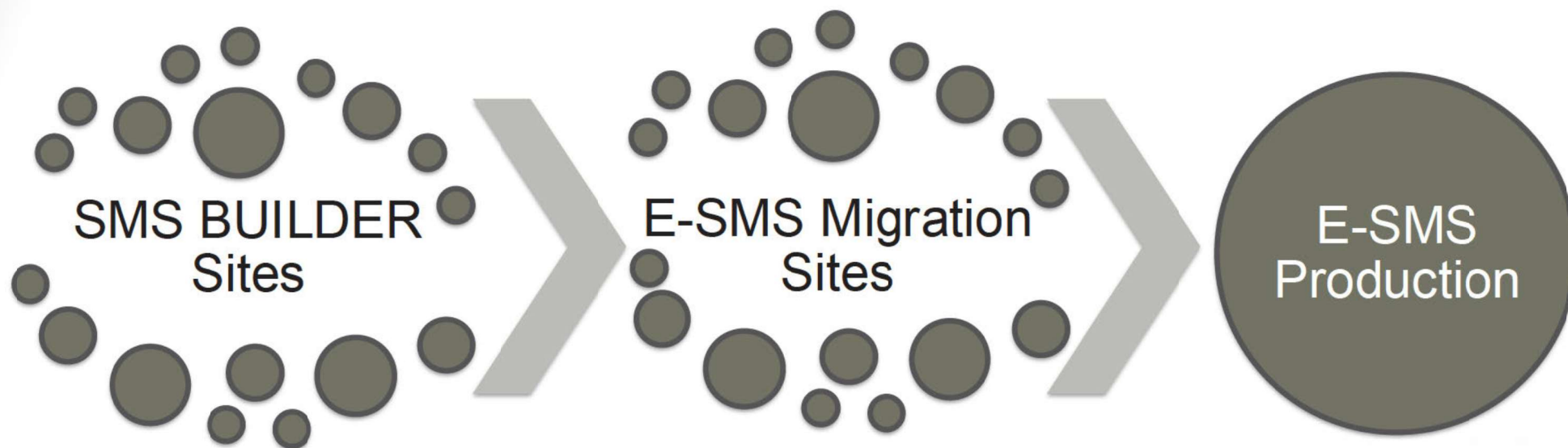
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BUILDER TO E-SMS MIGRATION FLOW



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BUILDINGS MIGRATIONS – STRESS TESTING



- Ample feedback from Services/Agencies during pilot migrations
 - Bugs
 - Feature Improvements
 - Worked in test; faltered with “real” data
- SMS-TCX Team has been working through that feedback and making the requisite corrections/fixes/improvements
- Rolling out the latest version to migration testing sites to validate the final fixes/corrections

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NEW FEATURES IN E-SMS (DEMO)



ENTERPRISE
SUSTAINMENT MANAGEMENT SYSTEM

Current Organization: Department of Defense
Example Organization

Domains Active: (1)

Home

Inventory

Organizations

Sites

Assets

Components

Assess

Work

Catalog

Reference Books

Administration

Import/Export

Documents

BASEMENT - MECH RM

Create New Component Edit Component Delete Component Weather Impact

General

Installation JBAS Joint Base Archer Sullivan Site JBAS-AR Archer Air Force Base 12 Asset 2703 BUILDING 2703 90050347

Click to Add Image

Component Name BASEMENT - MECH RM

Number NONE

Alternate ID NONE

Component Type Hydronic Unit Heater

Component Type Domain Facility - Building

Specification Hydronic Unit Heater, 100 MB

Uniformat Classification D305002 - UNIT HEATER

Operational Status Active

Year Installed 1995

Year Repaired NONE

Replacement Value (Computed) \$13,974.00

Quantity 1 SF

CI 65

RSL 7

RDL 2

Design Life 30 (Service Life Book)

Details

Description

Comments

Component Search: ROOF W [In-Service]

No images yet
Tap to add a photo

Uniformat D304008

Last Assessment 3/11/22

Installation Date 1/1/99

Repair Date None

Design Life None (Specification)

Specifications Air Handling Unit, Central Station, 5000 CFM, VAV

ID 108

Age None

Effective Age None

Remaining Design Life None

Description None

Replacement Value \$0.00

Remaining Service Life None

Quantity 1 Each

Comments

Section Details

Assessments

Work Items

Child Components

Asset Details

Name	Assessment Template	Assessment Date	Score	Sample Count
Legacy BUILDER Inspection	Direct Condition Rating	2022-03-11	86	1

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Resuming at **1:00 PM**
Central Time





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UTILITIES SMS GOALS AND OBJECTIVES



Enterprise-wide view of utility assets along with the portfolio of other real property assets



Component-level register of utility asset inventory



Standardized assessment and data collection across MILDEPs



Data-driven facility investment planning and what-if investment analysis

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UTILITIES SMS DATA PRODUCTS



Condition Index data for components, systems, and assets

A quantitative measure of condition/health considering accumulated deterioration over the lifespan. Supports awareness of impending condition critical issues, planning for intervening work activities (see below), and organizational condition reporting.



Proactive Work Opportunities based on condition

Identification of candidates for repair, replacement, or other corrective/intervening actions (primarily prior to major failure), using the current condition state and the future projected trajectory of the condition state.

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SMS PROCESS FOR UTILITIES

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Inventory

Asset real property along with component inventory for each asset



Assess

Component-level assessments to capture observations on current state of assets and components



Forecast

Condition index to measure current condition state, forecast future degradation, and metrics aggregation



Plan

Identify work candidates based on asset and component level metrics compared against organizational work policies



Analyze

Analysis and visualization of utilities portfolio from a high level to detailed level to include component composition, condition state, and work needs/opportunities

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UTILITIES DOMAIN DEMO

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Supports facility managers with the following information:

- What rail assets exist.
- What defects and deficiencies exist and costs to fix.
- What restrictions are imposed – and the effect on operations and readiness.
- What is the physical track health/condition
- Short and long-term maintenance strategies showing costs and affects of funding levels.
- Assists both installation and HQ level decision support through objective and consistent metrics

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FOR RAIL U.S. ARMY **ASSETS**

Component Level inventory and
Attributes

Detailed track inspection with
identification of deficiencies

Track Structure Condition Index
and operational restrictions

Maintenance and Repair

Planning

Results reporting

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RAILS / FUELS / WATER CONTROL ASSESSMENTS

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**Day 1 Closeout -
Thank YOU!**

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WELCOME! – DAY 2

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DAY 2 AGENDA

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- 0800 – 0830** Day 1 Recap / Day 2 Agenda Intro
- 0830 – 0900** USACE Office of Research and Tech Transfer (ORTT) E-SMS non-Fed
- 0900 – 0930** Break
- 0930 – 1030** Third-party Integration Framework
- 1030 – 1100** Break
- 1100 – 1200** FSRM Optimization Update and Demonstration
- 1200 – 1330** Lunch
- 1330 – 1430** Leveraging AI for Assessor Training
- 1430 – 1530** SMS Innovations Lab

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**CONNECTING
THE DOTS TO
INNOVATION**

E-SMS COMMERCIAL LICENSING

Jeffrey DiTullio
2 September 2026



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E-SMS COMMERCIAL LICENSE SUMMARY



- **E-SMS Access:**
 - Commercial licensees will have access to executable E-SMS Code only.
- **License Grant:** All licenses are to be non-exclusive without the right to sublicense.
 - Using E-SMS for a licensee's internal purposes IS permitted.
 - Using E-SMS to provide fee based services for third parties IS permitted.
 - Hosting E-SMS for a third party that is also a licensee IS permitted.
 - Selling access to E-SMS to a third party that is not a licensee is NOT permitted.
- **License Fees & Royalties:**
 - License issue fee will be due at signing (30 days).
 - A discounted license issue fee will be available to existing BUILDER commercial licensees with up-to-date licenses in good standing as determined by ERDC. Licenses will otherwise be uniform.
 - Maintenance fees will be due annually.
 - Royalties will be assessed on revenue generated via E-SMS.
- **Current BUILDER Licensees:**
 - Current BUILDER licensees are under no obligation to upgrade to E-SMS, although BUILDER is scheduled to be sunset.

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E-SMS COMMERCIAL LICENSE SUMMARY



QUESTIONS / DISCUSSION

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THIRD PARTY INTEGRATION FRAMEWORK



- Application Programming Interface (API) Centric Integration
 - Utilizes E-SMS Business Rules
 - Authentication/Authorization same as E-SMS Web App
- Example Integration Concepts
 - Computerized Maintenance Management System (CMMS)
 - Geographic Information Systems (GIS)
 - E-SMS Workspaces
 - Custom Reporting Requirements
 - Field Applications (third-party)
 - Data Importation

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WEB API UPDATES (WHAT'S NEW & IMPROVED)



Streamlined & Cleaner Experience: We have consolidated our API endpoints to remove confusing duplicates and dead links. We've also cleaned up the data models — you will now see fields that are actually required or modifiable, removing previous clutter.

Clearer Lifecycles: We introduced official API versioning and a new deprecation system, giving you clearer visibility into what features are current and what is phasing out.

Upgraded Documentation: We are heavily investing in our documentation. You will see enhanced definitions now, and we are building a comprehensive “Getting Started” guide complete with examples for adding and updating inventory and assessments.

Workspace Focus & FY27: Our primary focus this year has been on manipulating data within Workspaces. Expect these continuous improvements to carry over and expand throughout FY27.

Key Takeaway: *Our recent updates are entirely focused on making the API easier to use, better documented, and more reliable for your integrations.*

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WHAT CAN YOU DO? (WORKFLOW EXAMPLES)



Automate Data Synchronization: Seamlessly sync data between external systems (like CMMS or ArcGIS) and our platform. *Recommended Workflow: Always sync your data into **Workspaces** first. This acts as a staging area, giving you the opportunity to review and validate changes before committing to a final merge.*

Create Custom Reports: Pull your data directly into the reporting tools you already know and love, such as PowerBI, Excel, Tableau, or PDF generators. Our endpoints use the standard **ODATA** (odata.org) protocol, giving you a globally recognized, highly customizable way to query exactly the data you need.

Scale Your I&A Efforts: Build customized workflows for your Inventory & Assessment (I&A) tasks. Whether you are managing a massive team of 100 assessors tackling thousands of assets, or you are a lone soldier in the field with an iPad, the Web API can automate tedious data entry and drastically accelerate your workflow.

Key Takeaway: *The Web API isn't just a backend technical feature; it is a tool to automate your daily tasks, scale your efforts, and connect your favorite software.*

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RESOURCES FOR INTEGRATORS



- API Developer Portal – Swagger pages with API definitions, parameters, responses
- "Getting Started" Material for basic integration starters
- Draft "E-SMS Inventory Management Guide" – estimated to be published in FY27 Q1

E-SMS Inventory Management Guide

Connecting the dots with the E-SMS process and API calls



GETTING STARTED	2
INTEGRATION FUNDAMENTALS	3
BEST PRACTICES	5
CORE CONCEPTS – WORKSPACE-CENTRIC MODEL	6
WORKSPACE LIFECYCLE OVERVIEW	7
CREATE AND POPULATE A WORKSPACE	7
RETRIEVE SUPPORTING REAL PROPERTY DATA ELEMENTS	8
RETRIEVE WORKSPACE DATA	9
PHOTOS AND MEDIA	9
PERFORM UPDATES	10
REVIEW AND MERGE	10
GETTING HELP	11
EXAMPLES FOR DEVELOPERS	12
DATA HIERARCHY	12
ODATA	12
COMMON WORKFLOWS AND API EXAMPLES	16
RETRIEVE SUPPORTING REAL PROPERTY DATA	22
PHOTOS AND MEDIA	34
MERGE WORKSPACE	63
ADDITIONAL EXAMPLES	67

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CMMS INTEGRATION FRAMEWORK



Asset Inventory

Equipment (dynamic) component assets only?
All bldg components (roof, envelope, interior construction, etc)?



Condition Ratings (Assessments/Inspections)

Direct Condition Ratings (captured as meter readings)
Observations from a PM job (ie. Corroded coils on condenser)



Work Plan

Work Items generated by SMS sent to CMMS for execution
Completed work from CMMS back to SMS for condition update



Forecasted degradation

Completion of PM actions on equipment can impact CI trajectory for SMS components
Service Call history indication of degraded condition state

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E-SMS / ARMY CMMS INTEGRATION

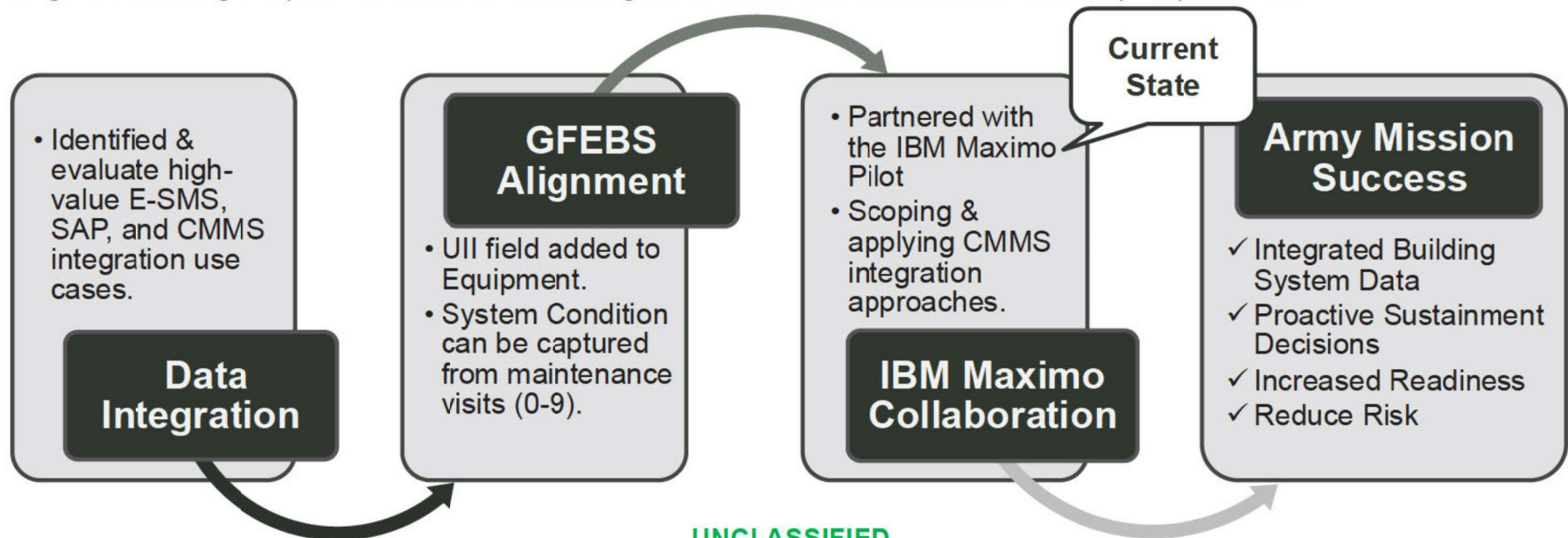


SAP/GFEBS

- Enhanced the GFEBS "SysCond" field with a standardized 0-9 rating aligned to the E-SMS Green-to-Red(-) condition scale, improving asset condition visibility and rating frequency.
- Activated the GFEBS UII field to enable enterprise-wide building equipment asset traceability, improving asset management, data synchronization, and sustainment readiness.

SMS Partnership

- Participating in Army Maintenance Application (ArMA – ServiceNow) and Army IBM Maximo pilots by providing integrated equipment inventories, validating data exchange requirements, and standardizing asset identification, condition, and work plan processes.





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E-SMS / IUID INTEGRATION



E-SMS users can generate, affix, and scan Unique Item Identifier (UII) data matrix codes assigned to inventoried facility system components, establishing a single authoritative Item Unique Identification (IUID) record for each qualified component from initial marking through its full lifecycle.

UII eliminates manual, error-prone item identification and duplicate data entry. It also improves inventory accuracy and enhances audit readiness by leveraging enterprise system agnostic DoW IUID requirements.

From...

Inefficient



- Pen & paper
- Spreadsheets
- Manual text entry
- Transcribing
- File upload/downloads

To...

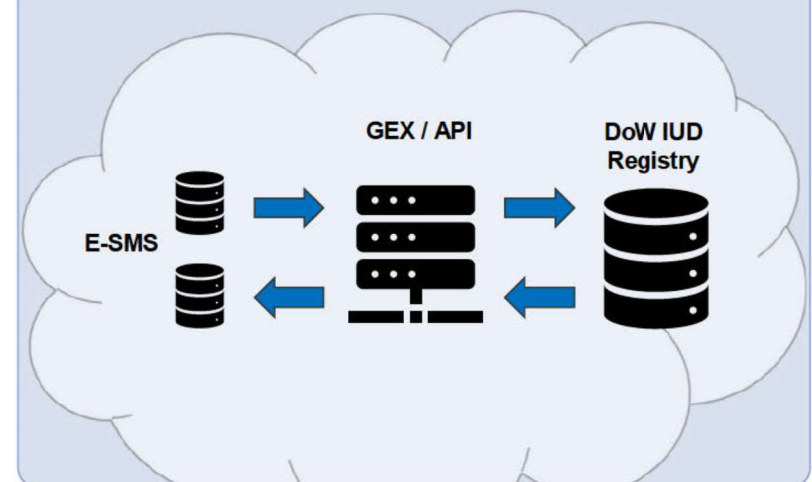
Efficient



- Enterprise-wide unique ID
- Mobile device readable
- Scalability to future tech
- Enables lifecycle tracibility

By...

Integrating IUID Data



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E-SMS GENERALIZED IMPORTER

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- Structured and systematic process for importing data into E-SMS
- Can be utilized for multiple files types/formats
- Creates linkages/mapping from source file to E-SMS data structure and a translation layer between source / E-SMS terms/values
- Demonstration import of a Building Information Model (BIM) into E-SMS

The screenshot displays the 'Enterprise System Management System' interface. On the left is a navigation menu with options: Home, Inventory, Assess, Work, Catalog, Reference Books, Administration, Import/Export (selected), Import Execution, Generalized Imports, Documents, and Innovation Lab. The main area is titled 'Import Configurations' and shows 'BIM Objects Import'. A modal window titled 'ManagedComponentModel Import Settings' is open. It contains the following fields and options:

- Name:** Component
- Destination Type:** ManagedComponentModel
- Source Keys:** Component
- Source Filter:** (empty)
- Source Id Generator:** (string)source["AltId"]
- Destination Id Generator:** dest.AltId
- Skip Missing Sources:** ☒
- Abort On Error:** ☐
- Create Record If No Destination Found:** ☒
- Field Mappings:**
 - Destination Field
 - OperationalStatusId
 - Name
 - ManagedComponentTypeId
 - ManagedAssetId
 - AltId
 - Quantity
 - InstallationDate

Buttons for 'Save' and 'Cancel' are at the bottom right of the modal.

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CUI

OPTIMIZATION MODULE PROTOTYPE DEMONSTRATION

September 2, 2026



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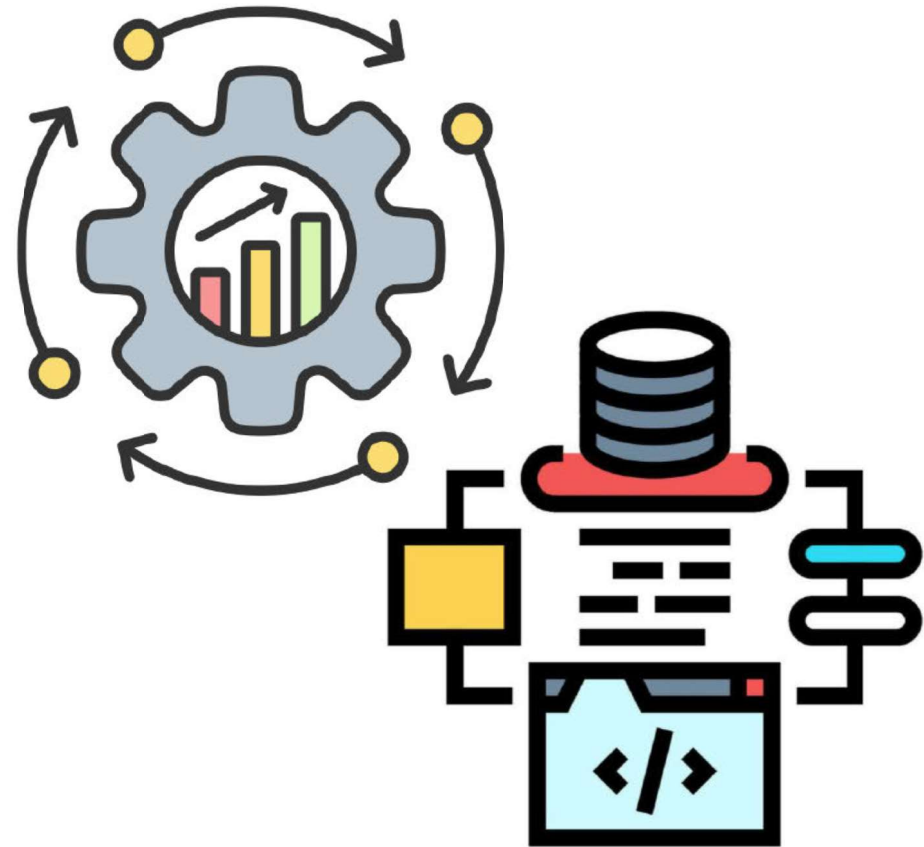
CUI



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AGENDA

- **Introduction**
 - Background
 - Technical Objective
- **Approach**
 - Decision Variables
 - Simulator
 - Optimizer
- **Architecture**
 - Infrastructure
 - Frontend
- **Demonstration**
 - Configurations
 - Visualizations



INTRODUCTION



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BACKGROUND

OLD APPROACH		
Standardized Uniform \$/SqFt Approach		
One-size-fits-all funding regardless of condition or need		
FACILITY	BUILDING CONDITION (TODAY)	MAINTENANCE ALLOCATION (\$ PER SQ FT)
 Barracks A 120,000 sq ft	GOOD	\$6.01 per sq ft
 Barracks B 250,000 sq ft	FAIR	\$6.01 per sq ft
 Barracks C 80,000 sq ft	POOR	\$6.01 per sq ft
 Barracks D 200,000 sq ft	FAIR	\$6.01 per sq ft
 Barracks E 90,000 sq ft	POOR	\$6.01 per sq ft
✗ Ignores differences. Wastes resources. Creates risk.		

Shift to
Data-Driven
Optimization

NEW APPROACH					
Optimized Maintenance Approach					
Data-driven decisions that prioritize need and maximize value					
1 CONDITION Assess current condition of each facility		2 FUNDING LEVELS Define funding scenarios MINIMUM MODERATE FULL		3 CONDITION CONSTRAINTS Minimum acceptable condition must be maintained Minimum Acceptable Condition Threshold	
FACILITY	CONDITION SCORE	CONDITION RATING	RECOMMENDED SUSTAINMENT	OPTIMIZED MAINTENANCE ALLOCATION (\$ PER SQ FT)	PRIORITY
 Barracks A 120,000 sq ft	82	GOOD	MINIMUM (Preserve)	\$2.75 per sq ft	5
 Barracks B 250,000 sq ft	58	FAIR	MODERATE (Sustain)	\$5.50 per sq ft	3
 Barracks C 80,000 sq ft	32	POOR	FULL (Renovate)	\$9.75 per sq ft	1
 Barracks D 200,000 sq ft	40	POOR	FULL (Renovate)	\$8.25 per sq ft	2
 Barracks E 90,000 sq ft	65	FAIR	MODERATE (Sustain)	\$3.80 per sq ft	4



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TECHNICAL OBJECTIVE

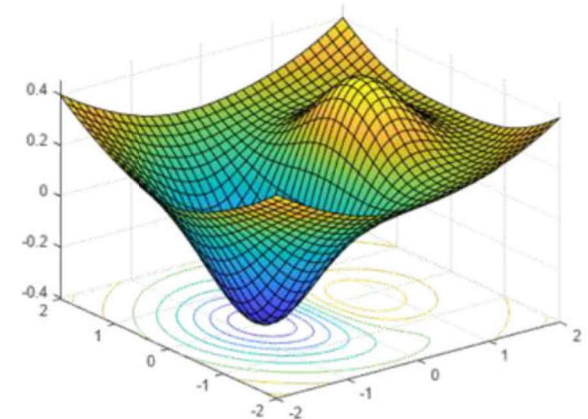


For a portfolio of assets, use E-SMS data to generate a maintenance management plan that either...

- *Maximizes portfolio performance given a portfolio budget constraint.*

or

- *Minimizes required funding given a minimum portfolio performance constraint.*



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MODULE PERFORMANCE GOALS



The ESMS Optimization Module will...

