S2978: Point Cloud Conversion to Detail Design

NSRP All Panel Meeting 2025

Presenter: Ken Crowe

Bath Iron Works

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Agenda

- Overview
- Objectives
- Project Team
- Technical Goals
- Benefits/Pay Off
- Technical Approach
- Technical Content and Status
- Transition/Implementation Plan
- Next Steps
- Q & A

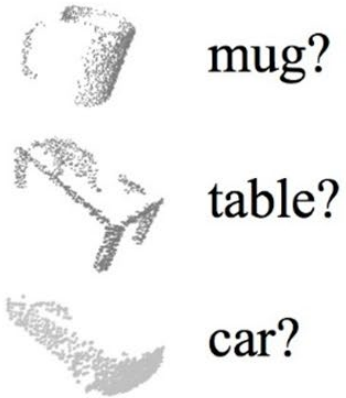
Overview

- Platform: DDG51

- Issue Description:
  - The majority of DDG51 hulls in service do not have 3D models. In order provide superior interference detection in dense spaces these 3D designs are required. DDG51 Planning yard has a robust 3D (LiDAR) scanning process but requires highly technical and manual processes (labor hours). The goal is to automate the conversion of the 3D scan data to CAD-agnostic detailed design 3D model arrangement. This would improve sustainment activity performance and associated reduce labor costs.

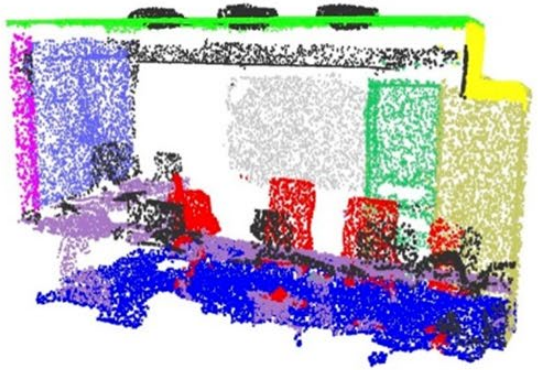
Objectives

- Develop software tools to automate the creation of 3D CAD model arrangements from point cloud data which can then be manipulated, attributed, used for interference checking, and subsequent development of 2D technical drawings.



Classification

Part Segmentation



Semantic Segmentation

Project Organizational Structure

Paul Huang – Program Officer

Robert Mashburn – Deputy Director
Scott Truitt – Project Manager
Jeff Walters – Project Technical Representative

Lee Fuglestad – PMS 400D

David Clark – CACI

Dan Finke – Project Manager
Simon Miller – Tech Lead

Scott Record – Program Manager
Ken Crowe – Project Manager
Casey Norris– Business Lead

ManTech Metrics

Goal 1: Reduce labor associated with identifying CAD library objects for individual ship equipment/components.

Parameter	Baseline Value	Requirement Threshold Value	Requirement Objective Value	How to Measure	Date to be Achieved	Achievement Value	Achievement Date	How Demonstration is Planned
Labor - identify CAD library objects for equipment and similar individual ship components	200 hrs/ship compartment	50%	60%	Establish control data set in test environment, execute prototype application	Completion Task 8	TBD	TBD	Virtual demo

Goal 2: Reduce labor associated with producing solid model geometry of structure and distributive systems present in point cloud.

Parameter	Baseline Value	Requirement Threshold Value	Requirement Objective Value	How to Measure	Date to be Achieved	Achievement Value	Achievement Date	How Demonstration is Planned
Labor - produce solid model geometry for ship structure and distributive systems	200 hrs/ship compartment	50%	60%	Establish control data set in test environment, execute prototype application	Completion Task 8	TBD	TBD	Virtual demo

Goal 1: Labor ⬇ | **Goal 2:** Labor ⬇

ManTech Metrics

Goal 3: Reduce labor to assemble a 3D graphical CAD file containing the items identified in Goals 1-2

Parameter	Baseline Value	Requirement Threshold Value	Requirement Objective Value	How to Measure	Date to be Achieved	Achievement Value	Achievement Date	How Demonstration is Planned
Labor - create a CAD model containing equipment and geometry	400 hrs/ship compartment	50%	60%	Establish control data set in test environment, execute prototype application	Completion Task 8	TBD	TBD	Virtual demo