- use projected **component-level** condition data
- to generate an optimized sustainment plan and **associated budget**
- that specifies a **categorical sustainment approach** (leading to repair and/or replacement actions based on which components/systems/assets meet the policy criteria associated with the sustainment category)
- for each year for the next **5-7 years (baseline minimum)**
- for **each asset** within an **average installation-sized portfolio of assets (baseline minimum)**, and
- be able to calculate the solution **within 4 hours** (using minimum baseline parameters).

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APPROACH



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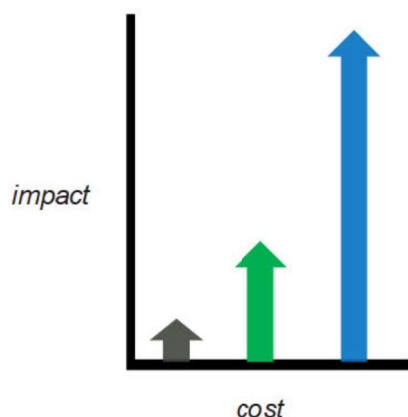
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DECISION VARIABLES



- We define the **costs** and **performance impacts** of the following facility-level investment decisions:

- Do Nothing/PM
- Sustainment
- Renovation



- “What is the optimal maintenance plan for a given portfolio?”



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- Optimality may refer to...
 - **Maximized** condition, functionality, or readiness metrics OR
 - **Minimized** sustainment and RM costs
 - while meeting user-defined budgets, facility/system performance requirements, and other factors.
- Example result interpretations:
 - “It would be **more cost effective** to wait two years before renovating the barracks.”
 - “The recreation center is in great condition, so **we can reallocate funding** towards sustaining the administrative facility.”
 - “Renovating the lab now **saves \$X** vs. sustainment for five years.”



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DECISION VARIABLES



- We allow **one investment decision per year** for each facility. A set of these decisions over some timeframe is referred to as a **plan**.

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DECISION VARIABLES



- We allow **one investment decision per year** for each facility. A set of these decisions over some timeframe is referred to as a **plan**.
- The following are examples of plans on a portfolio. Assume **budget is \$1M**.
- High-Level Approach:

1

Facility	FY27	FY28	FY29
Barracks	PM	PM	PM
Admin	PM	PM	PM
Utility	PM	PM	PM

2

Facility	FY27	FY28	FY29
Barracks	Ren.	Sust.	Sust.
Admin	Ren.	Sust.	Sust.
Utility	Ren.	Sust.	Sust.

3

Facility	FY27	FY28	FY29
Barracks	Sust.	PM	PM
Admin	PM	PM	PM
Utility	PM	Ren.	Sust.

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DECISION VARIABLES



- We allow **one investment decision per year** for each facility. A set of these decisions over some timeframe is referred to as a **plan**.
- The following are examples of plans on a portfolio. Assume **budget is \$1M**.
- High-Level Approach:
 1. Simulate all plans and collect their resulting metrics.

1

Facility	FY27	FY28	FY29
Barracks	PM	PM	PM
Admin	PM	PM	PM
Utility	PM	PM	PM

Total Cost: **\$50K**
Mean BCI: **63**

2

Facility	FY27	FY28	FY29
Barracks	Ren.	Sust.	Sust.
Admin	Ren.	Sust.	Sust.
Utility	Ren.	Sust.	Sust.

Total Cost: **\$2M**
Mean BCI: **97**

3

Facility	FY27	FY28	FY29
Barracks	Sust.	PM	PM
Admin	PM	PM	PM
Utility	PM	Ren.	Sust.

Total Cost: **\$998K**
Mean BCI: **84**

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DECISION VARIABLES



- We allow **one investment decision per year** for each facility. A set of these decisions over some timeframe is referred to as a **plan**.
- The following are examples of plans on a portfolio. Assume **budget is \$1M**.
- High-Level Approach:
 1. Simulate all plans and collect their resulting metrics.
 2. Determine the plan with optimal metrics.

1

Facility	FY27	FY28	FY29
Barracks	PM	PM	PM
Admin	PM	PM	PM
Utility	PM	PM	PM

Total Cost: **\$50K**
Mean BCI: **63**



2

Facility	FY27	FY28	FY29
Barracks	Ren.	Sust.	Sust.
Admin	Ren.	Sust.	Sust.
Utility	Ren.	Sust.	Sust.

Total Cost: **\$2M**
Mean BCI: **97**



3

Facility	FY27	FY28	FY29
Barracks	Sust.	PM	PM
Admin	PM	PM	PM
Utility	PM	Ren.	Sust.

Total Cost: **\$998K**
Mean BCI: **84**



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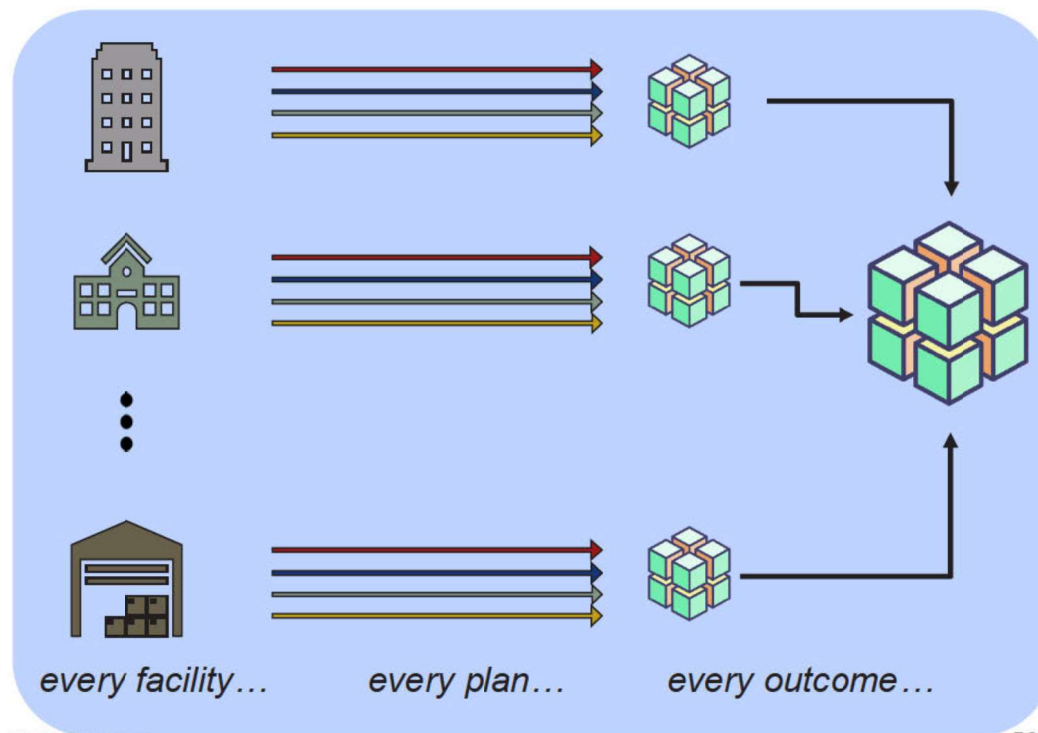
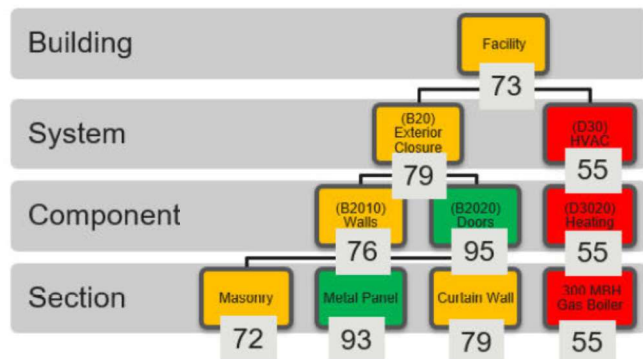
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PLAN SIMULATOR



- The plan simulator projects out **all combinations of maintenance actions** up to 10-years. The resulting metrics include:
 - Cost by funding type (S, RM, etc.)
 - Building performance
 - System condition
 - Remaining backlog
- These are computed via component-level metrics for accuracy, but stored at the facility/system level for efficiency.
- The simulator is **highly vectorized** to save resources and reduce runtime. The data structure of the metrics supports **accelerated computation** for further efficiency.



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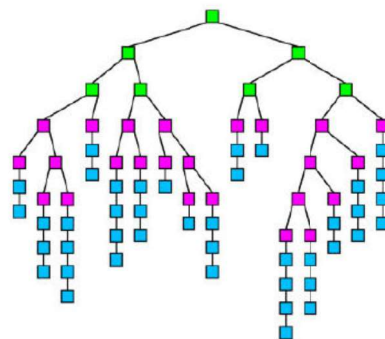


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- The number of potential solutions can be very large. The resulting metrics are provided to an algorithm to find an optimal solution.

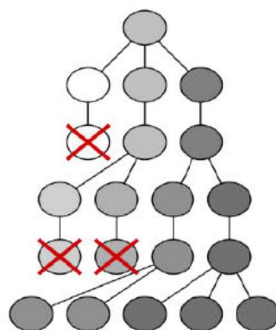
- **Integer program**

- Tree search
- Returns global optimal solution
- Can take extended time to solve



- **Genetic algorithm**

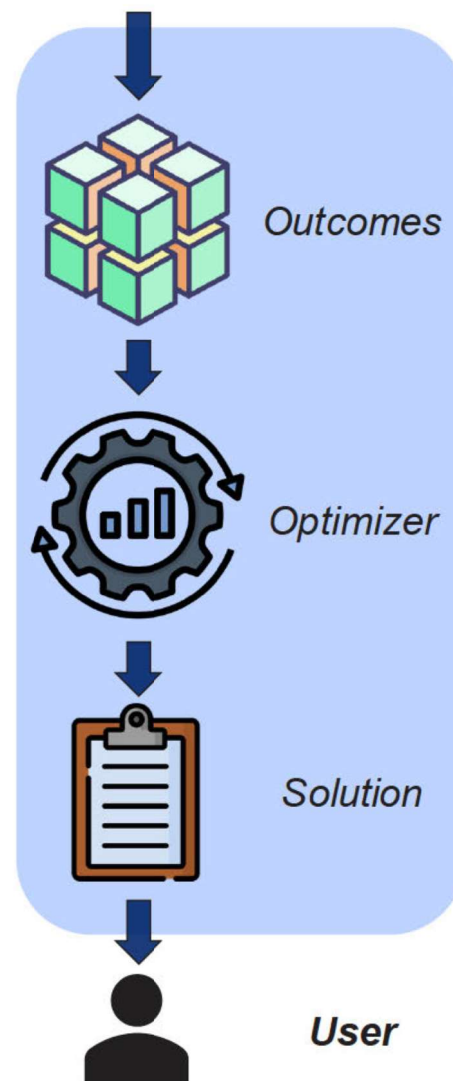
- Iterative
- Returns near-optimal solution
- Can be quicker to converge



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OPTIMIZER

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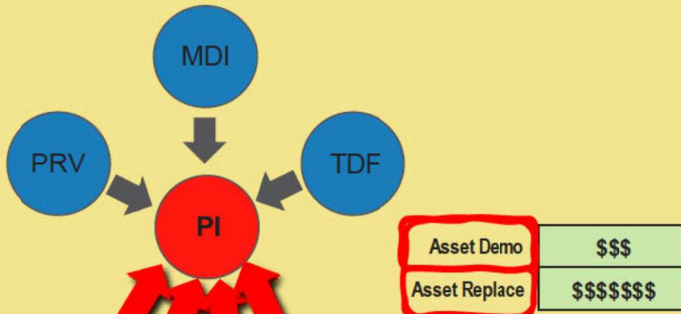
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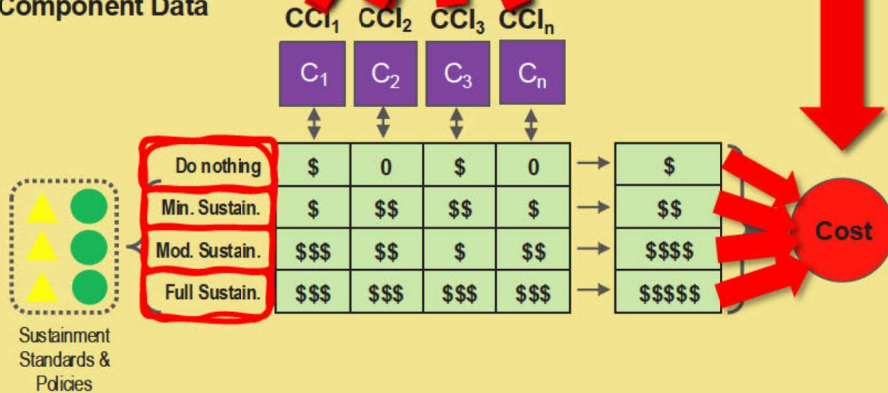


MAINTENANCE OPTIMIZATION ENGINE

Asset Data



Component Data



	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
Asset Demo								
Asset Replace								
Do nothing								
Min. Sustain.								
Mod. Sustain.								
Full Sustain.								

Action	PI	Cost
Asset Demo	-	\$\$\$
Asset Replace	100	\$\$\$\$\$\$
Do nothing	55	\$
Min. Sustain.	67	\$\$
Mod. Sustain.	77	\$\$\$
Full Sustain.	84	\$\$\$\$\$

	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07
MIN SUSTAIN								
FULL SUSTAIN								
DO NOTHING								
REPLACE								
FULL SUSTAIN								
MOD SUSTAIN								
DO NOTHING								
DEMO								

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ARCHITECTURE AND FRONTEND



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BUILT INTO ESMS



Maintenance Optimizer will be built right into ESMS!

No extra data transferring needed, the tool uses ESMS data directly!

*Not available at launch

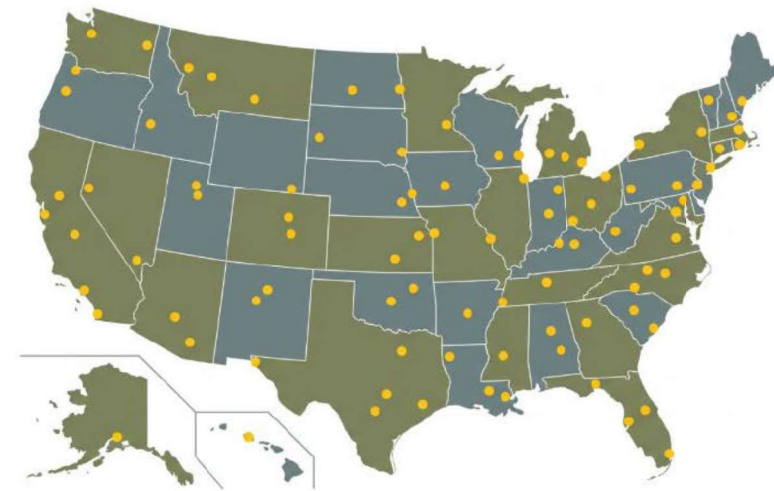
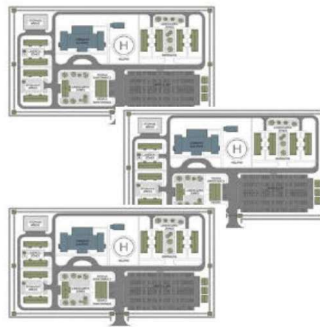
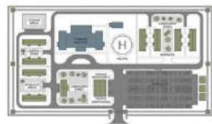
The screenshot displays the ESMS interface with a sidebar on the left and a main content area on the right. The sidebar contains a menu with items: Home, Inventory, Assess, Work, Catalog, Administration, Import/Export, Documents, Innovation Lab, and Maintenance Optimization (highlighted with a red box). The main content area shows the 'Maintenance Optimization Detail View' for 'Ft Hood Analysis'. It includes a 'Configuration Details' section with a table of settings, an 'Annual Budgets' section with a table of budget data, and a 'Performance Constraints' section at the bottom.

Name	Ft Hood Analysis	Global BCI Target	1
Objective Type	Maximize Performance	Portfolio PI Target	1
Discount Rate	0.951	Year Range	2026 - 2032

Fiscal Year	Budget (USD)
FY 2026	\$222,400,000.00 (USD)
FY 2027	\$222,400,000.00 (USD)
FY 2028	\$222,400,000.00 (USD)
FY 2029	\$222,400,000.00 (USD)
FY 2030	\$222,400,000.00 (USD)
FY 2031	\$222,400,000.00 (USD)
FY 2032	\$222,400,000.00 (USD)

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A few Assets

An Installation

A few Installations

A Service

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USER EXPERIENCE

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Submit
Config Form
on ESMS

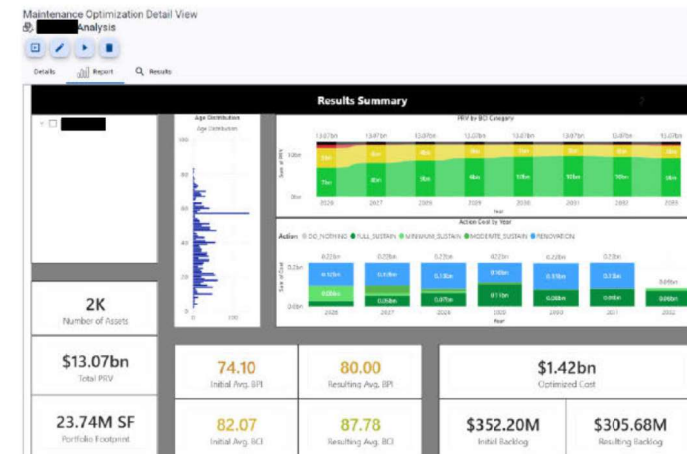
Wait for
optimization
to complete

View PowerBI
results on
ESMS

Configuration Form



~1-15 minutes for a
single installation



PowerBI Results

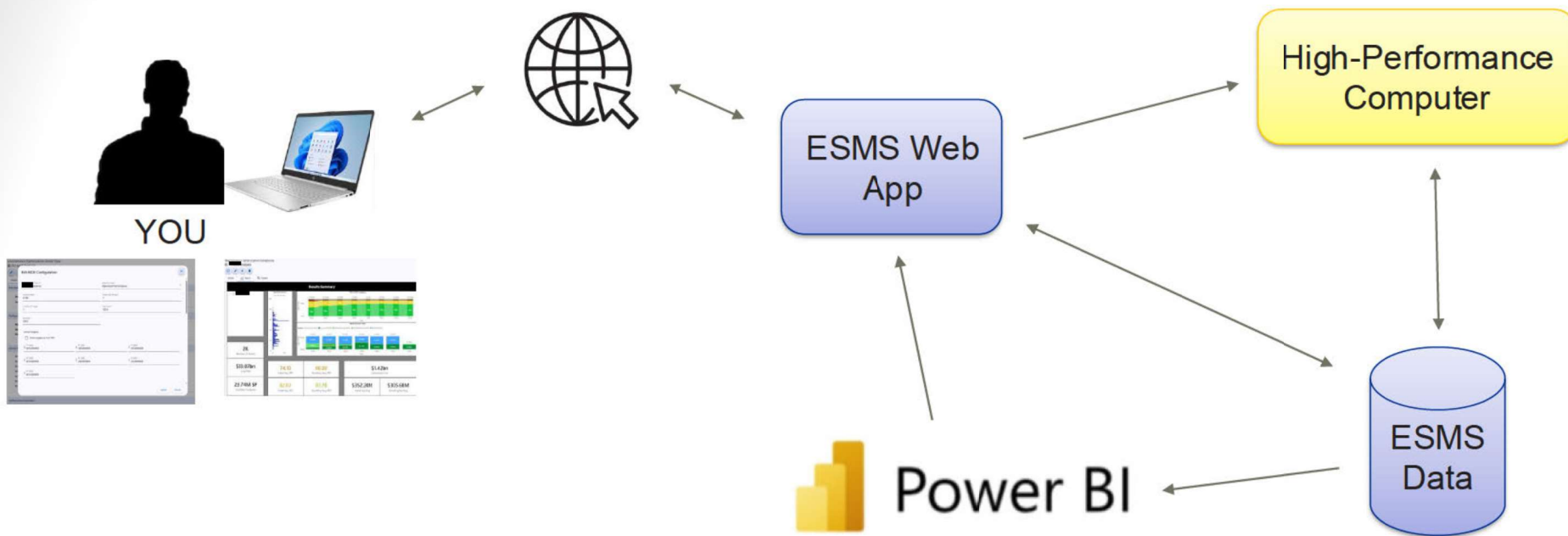
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DEMONSTRATION



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RESULTS TABLE

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Asset - ▼	Action - ▼	Timestep - ▼	Cost - ▼	Backlog - ▼	BCI - ▼	BPI - ▼	Effective Age - ▼
Hut - Divided	DO_NOTHING	0	\$0.00	\$25,077.58	74.51	67.14	26.17
Hut - Divided	DO_NOTHING	1	\$0.00	\$27,830.20	72.46	65.36	27.14
Hut - Divided	DO_NOTHING	2	\$0.00	\$32,100.96	70.32	63.53	28.11
Hut - Divided	FULL_SUSTAIN	3	\$39,939.88	\$39,504.64	68.09	61.65	29.08
Hut - Divided	MINIMUM_SUSTAIN	4	\$435.24	\$0.00	88.22	79.5	19.32
Hut - Divided	DO_NOTHING	5	\$0.00	\$0.00	86.96	78.16	20.31
Hut - Divided	DO_NOTHING	6	\$0.00	\$0.00	85.59	76.76	21.3
Hut - Divided	NA	7	\$0.00	\$0.00	84.09	75.28	22.29
Hut - Divided	DO_NOTHING	0	\$0.00	\$54,580.15	71.56	63.82	29.44
Hut - Divided	DO_NOTHING	1	\$0.00	\$54,829.60	70.28	62.64	30.28
Hut - Divided	DO_NOTHING	2	\$0.00	\$55,086.21	68.99	61.45	31.12
Hut - Divided	MINIMUM_SUSTAIN	3	\$53,954.55	\$57,311.97	67.69	60.27	31.95
Hut - Divided	DO_NOTHING	4	\$0.00	\$4,342.21	91.89	84.52	14.58
Hut - Divided	DO_NOTHING	5	\$0.00	\$5,018.62	91.1	83.46	15.51
Hut - Divided	DO_NOTHING	6	\$0.00	\$7,972.95	90.26	82.38	16.44
Hut - Divided	NA	7	\$0.00	\$8,965.07	89.37	81.28	17.38
Water Tower Bldg	RENOVATION	0	\$36,807.67	\$92,512.38	49.92	52.03	34.51
Water Tower Bldg	FULL_SUSTAIN	1	\$0.00	\$0.00	98.38	93.06	10.52
Water Tower Bldg	FULL_SUSTAIN	2	\$0.00	\$0.00	98.06	92.35	11.54
Water Tower Bldg	FULL_SUSTAIN	3	\$0.00	\$0.00	97.5	91.48	12.55
Water Tower Bldg	FULL_SUSTAIN	4	\$0.00	\$0.00	96.62	90.41	13.56
Water Tower Bldg	FULL_SUSTAIN	5	\$0.00	\$0.00	95.39	89.11	14.57
Water Tower Bldg	FULL_SUSTAIN	6	\$0.00	\$0.00	93.78	87.56	15.58
Water Tower Bldg	NA	7	\$0.00	\$0.00	91.75	85.75	16.59

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QUESTIONS?



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THANK YOU



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Resuming at **1:30 PM**
Central Time





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LLM-ENHANCED INFRASTRUCTURE INSPECTION TRAINING

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Juyeong Choi, Ph.D.

Associate Professor

Department of Civil and Environmental Engineering

Florida A&M University-Florida State University College of Engineering

<https://sites.google.com/view/jchoiresearchgroup/people>

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AI Enhanced Building Inspection Training

LLM-VR Support for Asset Inspection Training & Standardization

Dr. Juyeong Choi, Civil & Environmental Engineering, FAMU-FSU College of Engineering

Team Introduction



Dr. Juyeong Choi

Associate Professor, Civil & Environmental Engineering, FAMU-FSU College of Engineering



Mohammad Movahedi

Ph.D. Candidate, Civil & Environmental Engineering, Florida State University



Alexander J. Baldwin

Ph.D. Candidate, Civil & Environmental Engineering, Florida State University
Air Force Institute of Technology, Civilian Institute Program, Student

With support from:

Lt. Col. Daniel Weeks: Professor of Engineering Management & Program Chair,
Air Force Institute of Technology, Wright-Patterson AFB, OH

Facility Inspection Process & Challenges



Inspection challenges

- Human judgement subjectivity
- Language & data variability
- Maintaining consistency at enterprise portfolio scale

The practical challenge is not SMS systems, but **consistency & confidence with inspection data entering systems**

Inspection Consistency Challenges



Structure has moderate corrosion,
Condition **Amber**



Structure has some mild rusting,
Condition **Green -**

Same asset $\Rightarrow$ Different observations $\Rightarrow$ Different interpretations = **Different SMS data**

Common Inspection Training Methods:

- Text-based (*manuals, playbooks, inspection guides*)
- Hands-on (*centralized, on-the-job training*)
- Computer based training (CBTs)

VR for Inspector Training

Virtual Reality (VR) is widely used across industries for immersive, interactive training

Traditional VR

- Manually developed scenarios
- Limited scenario variation
- Moderate real-world complexity
- **No dynamic decision feedback**

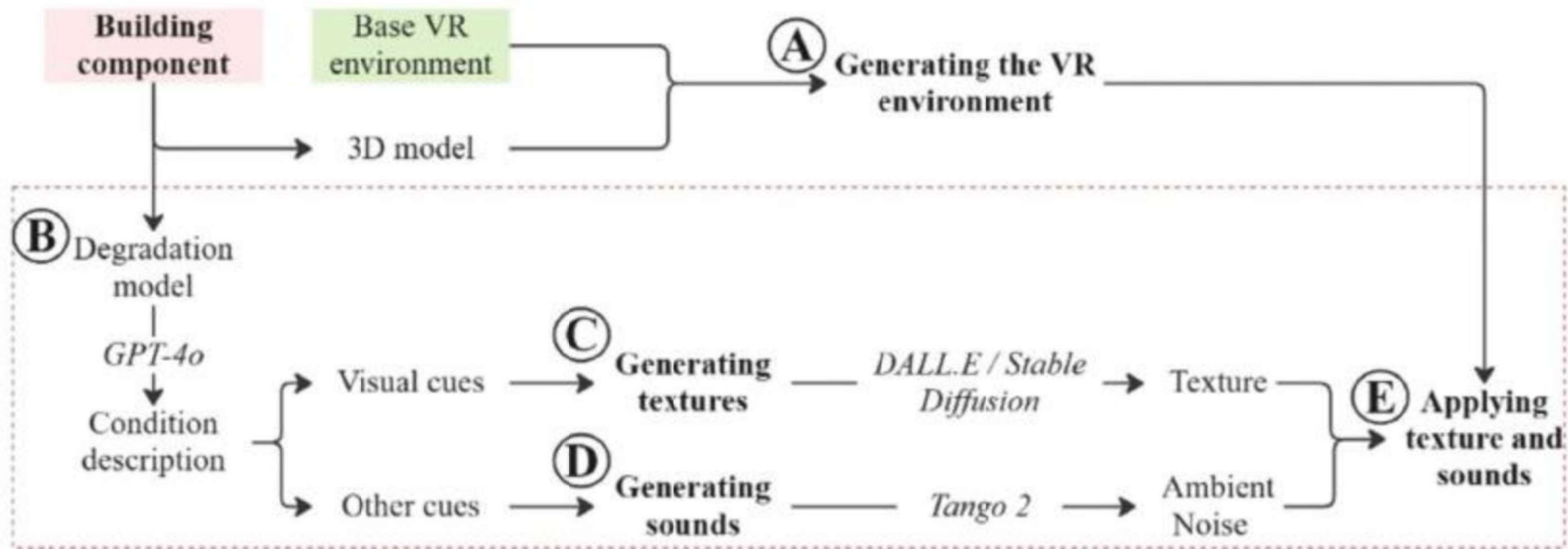


Generative-AI Enhanced VR

- Creates more realistic and varied training environments
- Expands condition variation
- Scalable content generation
- **Adaptable training content**

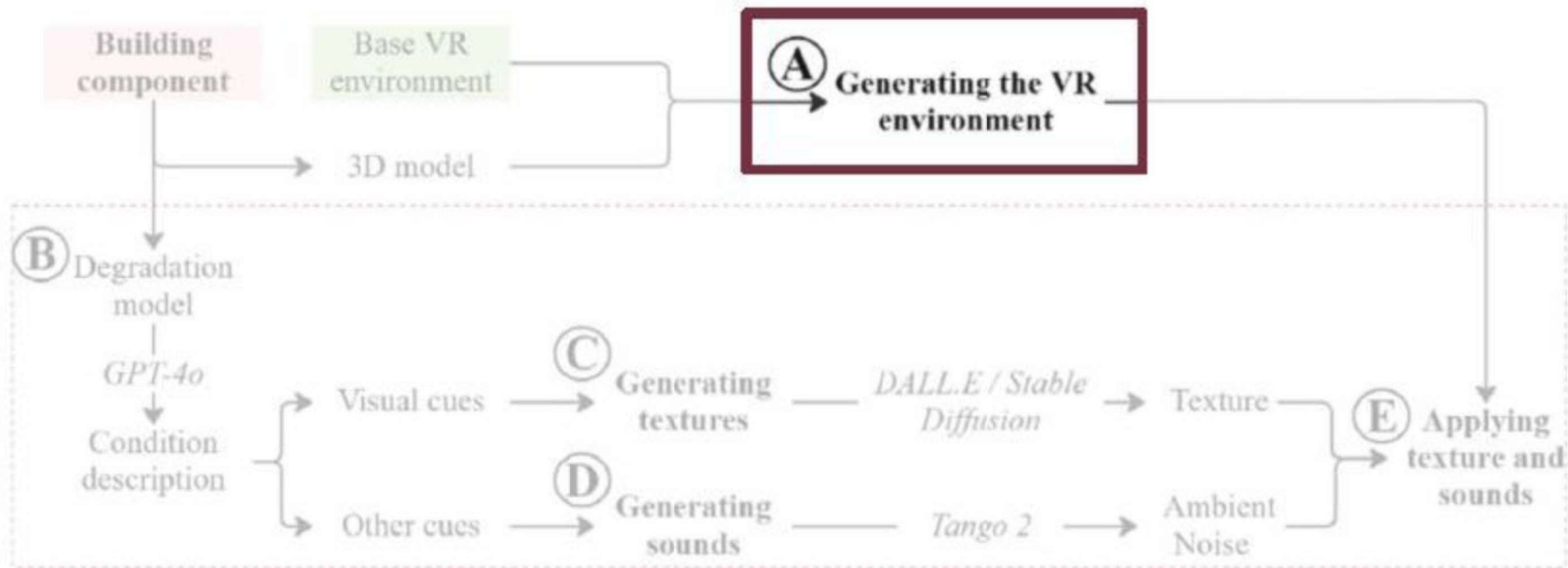
Gen-AI VR Inspector Training

Gen-AI can create new VR environments (*images, sounds, text*)



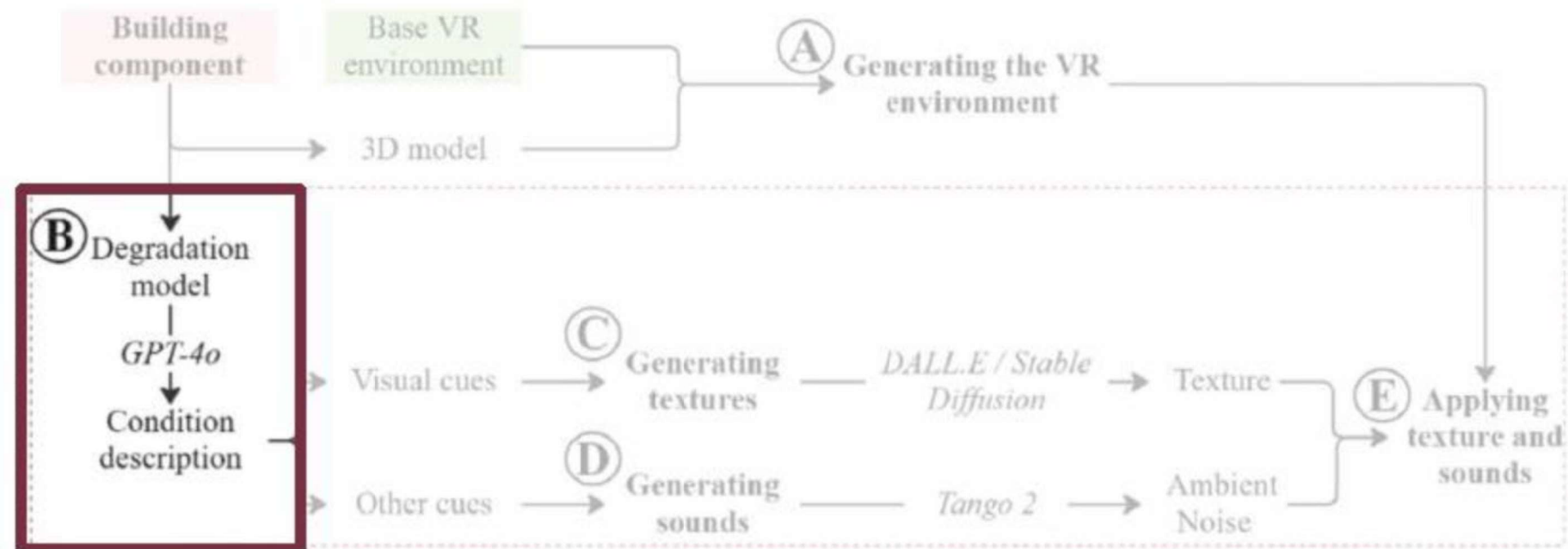
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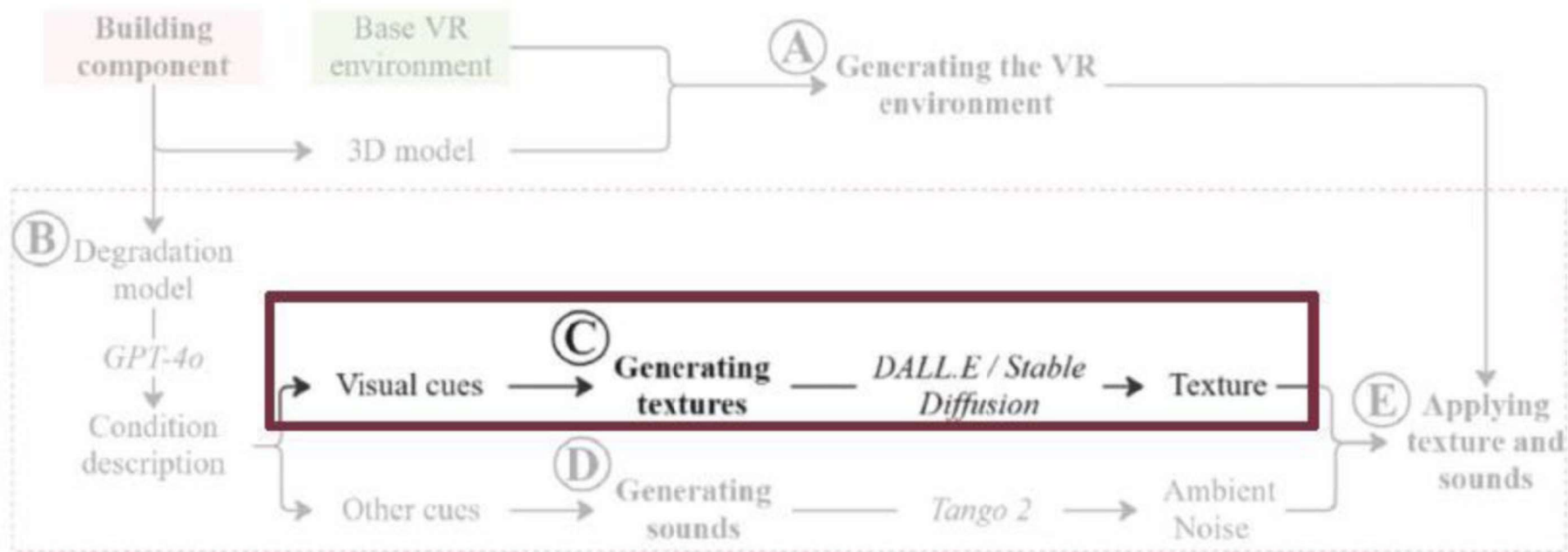
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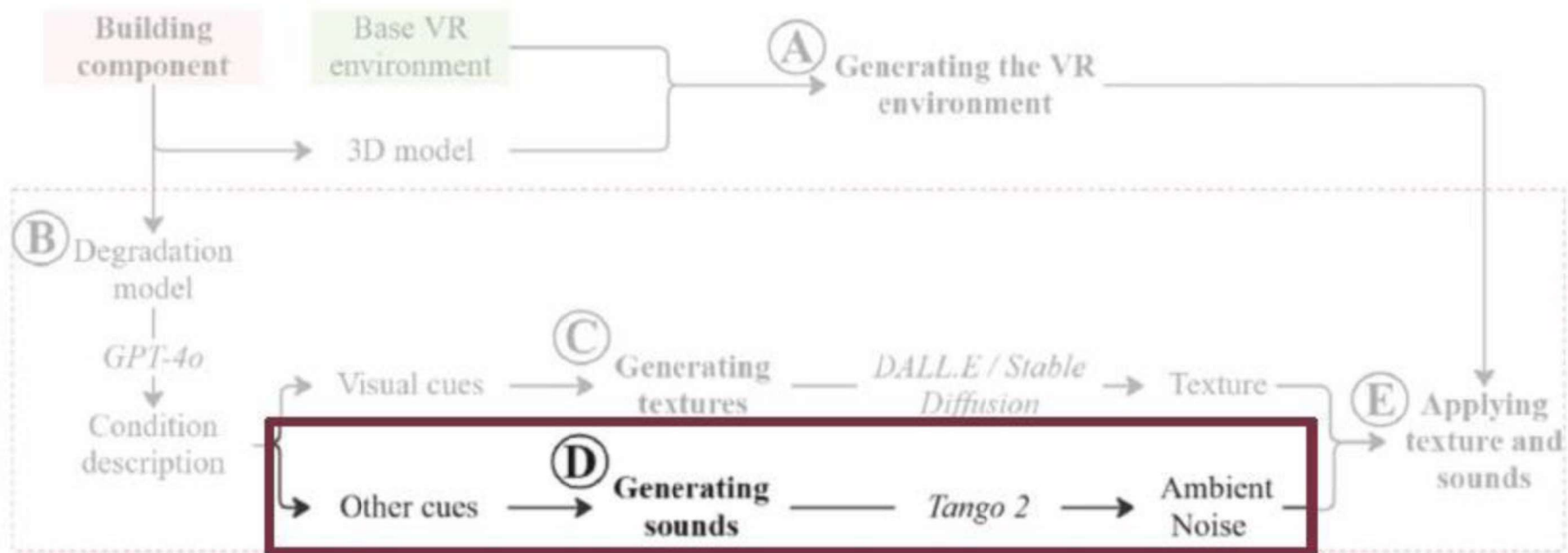
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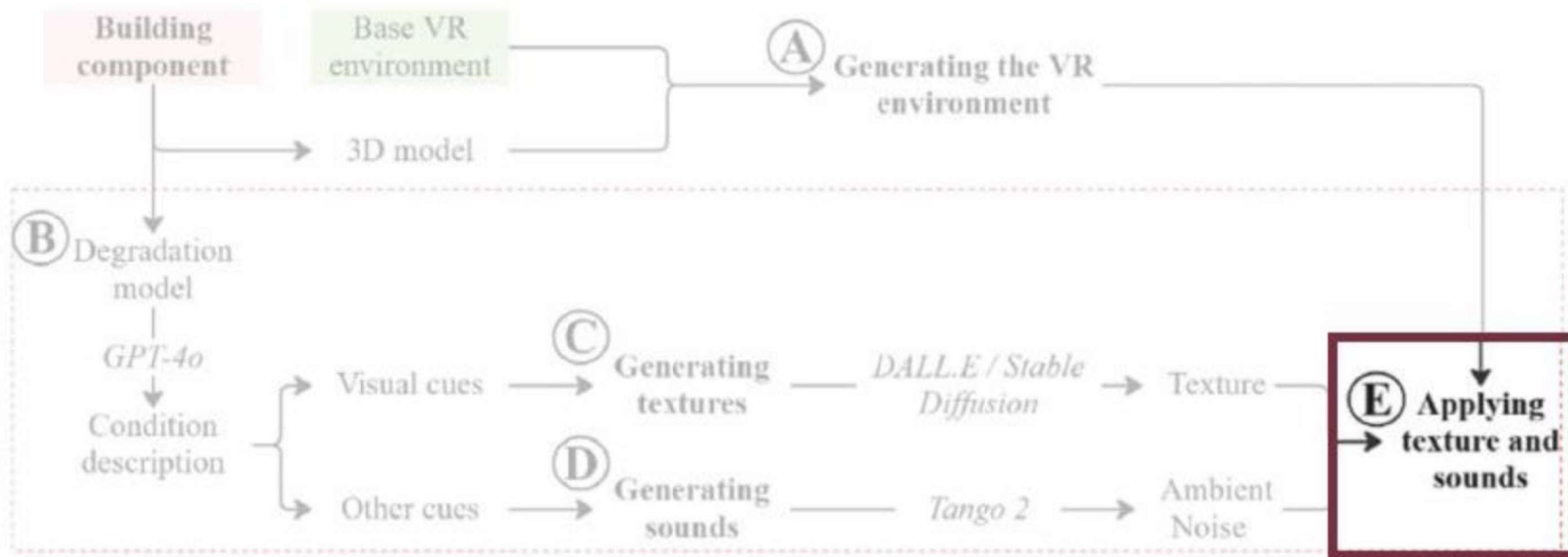
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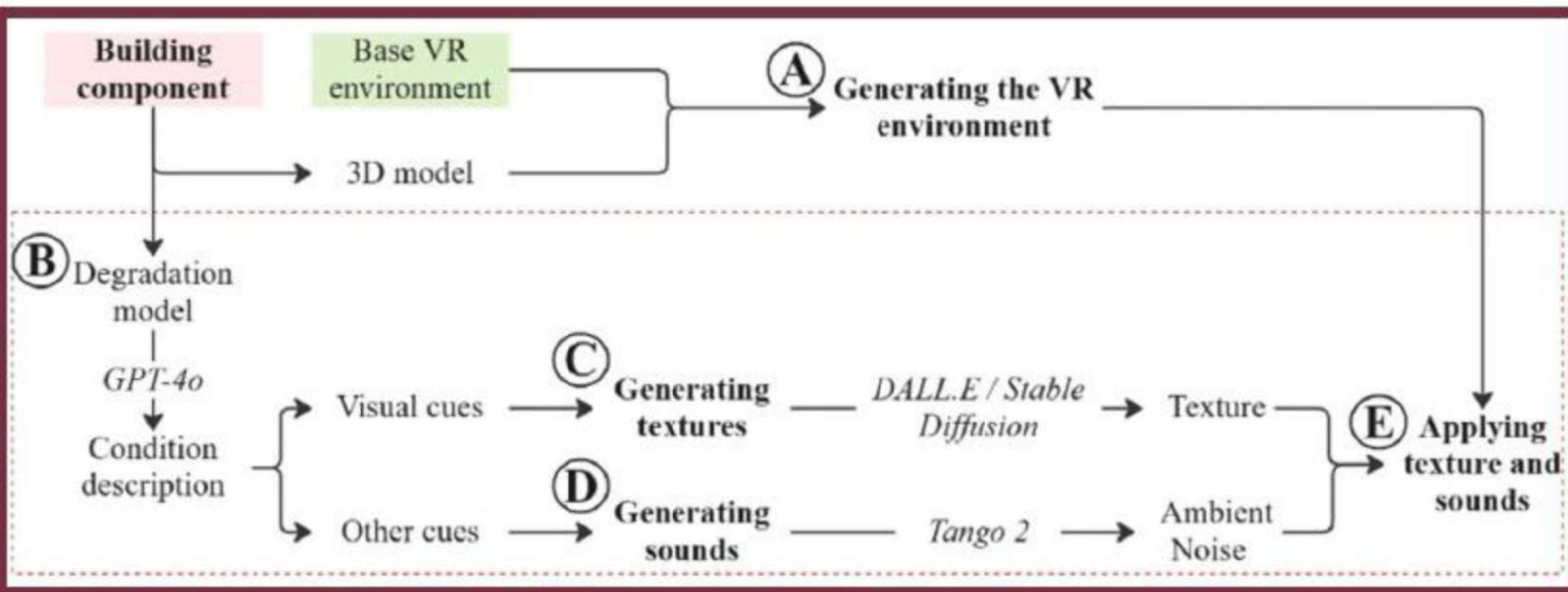
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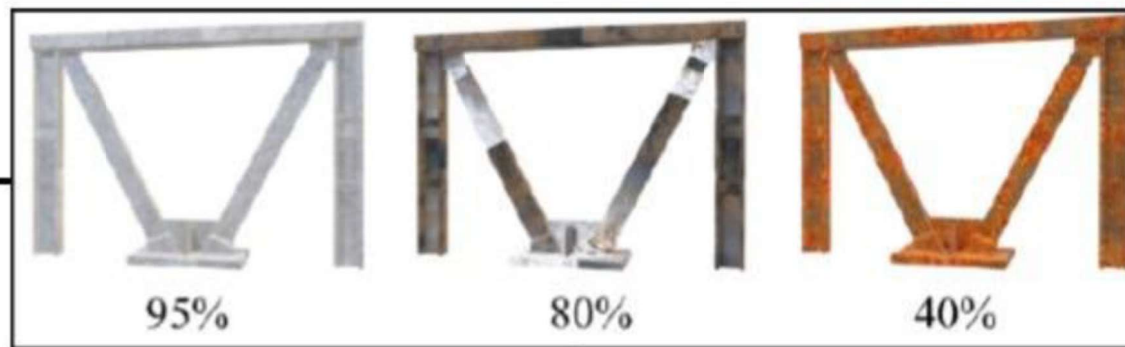
Gen-AI VR Inspector Training

Gen-AI can create new VR environments (*images, sounds, text*)



Gen-AI VR Inspector Training

VR changes what the trainee experiences, but an LLM assistant can change **what the trainee learns** from experiences



Training Objective: Identify early surface deterioration signs.

Target Condition Rating: **Green +**

Training Objective: Distinguish moderate corrosion and extent.

Target Condition Rating: **Green –**
Acceptable secondary rating: **Amber +**

Training Objective: Identify severe section / thickness loss and structural degradation.