Goal 4: Reduce number of LARs, RLARs, and LAR-RCCs

Parameter	Baseline Value	Requirement Threshold Value	Requirement Objective Value	How to Measure	Date to be Achieved	Achievement Value	Achievement Date	How Demonstration is Planned
Labor – associated with responding to a reduced number of LARs, RLARs, LAR-RCCs	High $$$ per year	22%	30%	Collect all LARs for a given space where design was done in 2D on paper – no model manually developed; create model using new process; conduct human evaluation to compare historical LARs for that space to MODEL and assess whether there would have been a reduced number of LARs, etc., had a model been available	Completion Task 10	TBD	TBD	Documented results

Goal 3: Labor ⬇ | **Goal 4:** LARs, RLARs, LAR-RCCs requests ⬇

Benefits / Payoff / Business Case Update

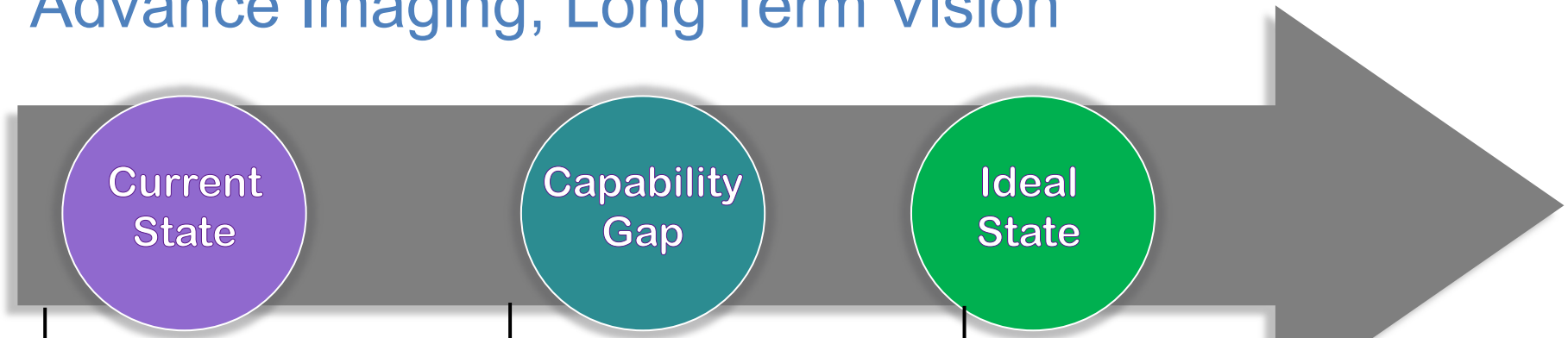
- Major Benefit: Reduced cost and schedule of creating 3D models, arrangements of models, and responding to Liaison Action Requests (LARs)
- Life-cycle Affordability: $1.45M/yr , $7.24M/5yrs
  - Creating 3D Components and Model Assembly - $360K/year
  - Reduced Planning Yard Support - $1.1M/year
- ManTech Investment – $1,418,000
- Shipyard Implementation Costs – Direct/Overhead – $716K
- 5yr ROI = 2.39
- Prototype for comparison of benefits gained would not occur until after Phase II

Technical Approach

- Phase I
  - Task 1 – Project Management [BIW/PSU]
  - Task 2 – Investigate Current and Future State [BIW/PSU]
  - Task 3 – Requirements and Concept Design [BIW/PSU]
  - Task 4 – Design Architecture & Development Plan [BIW/PSU]
  - Task 5 – Develop Point Cloud Prototype [BIW/PSU]
- Phase II
  - Task 4 – Project Management
  - Task 5 – Machine Build / Validation/Buy-off
  - Task 6 – Cell Install
  - Task 7 – Validation and Robustness
- Required Capability:
  - A tool that decomposes a point cloud into parts in an automated fashion, matches 3D models against that segmented point cloud, and then fits/places found models into a 3D coordinate space assembly while retaining original CAD metadata/origin.