Target Condition Rating: **Red +**

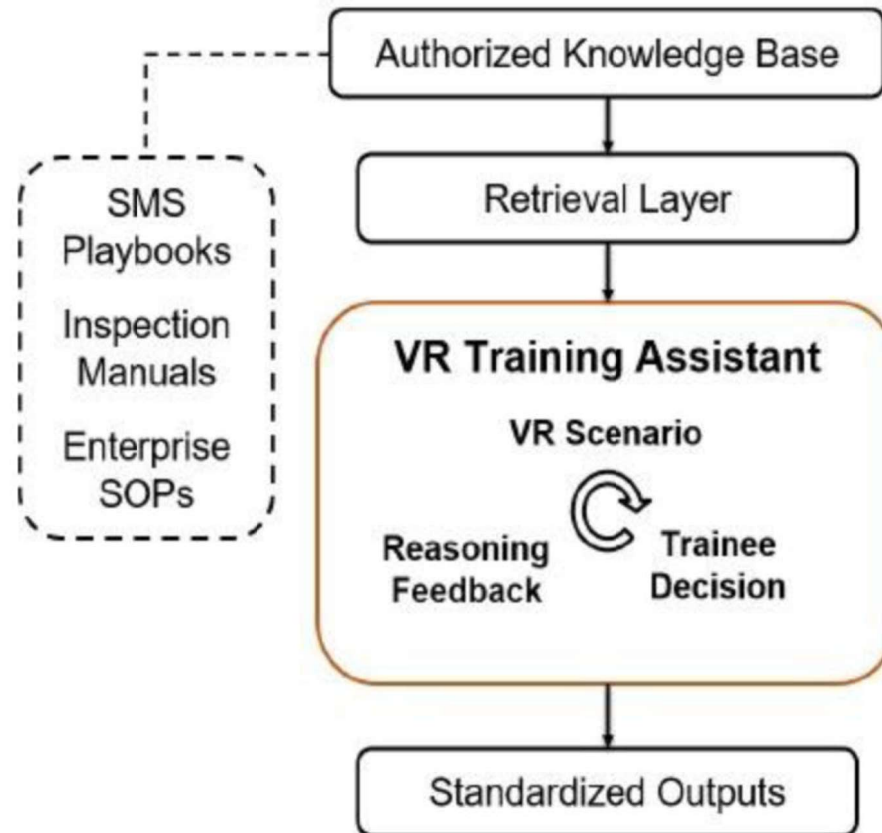


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LLM-Enhanced Inspector Training

VR Inspection Training Assistant

- Offers immersion and interactivity with training environments
- Practice difficult or boundary inspection scenarios with standards-grounded coaching
- Training adapts to student response to provide targeted feedback



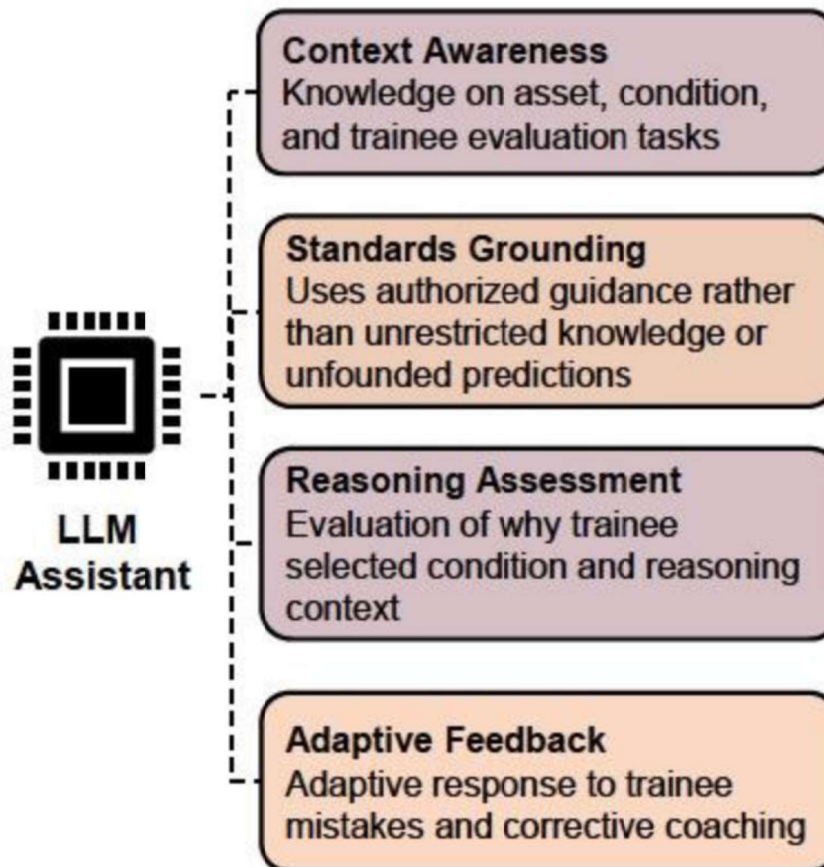
InspectXR

Inspection Training Tool Virtual Reality

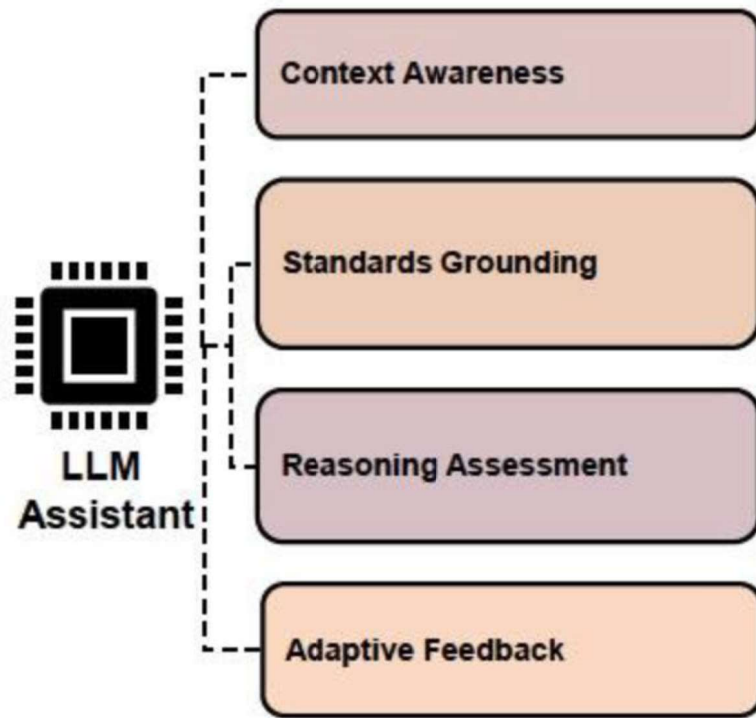
Mohammad Movahedi, Ph.D. Candidate, Civil & Environmental Engineering, FAMU-FSU College of Engineering
Alexander Baldwin, Ph.D. Candidate, Civil & Environmental Engineering, FAMU-FSU College of Engineering
Juyeong Choi, Associate Professor, Civil & Environmental Engineering, FAMU-FSU College of Engineering



What does the LLM NPC Do?



What does the LLM NPC Do?



The LLM does not determine official condition rating, it guides trainees through **standard-aligned practices** and provides **dynamic feedback**

LLM RAG Grounding

1 Ask a Question

Inspector or engineer asks about SMS policy, criteria, or process.



What is the definition of Condition 3 for HVAC systems in SMS?

AI Security & Safeguards

Local LLM deployment

- No external API calls require, proprietary content remains within the host environment.

No External Data Sharing

- Sensitive facility documents and inspection records do not need to leave organizations.

Controlled Knowledge

- The trainer is grounded only in approve, authorized SMS guidance

Human Authority

- The LLM assists and explain, instructors and inspectors retain decision authority.

Deployable AI-based training does not mean external AI connections

Evaluation & Future Work

Validate



Does it improve training?

- Rating accuracy
- Inspector consistency
- Reasoning quality
- Useability

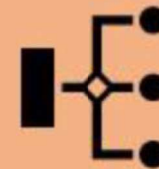
Field Test



Does it work with real inspectors?

- Workforce support
- Instructor feedback
- Deployability limits

Expand



Can it scale and improve?

- More components
- More condition states
- Borderline scenarios
- Additional SMS support

***Thank you for attending our
presentation!***

Dr. Juyeong Choi

Department of Civil and Environmental Engineering,
FAMU-FSU College of Engineering,
(850) 410-6190, jchoi@eng.famu.fsu.edu





SMS INNOVATIONS LAB

September 2, 2026



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CUI



CUI

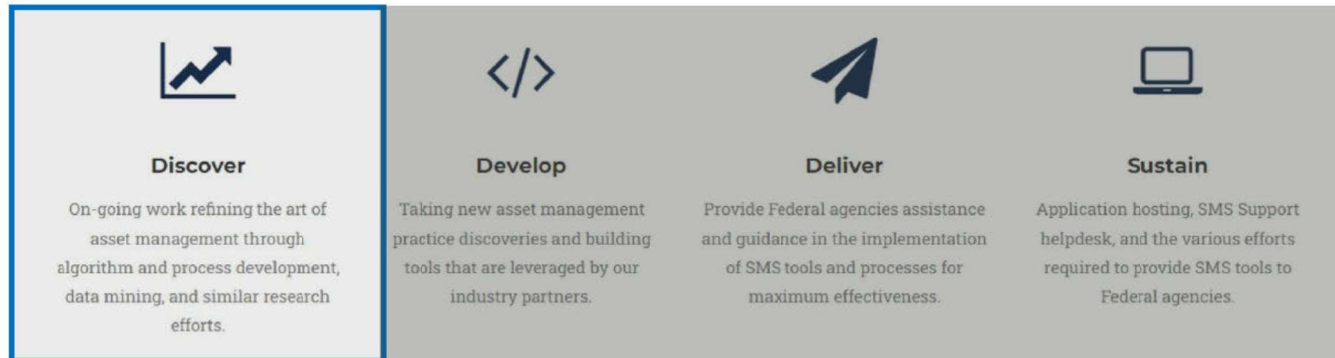
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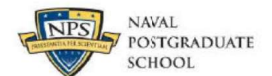
DISCOVERY: A CADRE OF RESEARCHERS



SMS LIFECYCLE



Lawrence Berkeley National Laboratory



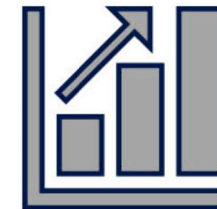
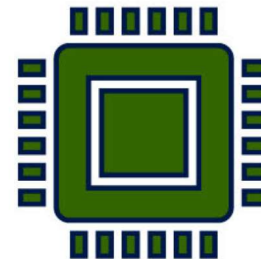
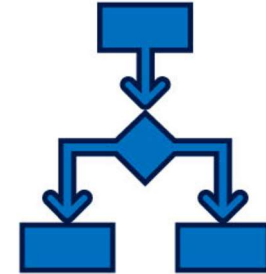
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AGENDA

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- **Innovations in Facility Data Acquisition**
 - Landscape
 - ROSIE
 - Inventory/Assessment from audio/images
- **Advanced Optimization Techniques**
 - Linear Programming
 - Genetic Algorithm
- **GPU Acceleration**
 - Rollout
 - Hardware
- **Enhanced Modeling**
 - Degradation Models
 - Risk Analysis
 - Physics-Based Degradation
 - Reliability-Centered Maintenance

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INNOVATIONS IN FACILITY DATA ACQUISITION



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of Engineers®

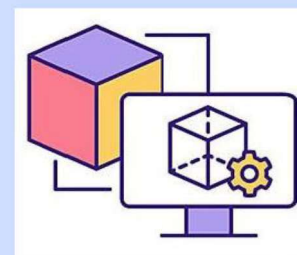
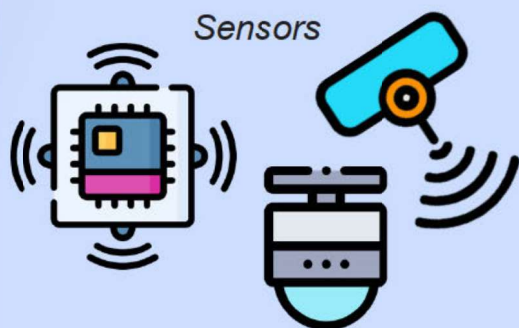


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FACILITY DATA ACQUISITION LANDSCAPE



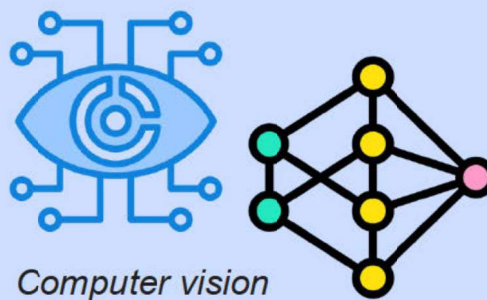
Globally...



Digital Twins



CMMS



Computer vision

within SMS...

Physical assessments



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U.S. ARMY

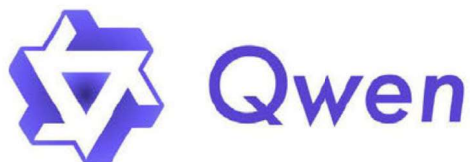


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“SPUTNIK MOMENT” – AI AND ROBOTICS



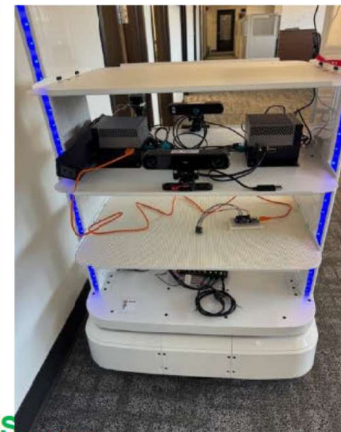
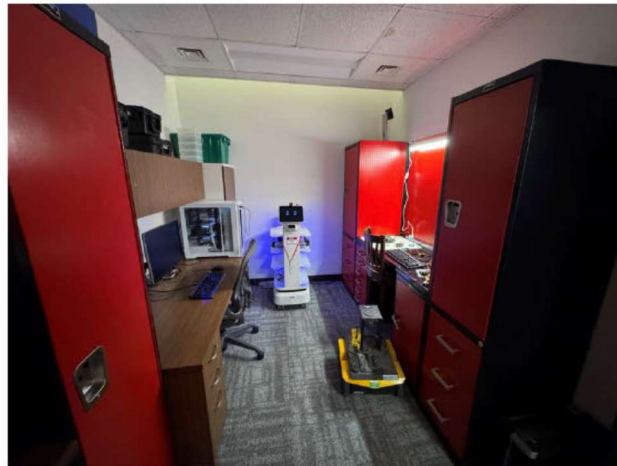
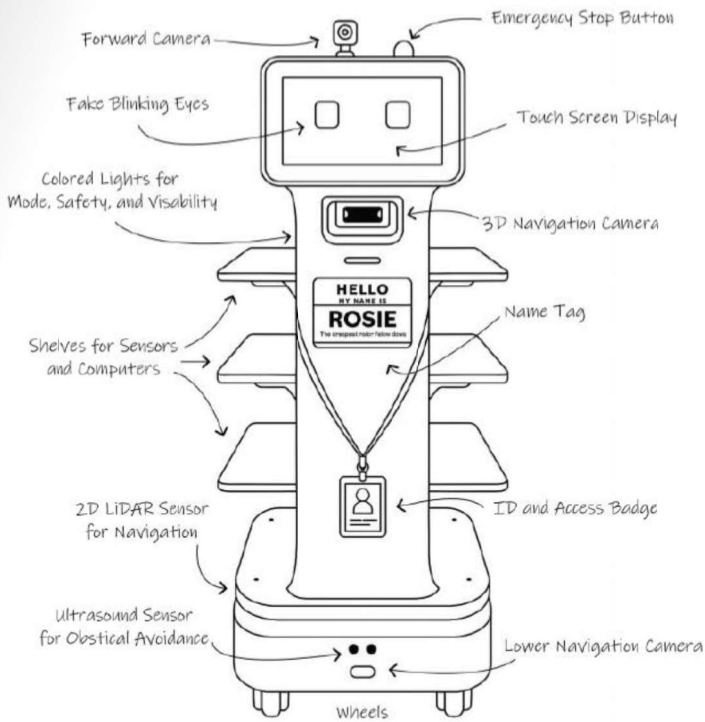
Large Language Models (LLM), Machine Learning, and Robotics



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“MOONSHOT” - ROSIE

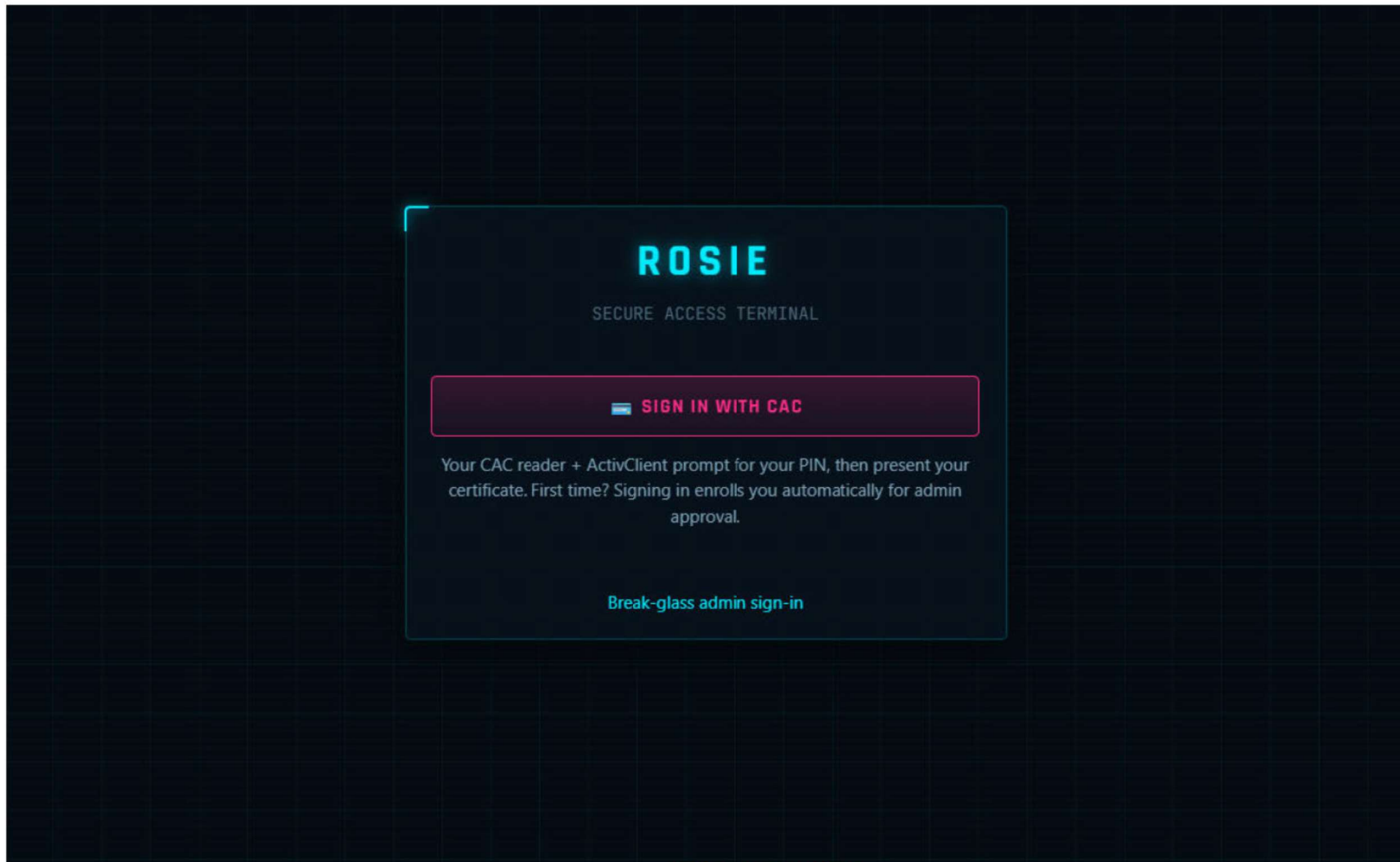
Robotic Observational System for Infrastructure Evaluation





UNCLASSIFIED

ROSIE – LOGIN SCREEN

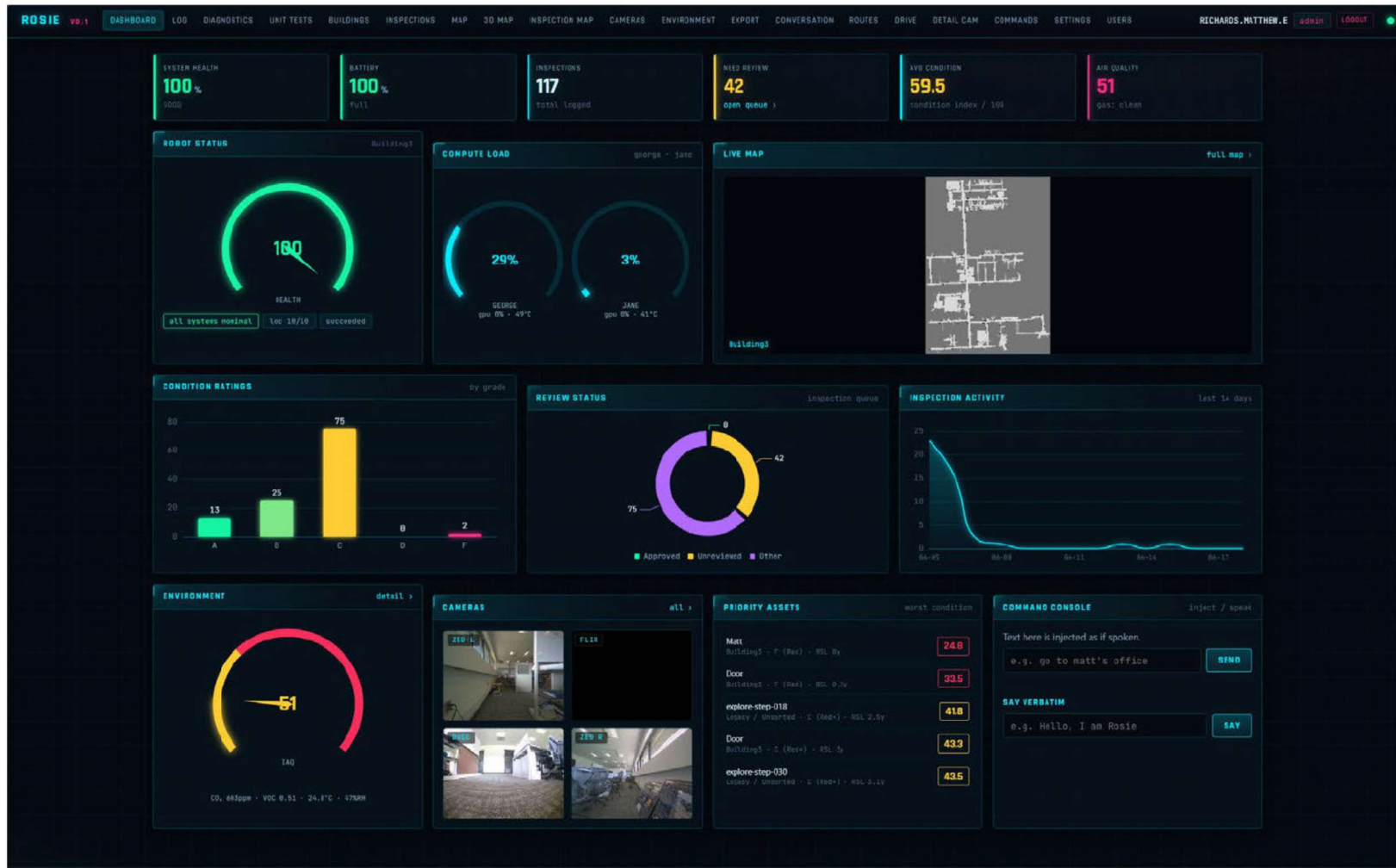


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UNCLASSIFIED

ROSIE – DASHBOARD



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U.S. ARMY

UNCLASSIFIED

ROSIE - INSPECTION



INSPECTION #105 UNREVIEWED

Building: [REDACTED]

Component: Ceiling (C3030 Ceiling Finishes)

When: 2026-06-06 11:05:08

Inspector: operator (manual)

Condition Index: 89.3 / 100 - A (Green)

Remaining service life: 10.8 yrs

Sources: rgb=flr8303scraw, thermal=flr8303scraw

Condition: Good condition with no visible distress.

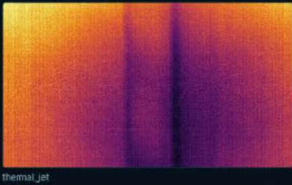
PHOTOS



visible_left



visible_right



thermal_jet



region

DISTRESSES

Type	SMS code	Severity	Density %	Deduct	Source
crack	CRACKING	L	1.1011	16.0	rgb
spalling	SPALLING	L	3.6406	28.0	rgb

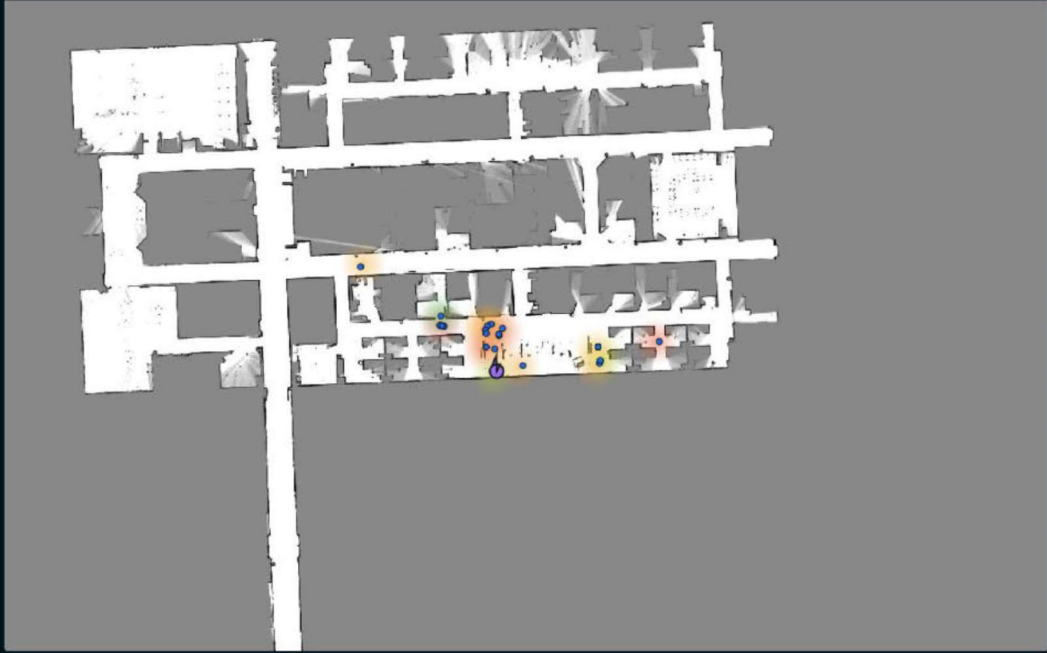
SAVE EDITS + RECOMPUTE CI APPROVE REJECT

Saved. CI 89.3 (A (Green)).

[back to queue](#)

INSPECTION MAP X=-0.04 Y=-0.00 CONDITION INDEX - 43 READINGS - 16 CELLS

Layer: Condition Index Window: All Opacity: ☒ readings ☐ follow FIT TO VIEW REFRESH



Condition Index: CI 40 CI 100

BUILDER CI: red ≤40 (failed) → green ≥85 (good).

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ROSIE - INSPECTION



INSPECT A COMPONENT

Pick a camera, drag a box around the item on the image, name it, then **Inspect Component**. The finding lands in the queue below as **unreviewed**.

Camera: **ZED Left** Component name: **e.g. north wall** Year installed: **e.g. 191** **INSPECT COMPONENT** **CLEAR BOX**

Box set. Name the component and inspect.



3D MAP

IDLE FRAMES: 0 POINTS: 0 POSE REJECTED: 0

START SCAN **STOP SCAN** Drive the robot manually (or run a saved Route) while a scan is running -- the scan itself does not move the robot.

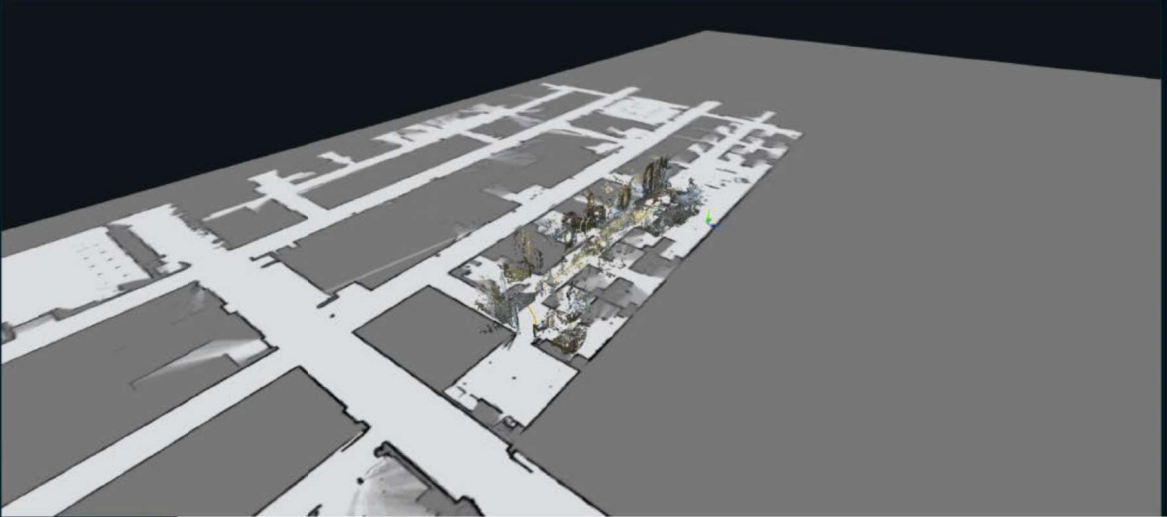
Loaded 49975 points, 137 frames

SESSIONS

6/8/2026, 1:32:15 PM - 49975 pts (done) **REFRESH** **DELETE SESSION**

☒ floor overlay ☒ trajectory ☒ session cloud ☐ follow live pose drag to orbit, scroll to zoom, right-drag to pan

☐ digital model level: **4 cm** color: **true color** ceiling clip: **off** **REBUILD MODEL** 3610080 voxels, 11 sessions



INSPECTIONS

Status: **Unreviewed** Building: **All** Robot-captured findings land here as **unreviewed** for your review & approval.

When	Building	Component	UniFormat	CI	Rating	Distresses	Status
2026-06-15 10:10:08		Wallplate	B2010	58.0	C (Red-)	1	unreviewed
2026-06-15 14:03:02		b	Z	46.7	C (Red-)	2	unreviewed
2026-06-08 09:27:55		Door	B2030	33.5	F (Red)	2	unreviewed
2026-06-07 14:32:38		Door	B2030	46.7	C (Red-)	2	unreviewed
2026-06-07 14:32:38		Door	B2030	46.7	C (Red-)	2	unreviewed

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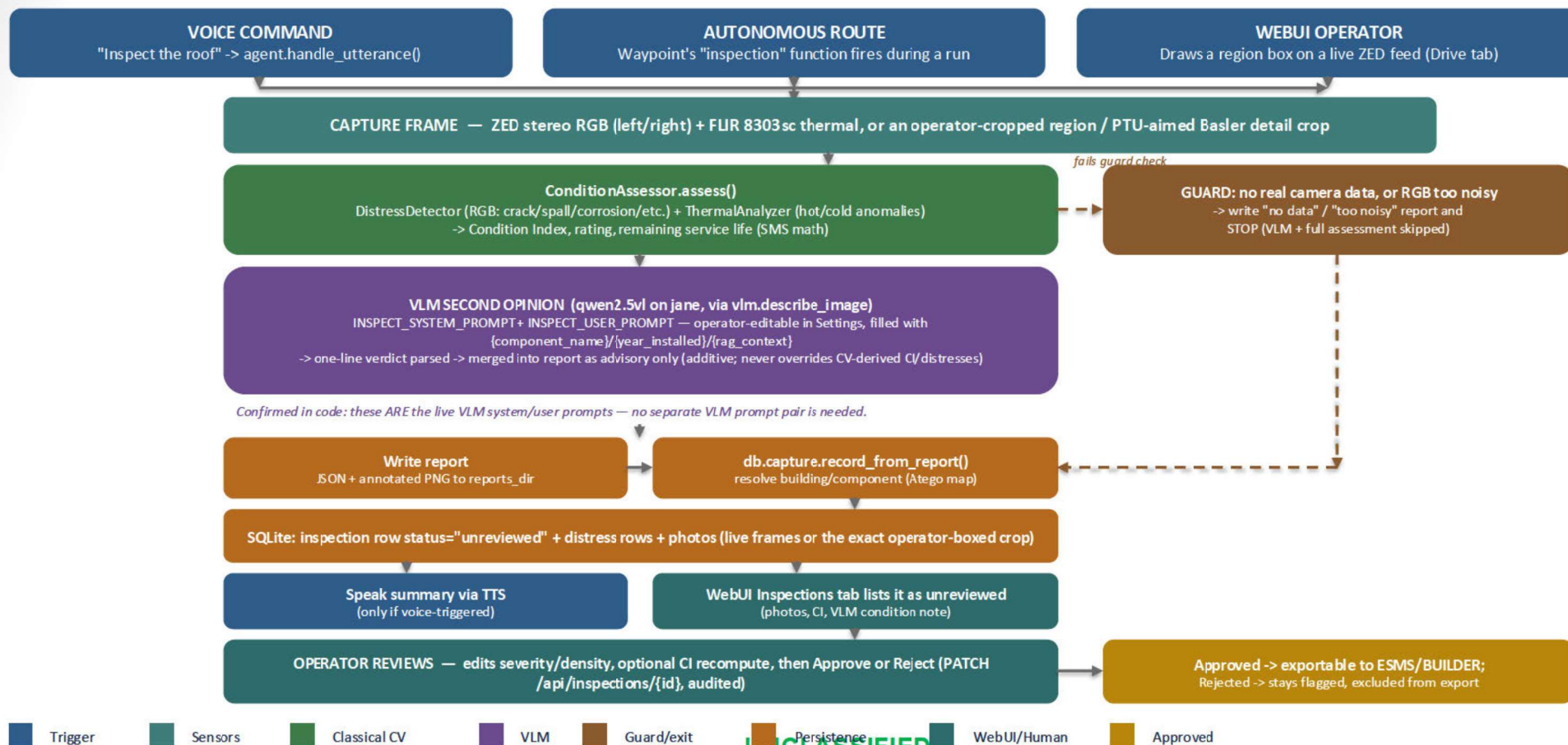
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ROSIE – CONDITION ASSESSMENT INSPECTION



ROSIE Inspection Pipeline — User Trigger to Stored, Reviewable Record

Three entry points converge on one condition-assessment path; every finding lands unreviewed and waits for a human decision before it counts as data.





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ROSIE – HVAC ASSESSMENT



24.75°C 46.66% 990.72 600.9 0.5 183743 0.166 v
temperature humidity hPa pressure ppm CO₂eq ppm VOCeq Ω gas (BME680) MiCS reducing gas clean
CO-alcohol-NH₃-H₂-HC likely gas (experimental)

Building3 near air quality sensor. , can you tell us about your air quality sensor (-0.0, -0.0)

MiCS-5524 gas detects: carbon monoxide (CO) · alcohol/ethanol · ammonia (NH₃) · hydrogen (H₂) · methane/propane/iso-butane (hydrocarbons). The voltage rises with gas. On its own it reports only a **combined** reducing-gas level — but ROSIE now **estimates the specific gas** by combining it with the BME680 (the two sensors respond differently to each gas). The **Gas (likely)** column shows that estimate. It is *experimental* and gets more accurate as more gases are benchmarked.

ASHRAE Standard 62.1 is a ventilation **design** standard — it sets the minimum outdoor-air rate an HVAC system must deliver, not pass/fail limits for a sensor. ROSIE reports indicative measurements against the 62.1 criteria it can actually sense; it does **not** by itself determine 62.1 compliance. (Notably, 62.1 has **no** indoor CO₂ limit — CO₂ is only a ventilation indicator.)

OK **Adequate**
12.6 °C / 55 °F moisture control ventilation (CO₂ indicator)
dew point (computed) RH≤65% & dew pt≤60°F ≤1100 ppm guide · not a 62.1 limit

62.1 IAQ Procedure design-limit reference (limits from EPA / CalEPA "cognizant authorities"):

Contaminant	ASHRAE 62.1 reference limit	ROSIE sensor	Coverage
PM2.5	9 µg/m ³ annual (EPA NAAQS, 2024)	—	no sensor
PM10	150 µg/m ³ 24-h (EPA NAAQS)	—	no sensor
Ozone (O ₃)	70 ppb 8-h (EPA NAAQS)	—	no sensor
Carbon monoxide (CO)	9 ppm 8-h (EPA NAAQS)	MiCS-5524 (non-specific)	indicative only
Formaldehyde	33 µg/m ³ (CalEPA CREL)	BME680 VOC (non-specific)	indicative only
CO ₂	no limit; ~1100 ppm = ventilation indicator	BME680 (estimated)	indicator ✓
Relative humidity / moisture	≤65% RH & dew point ≤60 °F (15.6 °C) — microbial control	BME680	measured ✓

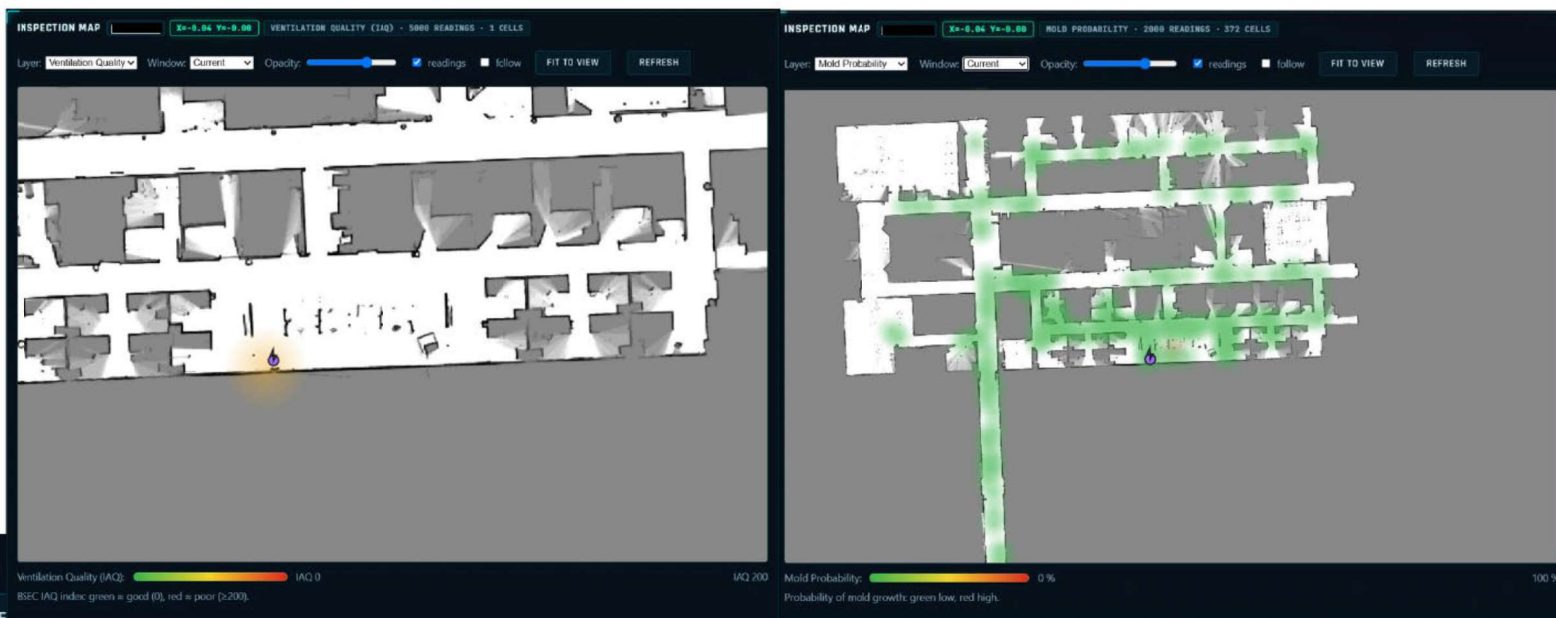
▲ **Coverage gap:** PM2.5, PM10 and ozone are the only contaminants ASHRAE 62.1 §4 actually requires controlling, and ROSIE has no sensor for any of them. For true 62.1-referenced coverage, add a particulate sensor (e.g. Sensirion SPS30 or Plantower PMSA003I) and an ozone sensor. Until then, the moisture criterion and the CO₂ ventilation indicator are the parts of 62.1 ROSIE can legitimately evaluate.

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ROSIE – HVAC ASSESSMENT



RECENT READINGS

[Download CSV](#)

REFRESH

Time	Air quality (IAQ)	Acc	Temp °C	Hum %	Press hPa	CO ₂ eq	VOCeq	Gas Ω	MiCS gas V COalcohol-NH ₃ -H ₂ -HC	Gas (likely) experimental	Location
2026-08-17 14:46:55	Fair 50.3	2	24.75	46.66	990.72	600.9	0.5	183743	0.166	clean	near air quality sensor. , can you tell us about your air quality sensor (-0.0, -0.0)
2026-08-17 14:46:22	Fair 51.3	2	24.73	46.67	990.74	603.4	0.51	183944	0.148	clean	near air quality sensor. , can you tell us about your air quality sensor (-0.0, -0.0)
2026-08-17 14:45:49	Fair 52.5	2	24.74	46.76	990.69	606.3	0.52	182348	0.15	clean	near air quality sensor. , can you tell us about your air quality sensor (-0.0, -0.0)
2026-08-17 14:45:16	Fair 51.6	2	24.73	46.75	990.71	604.2	0.51	182348	0.161	clean	near air quality sensor. , can you tell us about your air quality sensor (-0.0, -0.0)

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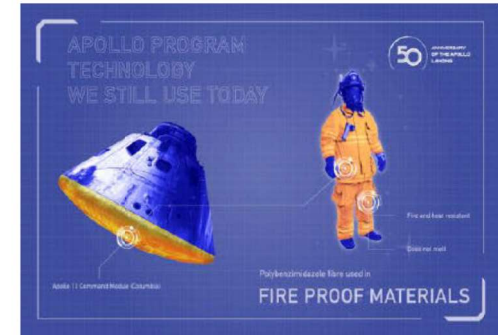
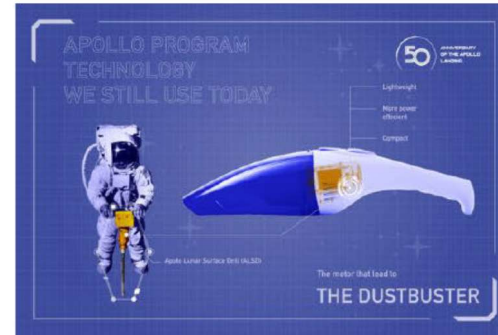
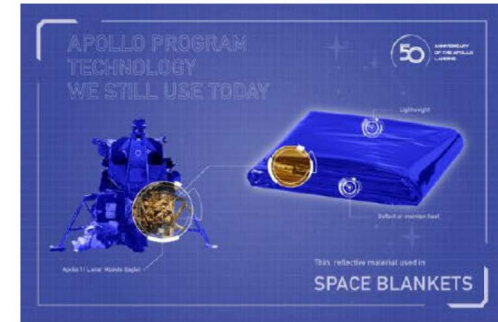
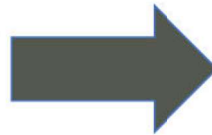


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MOONSHOT TECHNOLOGY TRANSFER



NASA

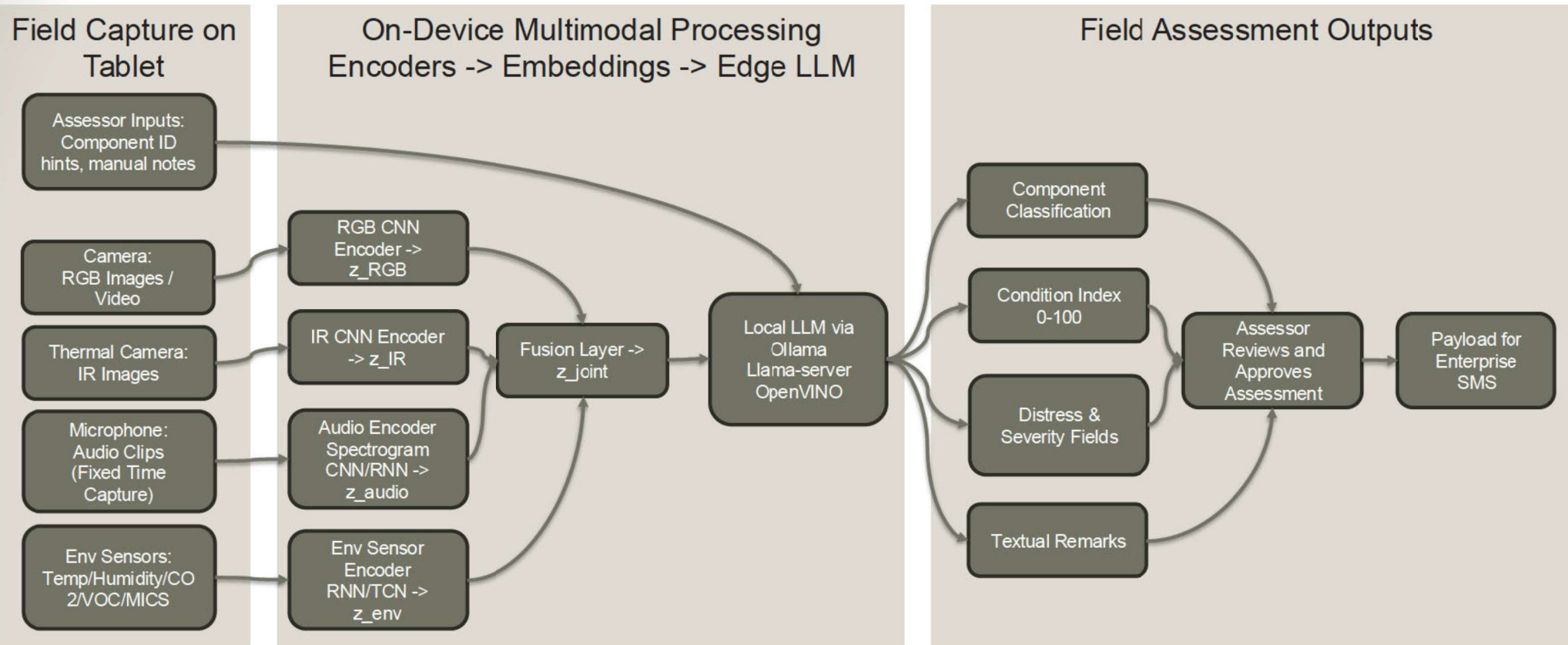


Source: Compare The Market. *Apollo Moon landing 50th anniversary. The technology we're still using today, 2026.* <https://www.comparethemarket.com.au/home-contents-insurance/features/apollo-technology-we-still-use/>. Accessed 17 Aug. 2026.

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ROSIE - TECHNOLOGY TRANSFER

E-SMS Mobile Field Application - Initial assessments from sensor data





VISION LANGUAGE MODELS (VLM)

Vision Language Model Assessments from RGB Camera Images
Cassia Sperry and Brooke Rhodes – Mahomet Seymour High School

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CAPTURE

Field Tablet, Camera, or
Robot Sensors



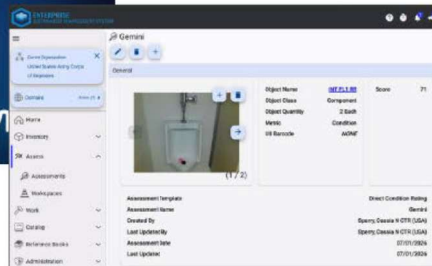
VLM INFERENCE

Cloud VLM, Local VLM,
or ROSIE's onboard VLM
— same task, pluggable
backend.



STRUCTURED ASSESSMENT

Condition Index / Score,
Green-Amber-Red
rating, plain-language
narrative.



E-SMS DRAFT RECORD

Written into E-SMS as
an unreviewed draft
tied to the specific asset
or component.

HUMAN ASSESSOR REVIEW

Field Application or Web E-
SMS — edits, confirms, or
overrides before it's final.

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LEGACY BUILDER ASSESSMENTS VS VLM



Vision Language Model Assessments from Legacy Builder Images Cassia Sperry and Brooke Rhodes – Mahomet Seymour High School



This assessment evaluates the condition of the suspended acoustical ceiling tile system, which was approximately 36 years old at the time of the photo. This age is well beyond the typical expected service life for this type of component.

Component Distress Survey Findings

Acoustical Ceiling Tiles Water Stains: Faint water stains are visible on at least one tile, indicating a past or present moisture issue from above.

Physical Damage: A visible crack is present on one tile. Another tile appears to have a broken or **misaligned edge**.

Sagging/Misalignment: At least one tile appears to be slightly sagging or not seated correctly in the grid.

Medium: Water stains and physical cracks are significant defects that cannot be repaired, only replaced. They indicate a failure of the material and potentially other building systems (roofing/plumbing).

Low: The visible distresses are spread across several different tiles but do not affect the majority of the ceiling in the image.

Rationale: The presence of multiple distress types (stains, cracks, sagging) across several tiles indicates the system is degrading. While still largely functional, it requires corrective action (tile replacement) and further investigation into the cause of the water stains. Its advanced age is a contributing factor to this degradation.

Overall System Condition Index (CI): ~75 Direct Rating

Using the simplified Green-Amber-Red direct rating system: Overall System G-A-R Status: A (Amber)

Conclusion: The 1986 acoustical ceiling tile system is in Fair (Amber) condition. **Findings:** The ceiling has reached the end of its expected service life and is exhibiting multiple signs of degradation, including water stains, cracked tiles, and sagging. **Required Action:** Corrective maintenance is required. **Investigate:** The source of the water stains must be identified and repaired to prevent further damage. **Replace:** The stained, cracked, and sagging tiles should be replaced to restore the ceiling's appearance and function. Given the age of the system, finding matching tiles may be difficult, potentially requiring a larger replacement project.

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LEGACY BUILDER ASSESSMENTS VS VLM



E-SMS Vision Language Model Assessments from RGB Camera Images
Cassia Sperry and Brooke Rhodes – Mahomet Seymour High School

General

General



+

Object Name

INT MEZZ

Score

95

Assessment Template

Direct Condition Rating

Object Class

Component

Assessment Name

Gemini tablet

Object Quantity

8760 Square Feet

Created By

Sperry, Cassia N CTR (USA)

Metric

Condition

Last Updated By

Rhodes, Brooke E CTR (USA)

Ull Barcode

NONE

Assessment Date

07/14/2026

Last Updated

07/14/2026

Comments

Based on a visual assessment of the provided image and applying the principles of the USACE CERL SMS Builder method, here is a condition assessment for the 1996 wall. ### Assessment Summary Similar to the previous assessment, there is a discrepancy between the stated age of the wall (1996) and the pristine condition of its finish. An interior paint finish has a service life of around 7-15 years, meaning this wall has almost certainly been repainted since its original construction. Therefore, this assessment is based on the condition of the *current visible finish*. The wall finish is in ****Excellent condition****. ### Visual Analysis ****Wall Surfaces:**** The visible wall areas are painted a light neutral color. The finish is smooth and uniform, with no visible scuffs, stains, scratches, or any other form of damage. ****Overall Condition:**** The wall appears clean and very well-maintained, consistent with a recently painted surface. ### Condition Index (CI) Estimation The CI is based on the current condition of the paint, which appears to be relatively new. ****Wall Finish Condition Index (CI): 95 (Excellent)**** ****Rationale:**** A CI of 95 is assigned because the paint finish appears to be in "like-new" condition. There are no observable defects in the image provided. This rating reflects a finish that was likely applied in recent years and is being well-maintained. ### Conclusion The wall finish is rated as ****Excellent**** with a ****CI of 95****. This assessment assumes the finish has been renewed since 1996. The component is fully functional and requires no maintenance at this time. Is there another component you would like to assess?

"Assessment Summary Similar to the previous assessment, **there is a discrepancy between the stated age of the wall (1996) and the pristine condition of its finish**. An interior paint finish has a service life of around 7-15 years, meaning **this wall has almost certainly been repainted since its original construction**. Therefore, this assessment is based on the condition of the *current visible finish*. The wall finish is in ****Excellent condition****" *This assessment by the LLM was correct, the wall was repainted in 2022.*

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LEGACY BUILDER ASSESSMENTS VS VLM

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E-SMS Large Language Model Assessments from RGB Camera Images Cassia Sperry and Brooke Rhodes – Mahomet Seymour High School

Legacy BUILDER Inspection

General



Object Name: [INL FL1](#) Score: 88
Object Class: Component
Object Quantity: 13862 Square Feet
Metric: Condition
Ull Barcode: NONE

Assessment Template: Direct Condition Rating
Assessment Name: Legacy BUILDER Inspection
Created By: [REDACTED]
Assessment Date: 03/11/2022
Last Updated:

Sample 1 - Default Sample 9.29% (1287.827 / 13862 Square Feet) - Rep

Sample Location	Default Sample	Representative	Yes	Score
Sample Quantity	1287.827			88

What is the Direct Rating?

Answer	Points	Images
0-	88	

Gemini old photo

General



Object Name: [INL F.1](#) Score: 71
Object Class: Component
Object Quantity: 13862 Square Feet
Metric: Condition
Ull Barcode: NONE

Assessment Template: Direct Condition Rating
Assessment Name: Gemini old photo
Created By: Sperry, Cassia N CTR (USA)
Last Updated By: Sperry, Cassia N CTR (USA)
Assessment Date: 07/02/2026
Last Updated: 07/02/2026

Comments

Component-Level Assessment: Acoustical Ceiling Tiles & Panels (1986) This assessment evaluates the condition of the suspended acoustical ceiling tile system, which was approximately 36 years old at the time of the photo. This age is well beyond the typical expected service life for this type of component. Component Distress Survey Findings Severity Density Estimated CCI Acoustical Ceiling Tiles Water Stains: Faint water stains are visible on at least one tile, indicating a past or present moisture issue from above. Physical Damage: A visible crack is present on one tile. Another tile appears to have a broken or misaligned edge. Sagging/Misalignment: At least one tile appears to be slightly sagging or not seated correctly in the grid. Medium: Water stains and physical cracks are significant defects that cannot be repaired, only replaced. They indicate a failure of the material and potentially other building systems (roofing/plumbing). Low: The visible distresses are spread across several different tiles but do not affect the majority of the ceiling in the image. ~75 (Amber) Condition Index (CI) and Component Condition Index (CCI) The Component Condition Index (CCI) is a score from 0 to 100. The ceiling is no longer in "as-new" condition due to multiple visible distresses. Component Condition Index (CCI) for Ceiling Tiles: ~75 (Amber) Rationale: The presence of multiple distress types (stains, cracks, sagging) across several tiles indicates the system is degrading. While still largely functional, it requires corrective action (tile replacement) and further investigation into the cause of the water stains. Its advanced age is a contributing factor to this degradation. The overall Condition Index (CI) for the ceiling system is the same as the CCI. Overall System Condition Index (CI): ~75 Direct Rating (G-A-R) Using the simplified Green-Amber-Red direct rating system: Overall System G-A-R Status: A (Amber) Conclusion The 1986 acoustical ceiling tile system is in Fair (Amber) condition. Findings: The ceiling has reached the end of its expected service life and is exhibiting multiple signs of degradation, including water stains, cracked tiles, and sagging. Required Action: Corrective maintenance is required. Investigate: The source of the water stains must be identified and repaired to prevent further damage. Replace: The stained, cracked, and sagging tiles should be replaced to restore the ceiling's appearance and function. Given the age of the system, finding matching tiles may be difficult, potentially requiring a larger replacement project.

What is the Direct Rating?

What is the Paint Rating?

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INSPECTOR BIAS

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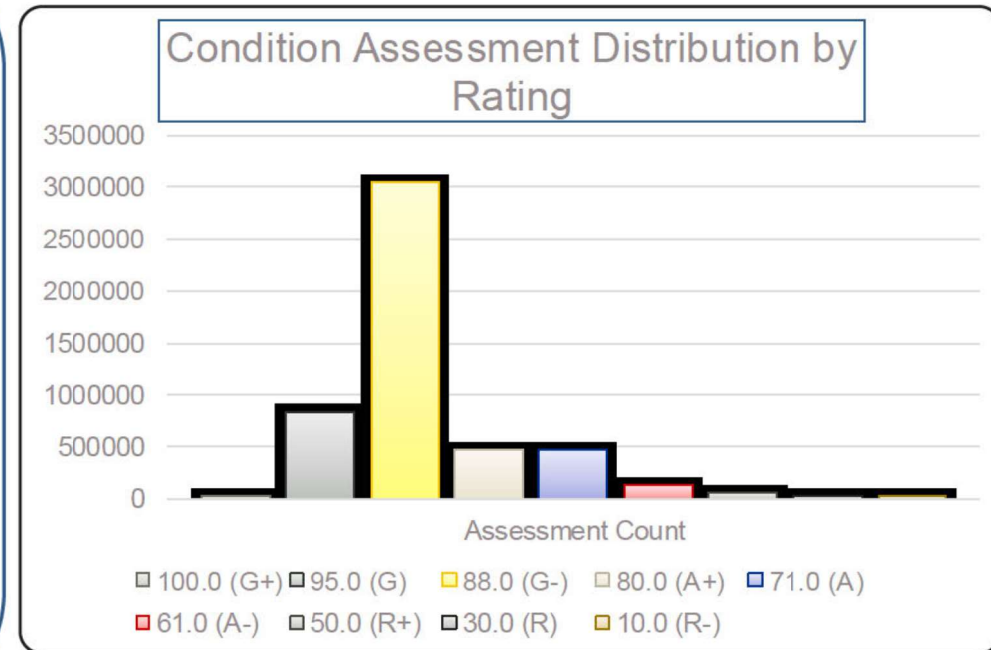


Cassia Sperry and Brooke Rhodes – Mahomet Seymour High School

Background: Assessment Bias

There is evidence that facility assessments are biased based on the assessor's experience, time constraints, environmental conditions, and test equipment.

70% of all building component assessments for the DoW were rated with a Condition Index of 88 (G-). Random analysis of the components revealed that many of these components were well beyond their remaining useful service life. The SMS Builder software requires any assessment of less than G- include a written comment and photos. Contracts are written to rate inaccessible components as G-. This poisons any machine learning model trained on this data.



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AUDIO CLASSIFICATION FOR ASSESSMENTS

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E-SMS Mobile Field Application – Audio Assessment

Adam Westerhold – Sophomore in Mechanical Engineering at Illinois State University

Microphone:
Audio Clips
(Fixed Time
Capture)

Audio Encoder - Spectrogram
CNN/RNN Trained on MIMII Dataset

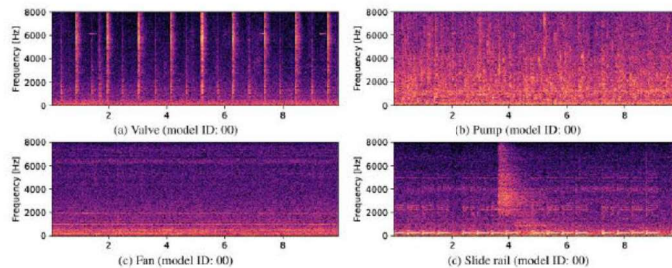


Figure 3: Examples of power spectrograms under normal condition at 6-dB SNR.



"Embeddings"
Outputs a Distress Survey

Table 2: List of operations and anomalous conditions.

Machine type	Operations	Examples of anomalous conditions
Valve	Open / close repeat with different timing	More than two kinds of contamination
Pump	Suction from / discharge to a water pool	Leakage, contamination, clogging, etc.
Fan	Normal operation	Unbalanced, voltage change, clogging, etc.
Slide rail	Slide repeat at different speeds	Rail damage, loose belt, no grease, etc.

Fusion Layer
Combines
Vision,
Thermal,
Environmental,
BAS, and
Other Sensor
Distresses
from the
Embeddings

Local Edge
Based LLM
(On Field
Device, Not
in the Cloud)

Source: Harsh Purohit, et al. "MIMII Dataset: Sound Dataset for Malfunctioning Industrial Machine Investigation and Inspection". 2019. <https://arxiv.org/abs/1909.09347>

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Audio classification for identifying faulty industrial employed on mobile systems

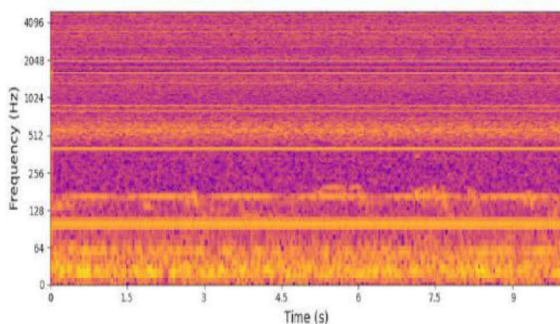
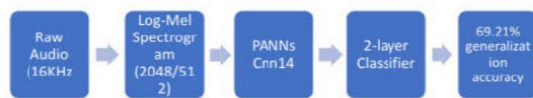


Goal:

The goal of my project is to create an audio classification neural network which can determine whether industrial equipment is malfunctioning based on the sounds it produces and deploy this model on systems which are used to assist in building inspections

Spectrogram processing:

In order to use the MIMII datasets vast amounts of auditory data we must ensure a standard data input for the neural network the data was down sampled to 16 KHz we then converted this one-dimensional signal into a 2D image of the audio with a window size of 2048 and a hop size of 512 this gives a 75% overlap and allows us to capture sudden noises like clicks or scraps without losing details in the frequency. These spectrograms for the purpose of speeding up testing are preprocessed



Neural net training and testing:

then they are given to pretrained audio neural network (PANN), specifically I used the Cnn14 architecture which is a 14-layer Convolutional neural net which was trained on Google's audio set containing over 2 million hours of YouTube audio. This pretrained neural net changes the images into 2048-dimensional embedding vectors which act as a detailed summary of the spectrogram. This is then fed into a lightweight classifier to obtain the final prediction of whether a machine is normal or abnormal sounding. To validate the model's prediction, it is tested for accuracy against a withheld set of data, the specific data which is withheld is Id_02 from each machine type and background noise level which represents a certain brand of each machine type. This provides a robust test ensuring that this model is capable of predicting anomalies properly without worrying that the brand of machine may affect accuracy. It is also tested at different levels of background noise which creates a percent accuracy at an easy, medium, and hard level. I have also added an area under curve (AUC) test which represents how confident the AI is with its predictions with and AUC of 50% meaning that the AI is randomly guessing

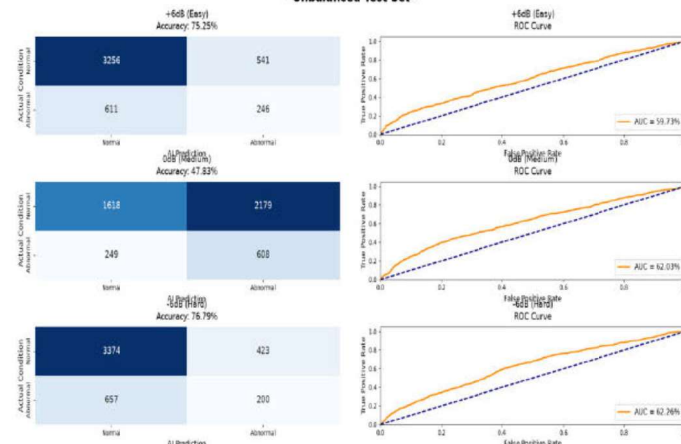
Results/analysis:

The accuracy test has yielded a roughly 76% accuracy at the easy and hard levels however for the medium difficulty test the accuracy dropped significantly down to 47.83% accuracy. This dip in accuracy in the medium category is unexpected but can tell us a lot about how the model processes its data. I believe that the model is able to discern the important data better at the easy level because of how much louder the machine noise is compared to the background noise and that the inverse is likely for the hard category, This would explain why the accuracy plummets at the medium category as the model is not able to pick out the machine noise from the background noise based on volume alone. The AUC test allows us to gauge how confident the model is in its predictions with the model having a completely random guess when the AUC is 50%. The three tests yielded an average of 61.43% between the three difficulty levels this result is less than satisfactory but is an important metric to keep track of in future models to ensure that our model's accuracy isn't up to luck but is a concrete prediction from a confident model.

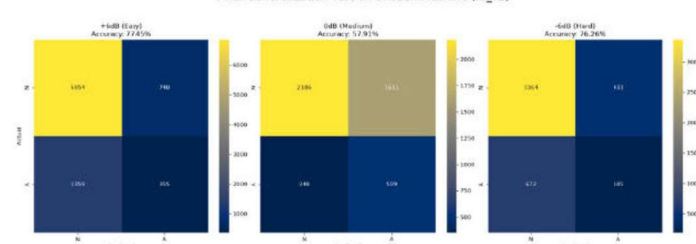
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Generalization Test on Unseen Machine (id_02)
Unbalanced Test Set



Final Generalization Test on Unseen Machine (id_02)



Future work and goals:

To further improve the accuracy and generalization of my model I need to



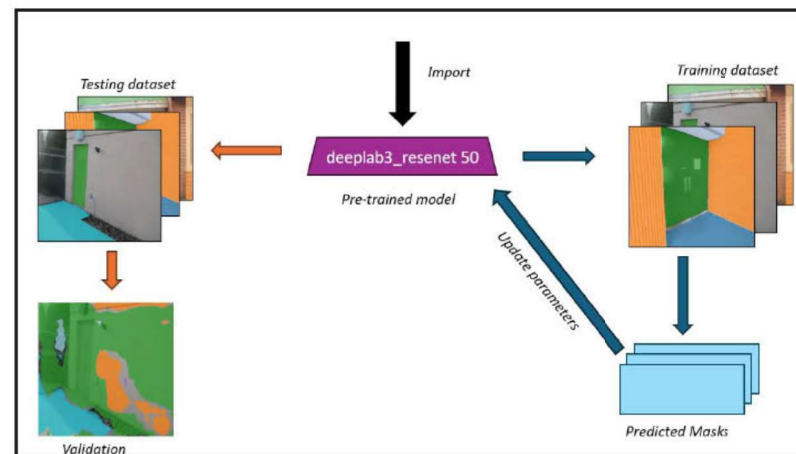
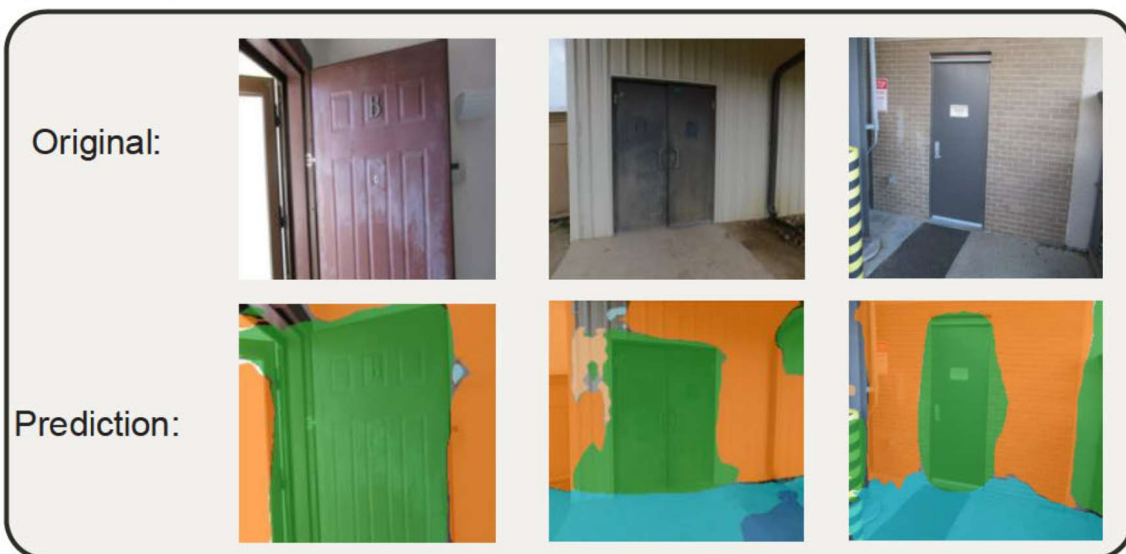
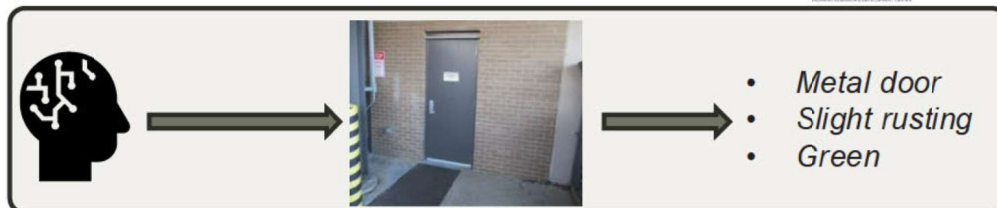
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COMPUTER VISION APPLICATION



- **Goal:** Train a vision model to catalog parts, identify distresses, and estimate condition within images of components.
- **Methodology:**
 1. Apply a pre-trained image segmentation model and manually label the results.
 2. Use this resulting dataset to train and validate a vision model.
- **Results:**



ADVANCED OPTIMIZATION TECHNIQUES



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MAINTENANCE POLICIES

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FSRM: Facility Sustainment Restoration and Modernization

A **maintenance policy** describes an application of **maintenance rules** to a portfolio of assets and components.

Reactive Policies:

- "Repair X when it fails"

Temporal Policies:

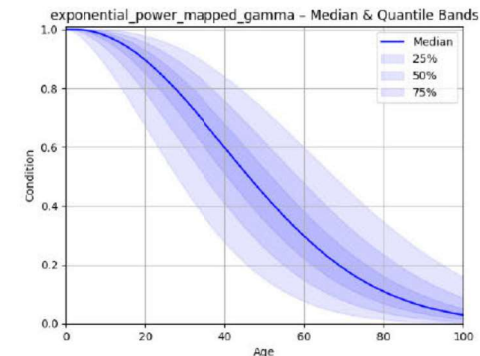
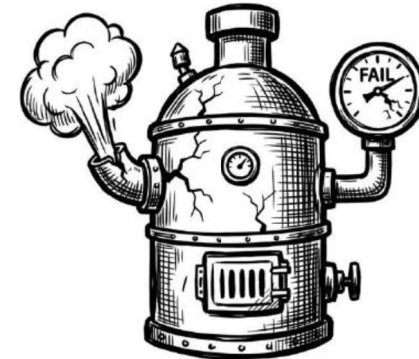
- "Repair X every 5 years"

Condition Policies:

- "Repair X when its CI is less than 50"

Reliability-Centered Maintenance:

- Make decisions based on Service Life ROI



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OBJECTIVES

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There are two primary types of metrics that we focus on:

Performance Metrics:

- Facility Condition
- System Condition
- Component Condition
- Mission Readiness
- Functionality Index

Cost Metrics:

- Total Cost
- Annual Costs
- Costs per funding category

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 Performance



 Cost



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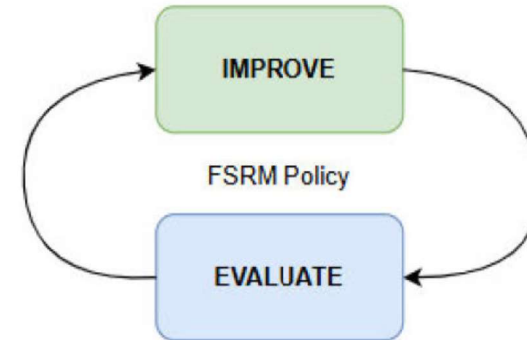
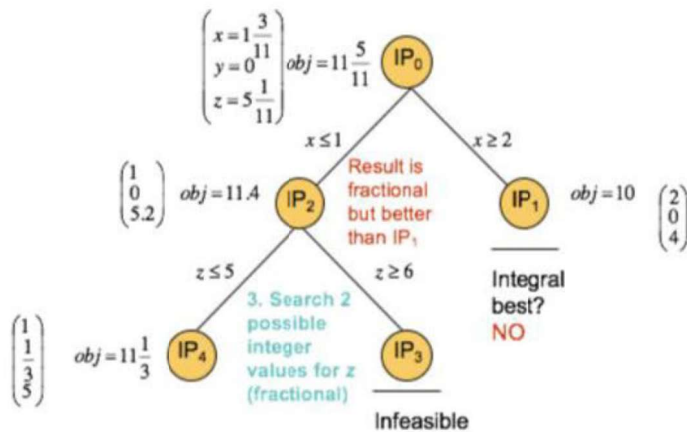
OPTIMIZATION TECHNIQUES

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Mathematical Programming techniques search through all possible solutions to find the optimal solution.

Policy Iteration techniques cycle between improving and evaluating a solution.



These techniques often require evaluating all viable solutions prior to optimization

These techniques are near-optimal, but do not require evaluating all solutions.

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EXAMPLE: INTEGER PROGRAMMING



- Integer programming is a type of **mathematical programming** where the solution is restricted to integers. For many decision-making tasks, the solution is further **restricted to just 0 and 1**:
 - 0 = No
 - 1 = Yes

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EXAMPLE: INTEGER PROGRAMMING



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 - 0 = No
 - 1 = Yes
- Simple problem:
 - Consider buildings A, B, and C.
 - We may do nothing, repair, or replace.
 - What is the optimal set of maintenance actions for the portfolio?

	FY26
A 	
B 	
C 	

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EXAMPLE: INTEGER PROGRAMMING



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	FY26
A 	
B 	
C 	

Replace Everything?  **Maximum Condition!**
Over Budget!

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EXAMPLE: INTEGER PROGRAMMING



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 - Consider buildings A, B, and C.
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 - What is the optimal set of maintenance actions for the portfolio?

	FY26
A 	
B 	
C 	

Do Nothing at all?  **Poor Condition!**
Under Budget!

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EXAMPLE: INTEGER PROGRAMMING



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- Simple problem:
 - Consider buildings A, B, and C.
 - We may do nothing, repair, or replace.
 - What is the optimal set of maintenance actions for the portfolio?

	FY26
A 	
B 	
C 	

Something in between? → **Good Condition!**
Under Budget!

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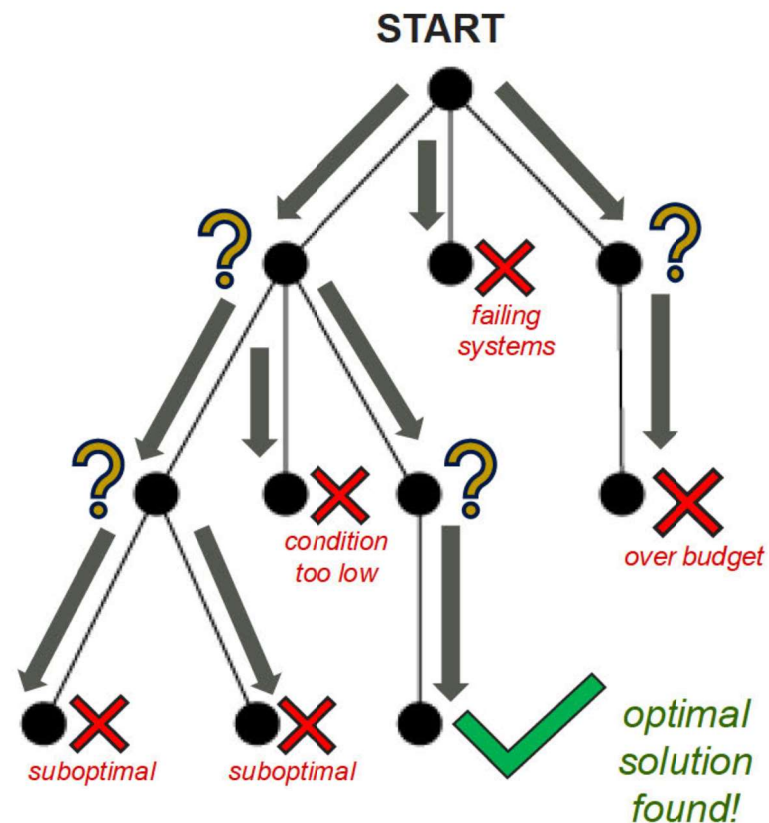
EXAMPLE: INTEGER PROGRAMMING



- Many integer programming optimizers perform a **tree search** through potential solutions. It can “cut off” branches that are unlikely to have the optimal solution for efficiency.
- These are very powerful optimizers, but are difficult to scale. If we have n facilities, m possible actions, and T timesteps, then the number of possible solutions is

$$p = m^{T \times n}$$

Simple problem: $3^{1 \times 3} = 27$
 Small problem: $5^{5 \times 5} = 2.98 \times 10^{17}$
 Medium problem: $5^{5 \times 100} = 3.05 \times 10^{350}$



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EXAMPLE: GENETIC ALGORITHM



Genetic algorithms are an **evolutionary strategy** for optimization inspired by nature.

Genetic Algorithms treat maintenance policies as a **population** that evolves over time to maximize an objective.

The Maintenance Policy is like **DNA** that **mutates** and **evolves** over time.



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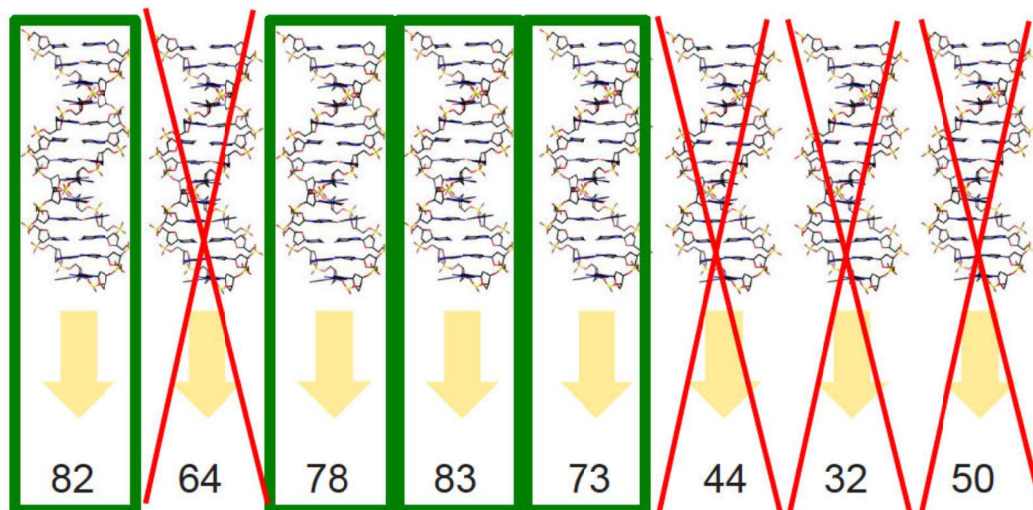
FIRST STEP: EVALUATION

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First, we evaluate the population of maintenance policies.

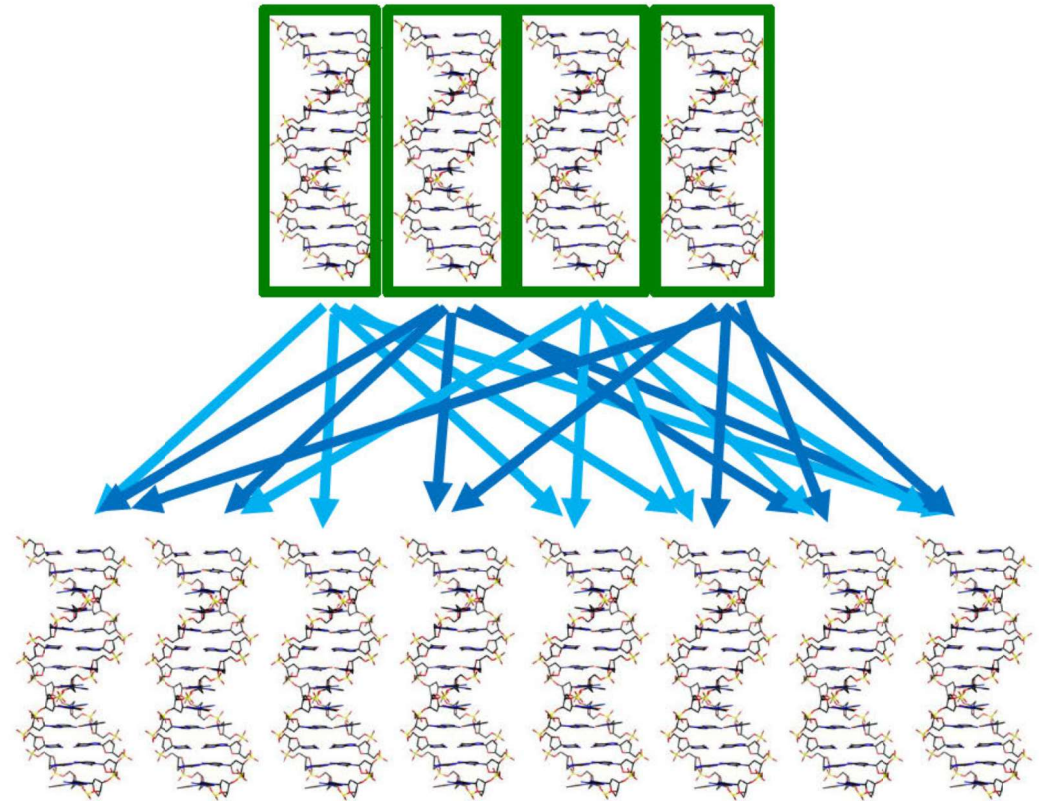
Then we select the top performing policies to become the "parents" of the next generation.



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Next, we combine parts of the best policies to initialize the new population



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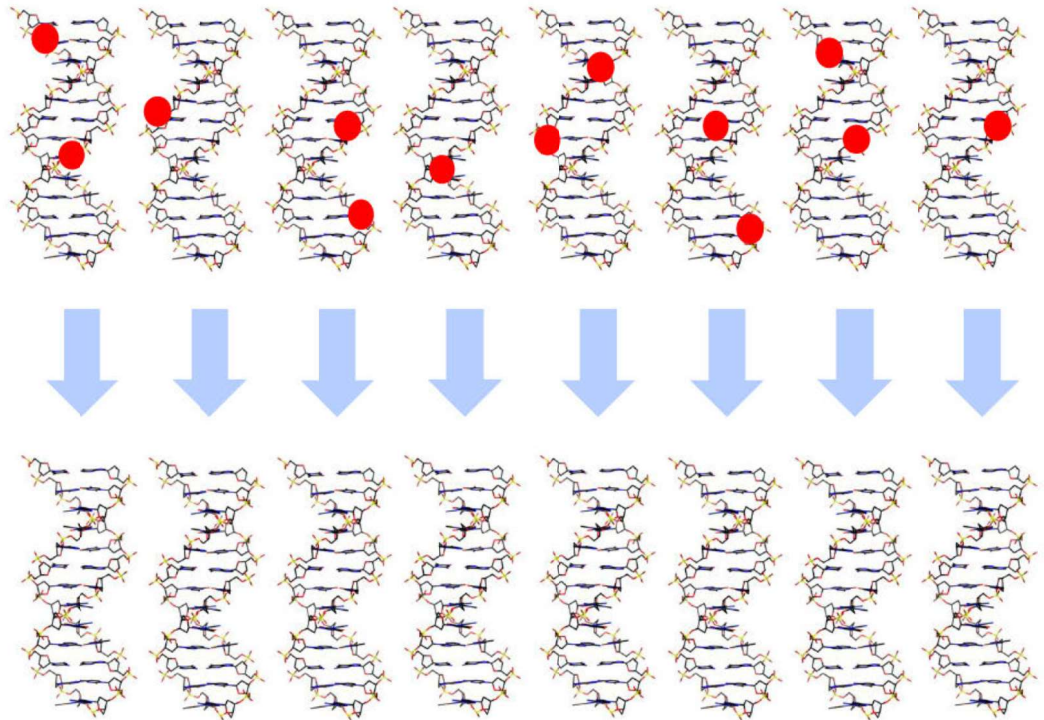
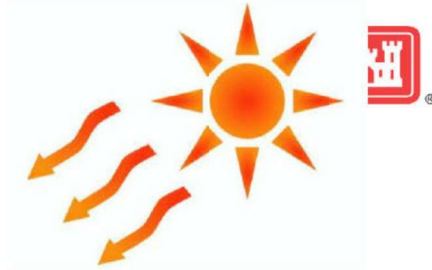
Then, we randomly "**mutate**"
the new population

Replace Roof when
Remaining Service Life = 0



Replace Roof when
Remaining Service Life = **1**

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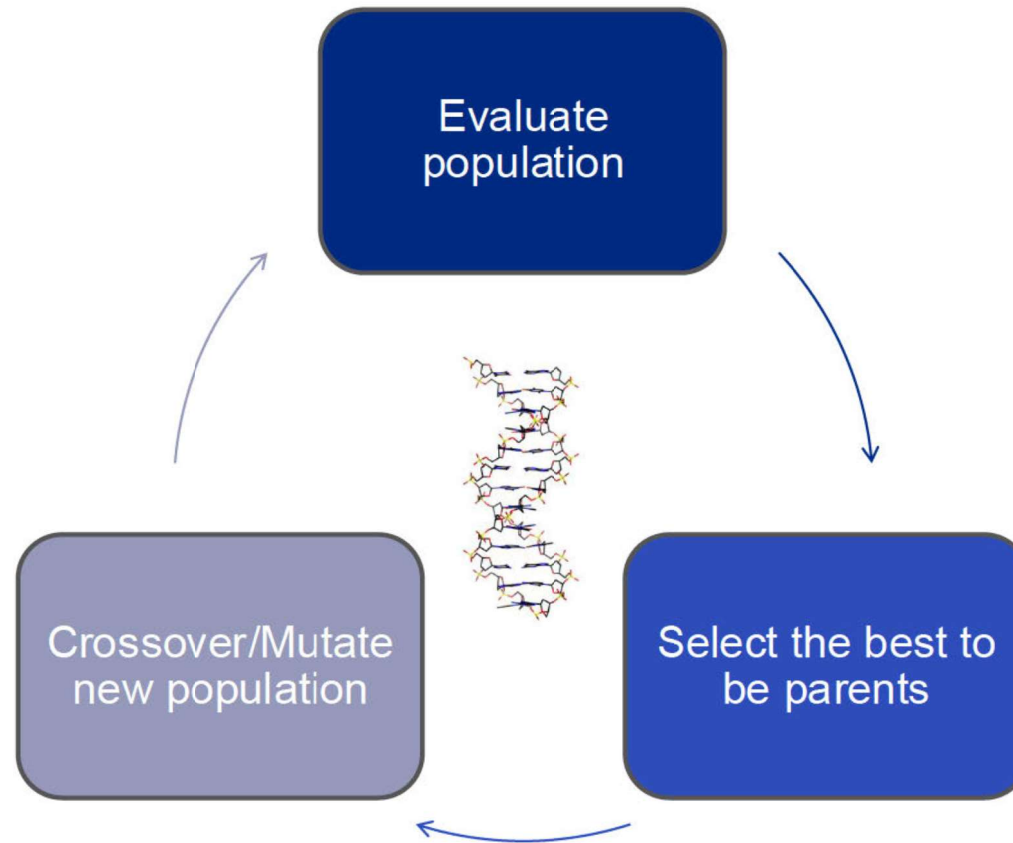


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GENETIC ALGORITHM STEPS

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HYPERPARAMETERS

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- How big should the population be?
- How many parents should be selected?
- How should crossovers occur?
- How many mutations should be made?

These are all hyperparameters that must be selected!

Selecting hyperparameters can involve optimizing many times.

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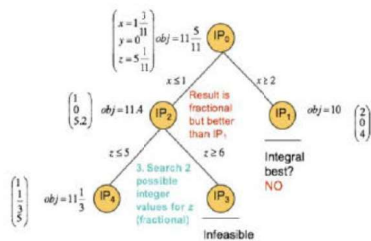
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COMPUTATIONAL COMPLEXITY

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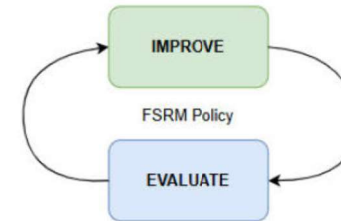


Mathematical Programming



Evaluate large sections of the problem prior to optimization

Policy Iteration



Constantly evaluate policies in each iteration

For a granular temporal policy...

$$\# \text{ Possible Policies} = (\# \text{ Actions}) ^ { (\# \text{ Components} * \# \text{ Timesteps})}$$

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GPU ACCELERATED MAINTENANCE SIMULATION

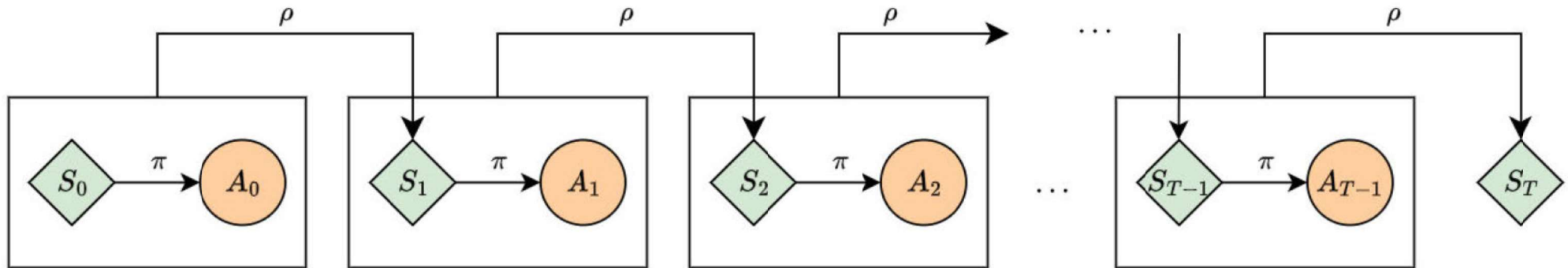


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Maintenance is a sequential decision problem with **long term effects**.



Evaluating a maintenance policy can require **long iterative simulations**. If we only want to decide maintenance actions in the next 3 years, we still need to simulate further to capture the effects of those actions.



THAT'S A LOT OF MATH!

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When evaluating a policy on **millions** of components across thousands of facilities...
There are **a lot of calculations!!**

$$SL = \beta_{init} \cdot DL \cdot \left(-\log \frac{100}{CI_{term}} \left(\frac{CI_{term}}{A} \right) \right)^{\frac{1}{\alpha_{init}}}$$

$$\Delta SL = \begin{cases} \beta_{shift} \cdot (Age_{Insp} - Age_{Eff} - \Delta SL_{bound}) + \Delta SL_{bound} \\ Age_{Insp} - Age_{Eff} \end{cases}$$

$$\Delta SL_{bound} = \max\{0, Age_{Insp} - DL \cdot \beta_{init}\}$$

$$f_{\Delta X_{t,h}}(x) = \frac{\beta^{\Delta \eta(t,t+h)} s^{\Delta \eta(t,t+h)-1} e^{-x\beta}}{\Gamma(\Delta \eta(t,t+h))}$$

$$\beta_{adj} = \frac{\beta_{init} \cdot DL + \Delta SL}{DL}$$

$$A \left(\frac{100}{CI_{term}} \right)^{- \left(- \frac{(1-\beta_{shift})t_{insp} - \beta_{init} DL}{\beta_{shift} \beta_{init} DL} \right)^{\alpha_{init}}}$$

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THE HARDWARE

Central Processing Unit (CPU)

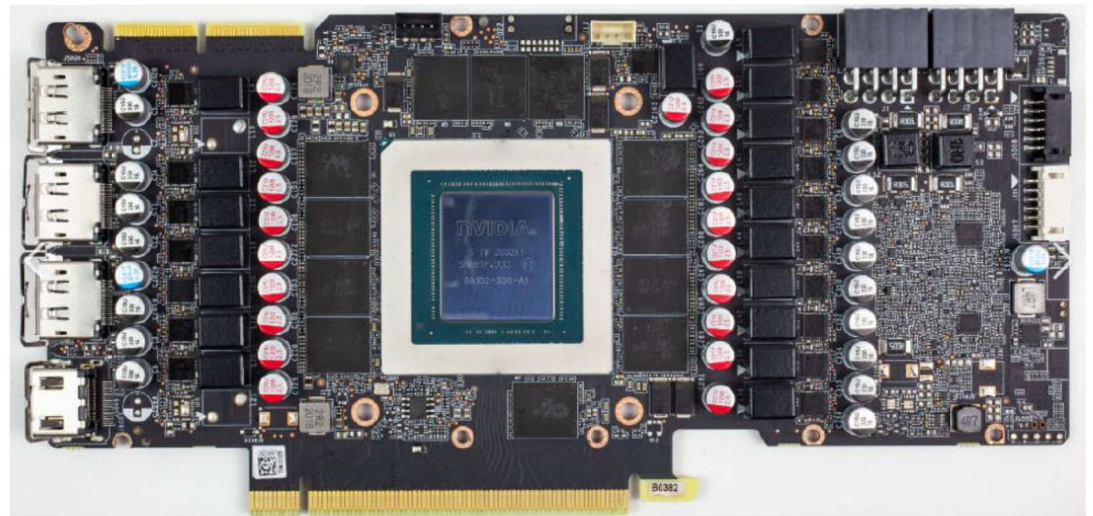


Very fast individual computations
Limited to mostly **sequential** work
(with some multithreading)

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Graphics Processing Unit (GPU)



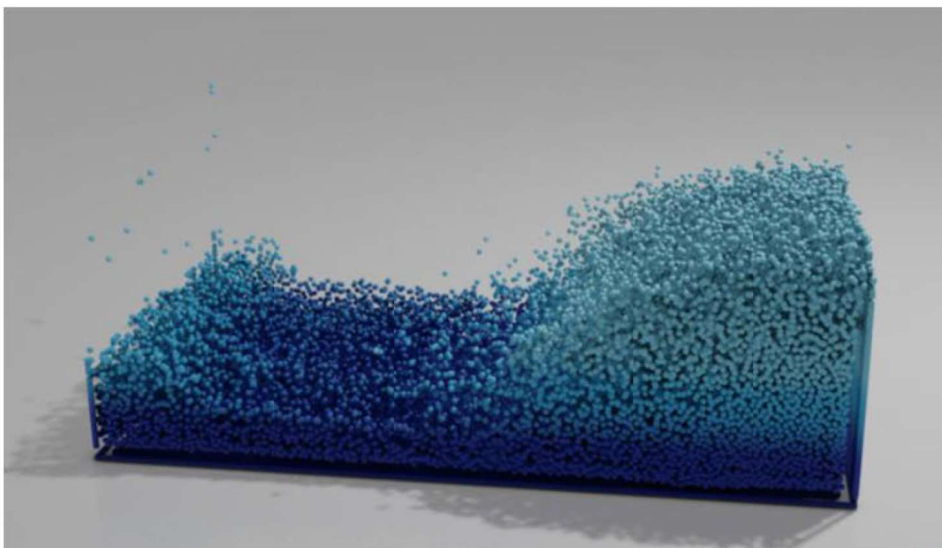
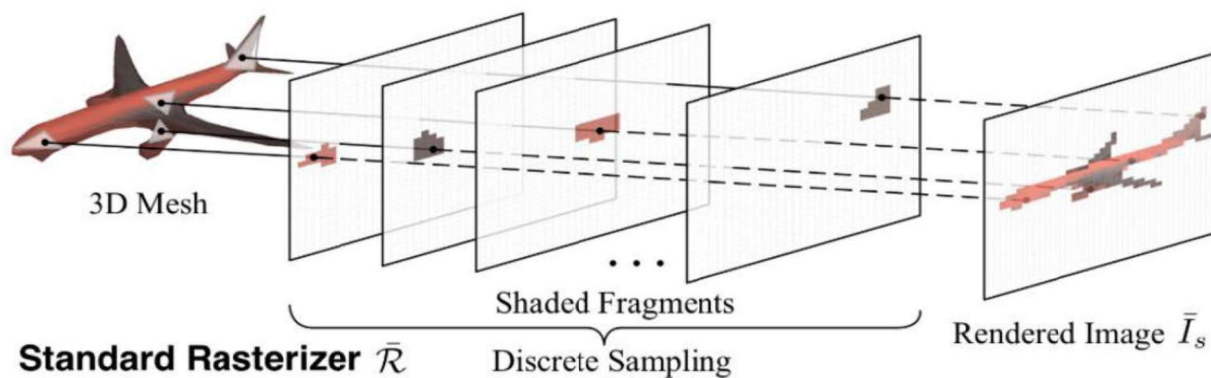
Slow individual computations
But can calculate the same
computation in **parallel** on a lot of
data

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SAME INSTRUCTION MULTIPLE DATA

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Name - ▼	Status - ▼	Component Type - ▼	Replacement Value - ▼
Standard Slab On Grade	In-Service	Slab on Grade	\$52,339
Other Floor Construction	In-Service	Floor System	\$92,008
Other Roof Construction	In-Service	Roof Deck/Structure	\$117,413
Exterior Closure	In-Service	Exterior Wall	\$78,655
Solid Doors	In-Service	Exterior Door	\$14,737
Other Roofing	In-Service	Roof Covering	\$8,175
Other Roofing	In-Service	Roof Covering	\$13,093
Other Interior Personnel Doors	In-Service	Interior Door	\$12,999

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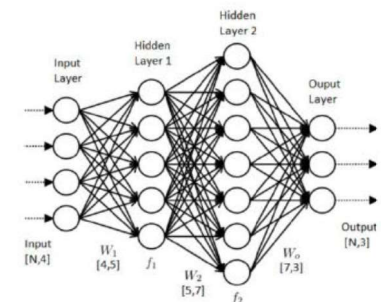


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In the early 2000s, Ian Buck from Stanford University experimented with using GPUs in an 8k gaming setup.

In his research, he found that the same **linear algebra** math that powers graphics, can be used for **general purposes** such as fluid simulations.

This research caught the eye of the **Defense Advanced Research Projects Agency** and **Nvidia**, and lead to the development of **Compute Unified Device Architecture** (CUDA)



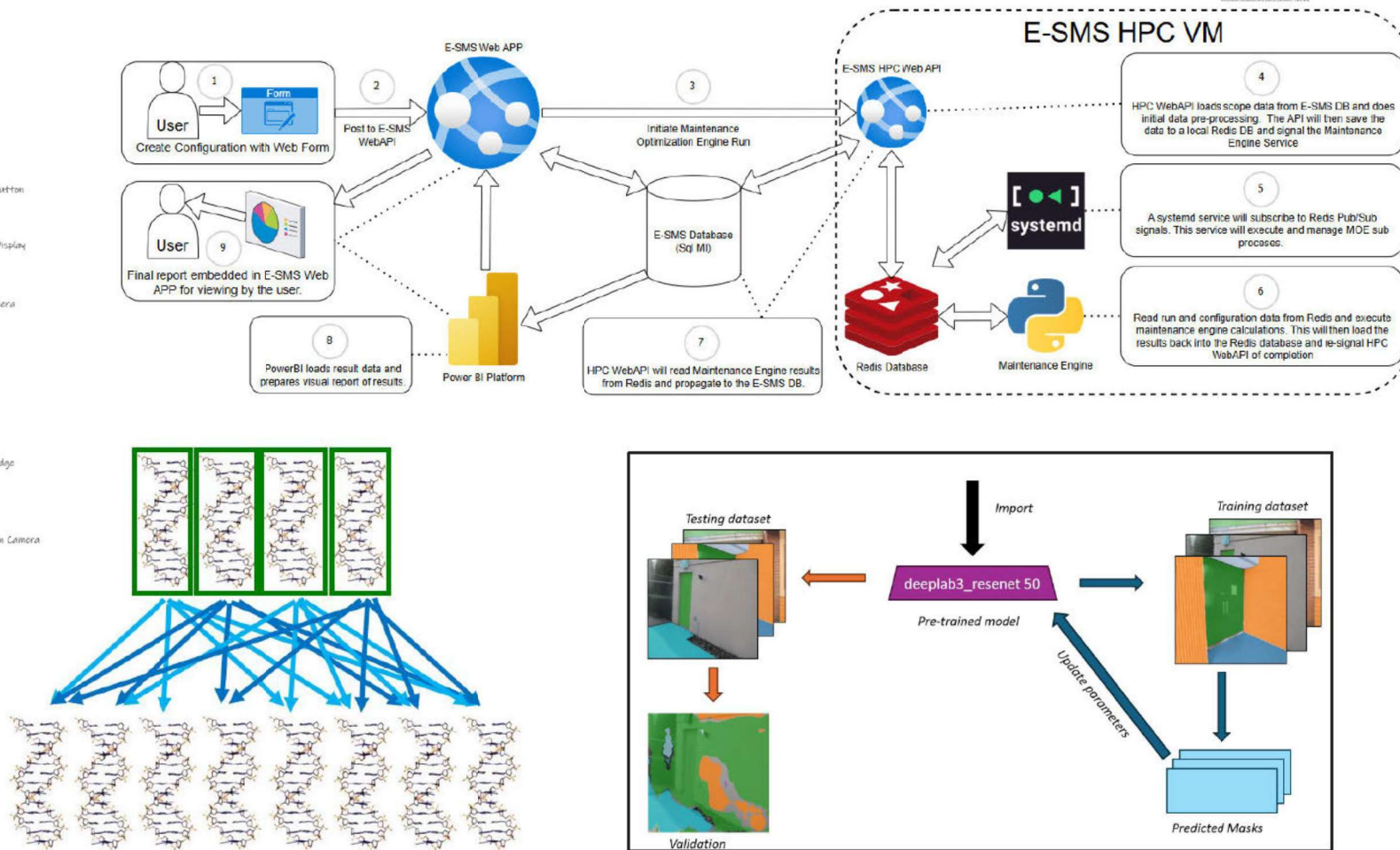
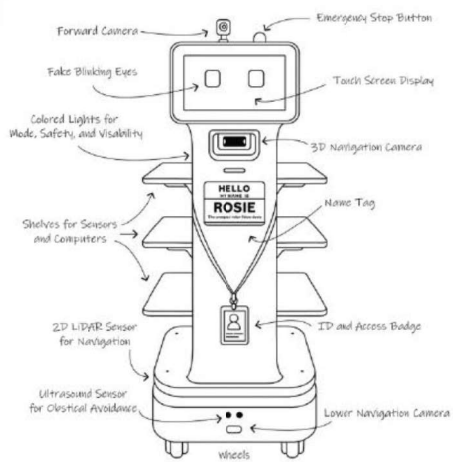
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GPU ACCELERATED RESEARCH

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ENHANCED MODELING



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DEGRADATION MODELING

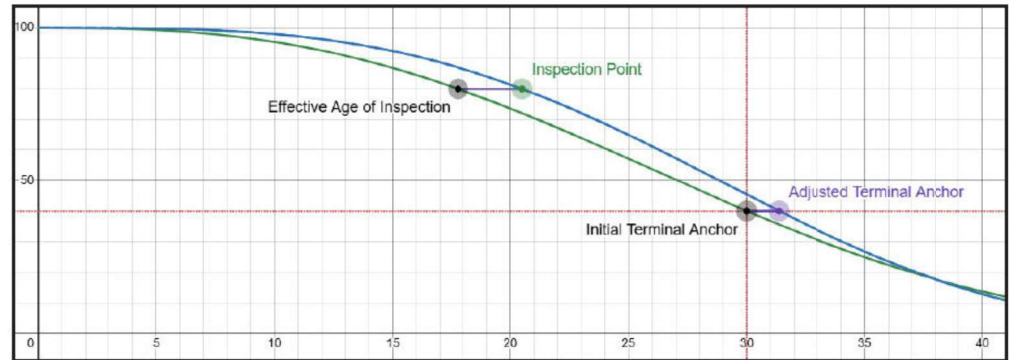
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- SMS utilizes the Weibull degradation curve to estimate the condition of a component.
 - Time-variant
 - Adjusts to assessment data
 - Very stable
- There are many variables that affect degradation behavior beyond time including...
 - Component and facility type
 - Climate/weather
 - Material
 - Size
 - Usage



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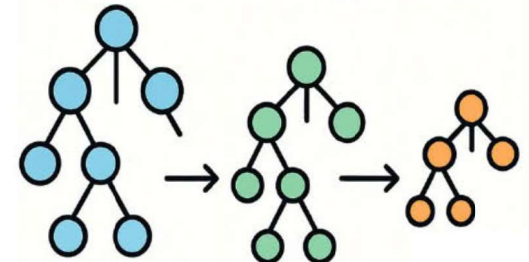
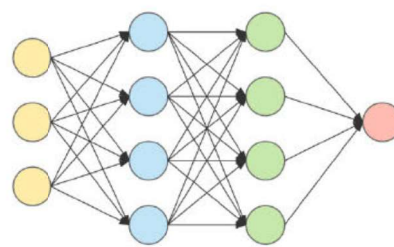
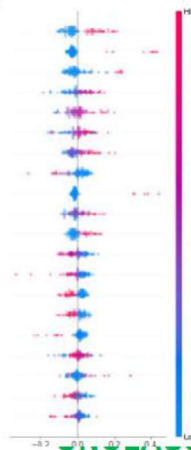
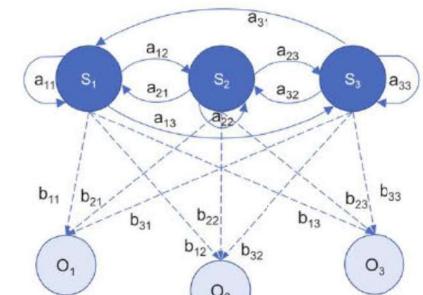
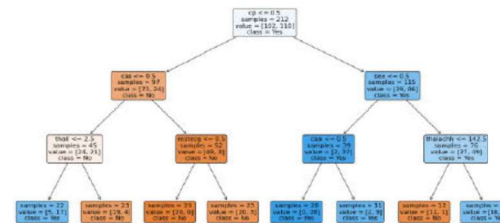
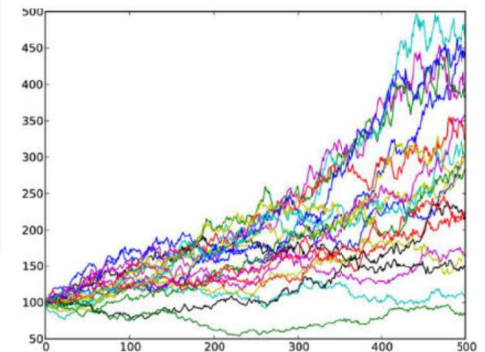
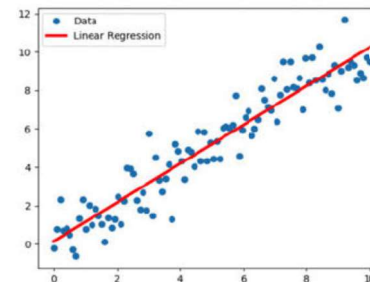
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DEGRADATION MODELING

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- We are exploring a wide variety of degradation models:
 - Quantitative analysis
 - Highest performance
 - Required inputs
 - Qualitative analysis (behavior)
 - Single-point vs. temporal projection
 - Stochastic vs. deterministic
 - Discrete vs. continuous
- Each model has potential advantages beyond performance
 - Feature importance
 - Interpretability
 - Stability
 - Risk analysis



* there will be no changes to production models without expressed affirmative direction of the E-SMS Configuration Support Panel



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EXAMPLE ADVANTAGE: RISK ANALYSIS

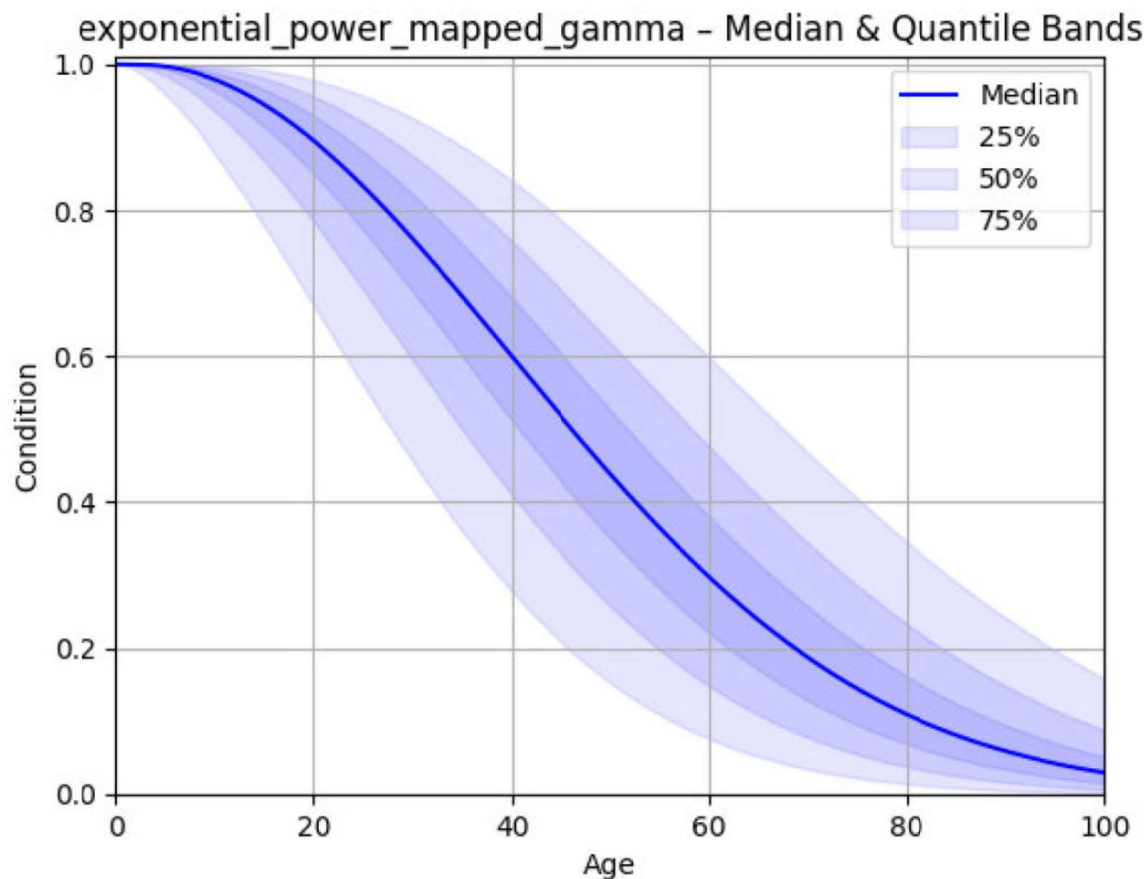
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A **Stochastic** models give **probabilities** of a components condition.

These probabilities allow us to analyze **risk** and bridge the gap between **reliability** and **condition**.

This also helps with **budget risk** analysis as well as **assessment planning**.



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PHYSICS-BASED DEGRADATION MODELING



A Novel Bayesian State-Transition Model for Climate Aware Infrastructure Degradation Prediction

Nate Nicholas – Junior in Physics at Illinois Wesleyan University

A Quantum State Transition Model

- Traditional lifecycle systems (E-SMS) treat degradation as a continuous deterministic curve governed by design life
 - These models are designed to blend raw inspection data to align with predetermined time to decay curves
 - E-SMS artificially weights the Condition Index (CI) of a 2-year-old asset vs the same 20-year-old asset thus assuming “amnesia” due to Markovian model
- This model uses a Non-Markovian Quantum System to model degradation by treating condition ratings (C1-C7) as absolute, quantized Metastable Energy States

$$C_n = \begin{cases} C1 (G+) & \text{if } CI > 99 \\ C2 (G) & \text{if } 92 < CI \leq 99 \\ C3 (G-) & \text{if } 85 < CI \leq 92 \\ C4 (A+) & \text{if } 75 < CI \leq 85 \\ C5 (A) & \text{if } 65 < CI \leq 75 \\ C6 (A-) & \text{if } 50 < CI \leq 65 \\ C7 (R) & \text{if } CI \leq 50 \end{cases}$$

Fig [1]

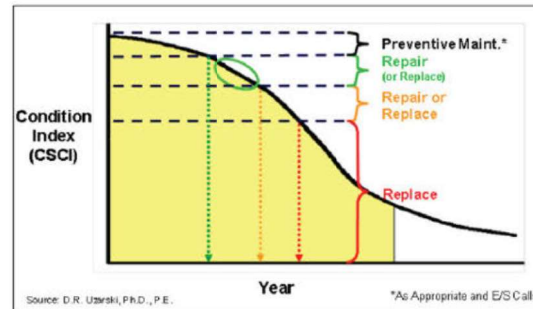


Fig [2]

Modeling Architecture

The Two Core Predictive Outputs

1. Dwell Time (When): Calculates the expected time interval ($E[T_n]$) a component/asset will survive in its current condition state before making a discrete transition, governed by a Memory Kernel K_n that mathematically translates to fatigue.
2. The Branching Ratio (Where): Probability distribution ($BR_n \rightarrow k$) of which specific lower energy state the asset will transition into once dwell time has expired, this captures non-linear jumps.

$$\frac{d}{dt}P_n(t) = - \int_0^t K_n(t-\tau)P_n(\tau)d\tau$$

$$BR_{n \rightarrow k} = \frac{\sum N_{n \rightarrow k}}{\sum N_{n \rightarrow \text{any}}}$$

The Bayesian Engine

- In order to mitigate effects of small sample sizes in specific climate regions, the model uses a Bayesian updated structure.
- Local observations ($E[T]_{\text{observed}}$) are blended with the data driven Global Prior ($E[T]_{\text{prior}}$).
- The weight assigned to local data is a dynamic function of its sample size (n) to ensure stability.

$$E[T]_{\text{Bayesian}} = (W_{\text{data}} \cdot E[T]_{\text{observed}}) + (W_{\text{prior}} \cdot E[T]_{\text{prior}})$$

Extracting the Memory Exponent (α)

- The theoretical Memory Kernel (K_n) is defined as a Power-Law function and solved via Laplace Transform resulting in a predictive equation for Dwell Time ($E[T_n]$)
- This equation is linearized into a standard $y = mx + b$ form (natural log of both sides)
- The model's physical constants, Memory Exponent (α) and Base Life (T_0) are derived directly through log-log linear regression on historical inspection records

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PHYSICS-BASED DEGRADATION MODELING



A Novel Bayesian State-Transition Model for Climate Aware Infrastructure Degradation Prediction

Results

Fig [4]: **State Survival Probability Distribution.** Probability density of Dwell Time (in years) for "Sinks" starting in State C1, grouped by ASHRAE climate zone

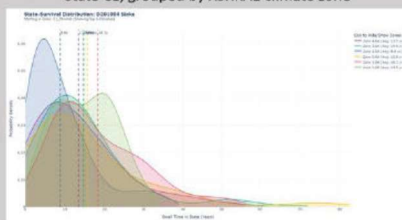


Fig [6]: **Calculated Memory Exponent (α) by Material Category.**

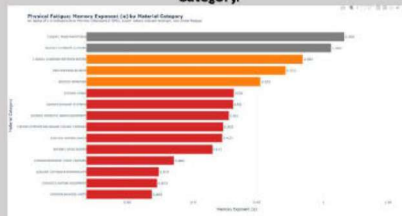


Fig [5]: **Degradation Severity (Branching Ratios) by Climate.** Probability of a "Sink" (in C1) transitioning to each lower state, segmented by climate zone

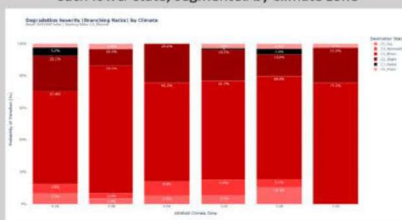


Fig [7]: **Log-Log Plot of Age vs. Dwell Time.**

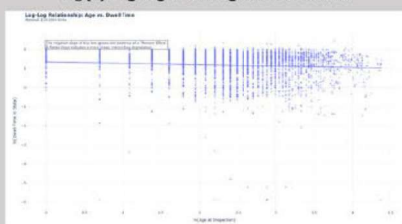


Fig [8]; [9]: **ASHRAE 90.1/IECC Climate Zone Map and Climate Category Table.** Geographical reference for the climate zones used in the analysis.

Zone Number	Zone Name	Thermal Criteria (°F Units)	Thermal Criteria (°C Units)
1A and 1B	Very Hot - Humid (1A) Dry (1B)	9000 < COOD°F 6500 < COOD°F < 9000	5000 < COOD°C 3000 < COOD°C < 5000
2A and 2B	Hot - Humid (2A) Dry (2B)	4000 < COOD°F < 6500	2500 < COOD°C < 3000
3A and 3B	Warm - Humid (3A) Dry (3B)	COOD°F < 4000 AND HDD°F < 3000	COOD°C < 2000 AND HDD°C < 2000
4A and 4B	Hot - Humid (4A) Dry (4B)	COOD°F < 4000 AND HDD°F < 3000	COOD°C < 2000 AND HDD°C < 2000
5A and 5B	Hot - Humid (5A) Dry (5B)	COOD°F < 4000 AND HDD°F < 3000	COOD°C < 2000 AND HDD°C < 2000
6A and 6B	Hot - Humid (6A) Dry (6B)	COOD°F < 4000 AND HDD°F < 3000	COOD°C < 2000 AND HDD°C < 2000
7	Very Cold	9000 < HDD°F < 13000	5000 < HDD°C < 7000
8	Subarctic	12000 < HDD°F	7000 < HDD°C

Future Work

1. Back-testing vs. Calibrated E-SMS Baseline

- Back-testing against a simplified Weibull model showed a great reduction in Mean Absolute Error (MAE) when predicting individual transition events
- Implement a fully calibrated Weibull model with accurate calculated parameters (beta and eta) for each material category for validated comparisons

2. Hierarchical Bayesian Priors (Service Life Integration)

- Update the current empirical prior by blending it with the calculated Service Life to establish engineering design limits and maintain accuracy

3. Continuous Weather Integration (WELDER)

- Move from discrete ASHRAE zones to continuous variables (e.g., precipitation, freeze/thaw cycles) from the WELDER platform to create accurate localized precision forecasting

4. Image Detection and Automation (ROSIE)

- Integrate with ROSIE for variations in inspection methods to create accurate inspection assessments with the ROSIE platform



Fig [10]

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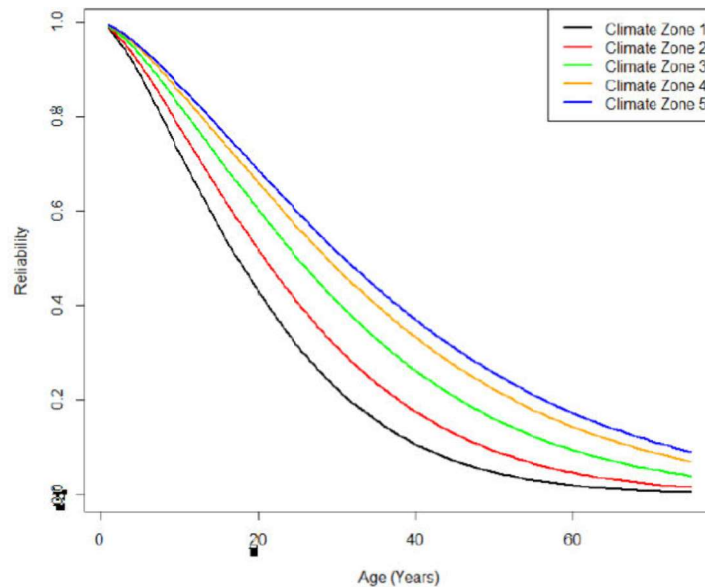
RELIABILITY-CENTERED MAINTENANCE (RCM)

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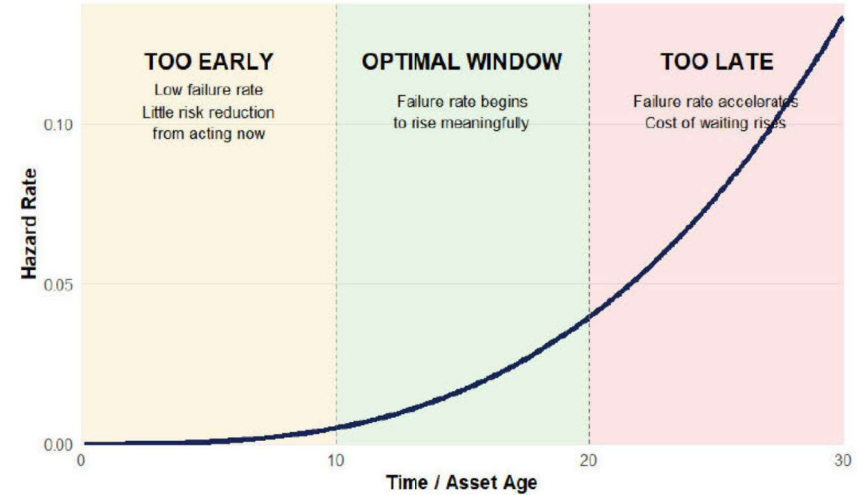


Sometimes maintenance is a bad investment

Reliability for AHUs with Climate Zone Covariates



Maintenance timing is an investment decision



SMS reliability models can help determine the optimal investment interval

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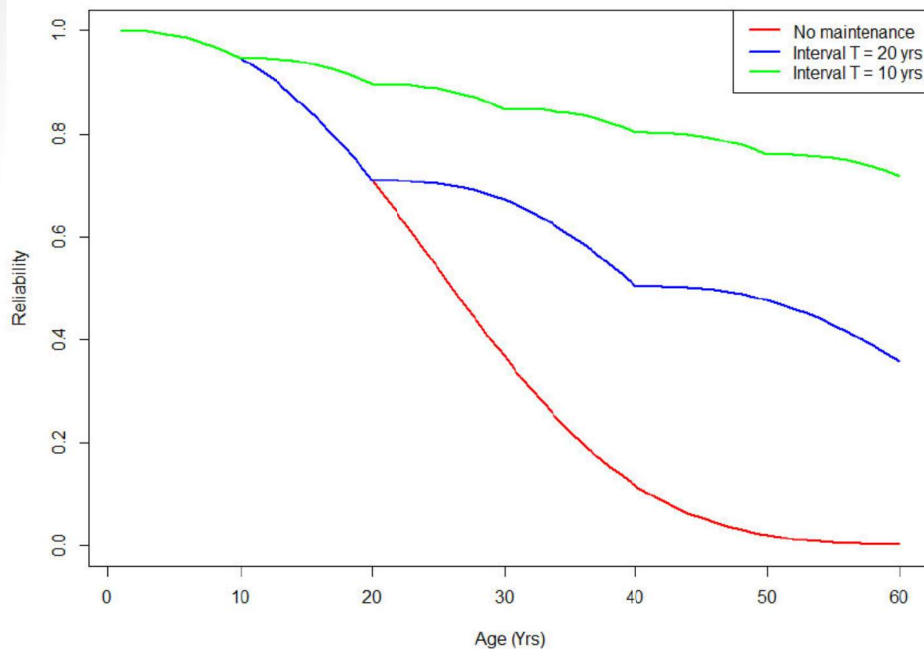


RCM AND RETURN ON INVESTMENT

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Reliability with Periodic Maintenance



1. Different maintenance intervals affect reliability
2. Changes in reliability impact expected design life
3. Work cost and design life extension give ROI

Design life under specified maintenance interval (red arrow) and Design life with no maintenance (blue arrow) point to the terms DL_m and DL in the formula below.

$$ROI = \frac{\text{Value of Maintenance}}{\text{Cost of Maintenance}} = \frac{CRV * (DL_m - DL)}{\sum_{j=1}^n \text{Cost}_{\text{repair}}}$$

where

Inspection age (blue arrow) points to t and Maintenance interval (red arrow) points to T in the formula below.

$$DL_m = t = nT + \theta \left[\left(\frac{T_0}{\theta} \right)^\beta - n \left(\frac{T}{\theta} \right)^\beta - \ln(R_{\text{target}}) \right]^{\frac{1}{\beta}}$$

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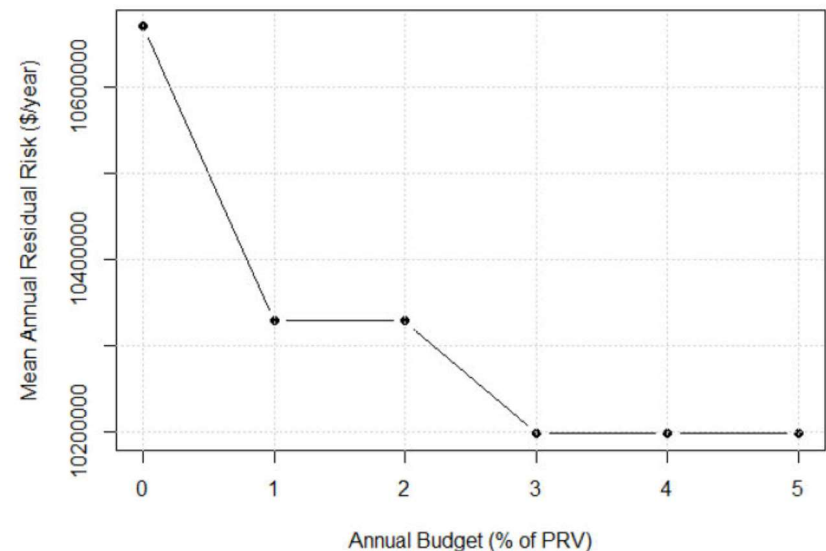
RCM AND OPTIMIZATION

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- Objective: Find the optimal maintenance plan for a portfolio to maximize ROI
- Given:
 - Component reliability targets (risk)
 - Budget limits
- Method:
 - Generate reliability model from historical data
 - Update component reliability with inspection information
 - Optimize maintenance intervals to maximize ROI
 - Assign work priorities based on ROI
 - If work is deferred, it gets a deferral “bump” to avoid continuous deferment
- Results:
 - Each facility funding is tailored to its inventory
 - Very scalable optimization (minutes for an entire service)
 - Displays comparative risk among different funding levels

Risk vs. Budget



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THANK YOU



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Thank You!

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