Task 2 Investigate Current and Future State

Advance Imaging, Long Term Vision



Current State

- Over 900 unique compartments have been scanned across 16 hulls
- LiDAR scanning provides interactive point-cloud data
- Point-cloud data utilized for interference detection & verification of shipcheck accuracy
- Limited export functionality
- Point-clouds cannot be directly used to generate smart 3D geometry

Capability Gap

- Segmenting the point cloud per part is a manual process
- Identifying objects within the point cloud is laborious
- Identifying known or similar objects in CAD database does not exist
- Reconstruction of 3D scene from known objects is not possible
- Reconstructing geometry in a (semi) autonomous process does not exist

Ideal State

- Point-cloud data in relevant spaces is converted to smart solid models
- Converted data is the baseline for downstream design activity
- Accurate baselining & automation of geometry creation will result in cost and schedule reduction during the design process
- Early interference detection will pay big dividends in cost and schedule during the execution phase

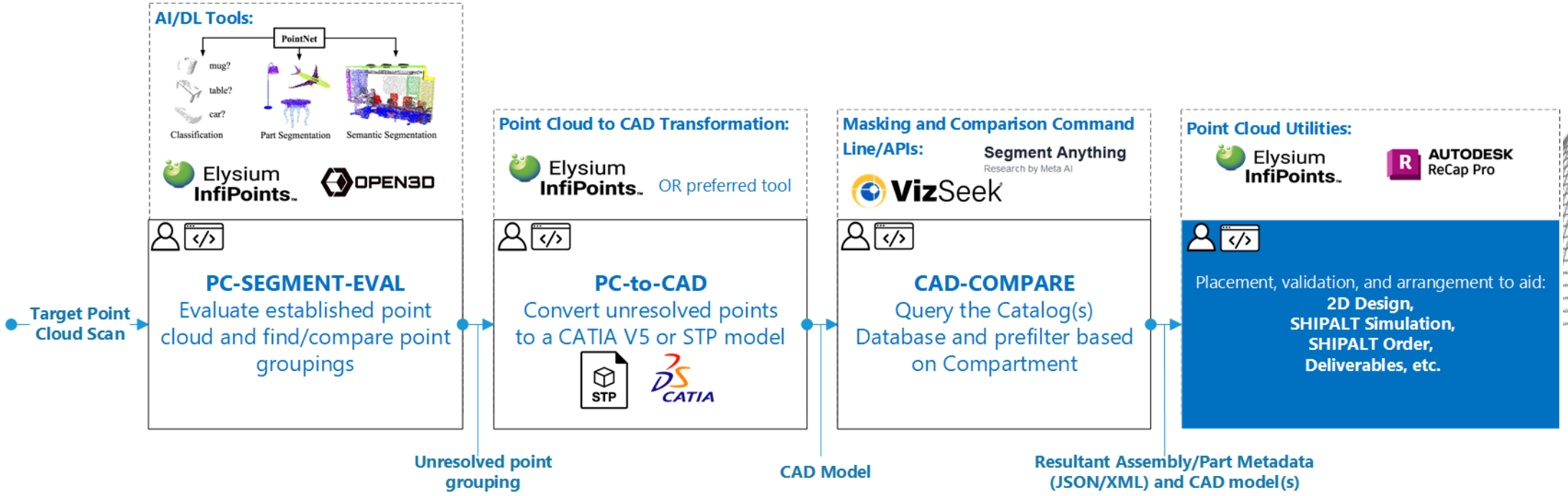
Task 3 Requirements and Concept Design

- Requirements across four categories:
  - End Users – requirements are functional requirements, i.e. what does the system need to do
  - IT/Cyber Security – must follow security standards and be compliant with BIW IT standards and practices
  - Performance – Establishing performance requirements in terms of processing time, number of users, etc.
  - User Experience – drawing from the categories above, these requirements seek to establish how the end users interact with the system

1.0	**STORY: As a Planning Yard Designer I need a software tool that will reduce labor associated with converting point cloud data to 3D geometry.**
1.1	System shall accept current point cloud data as inputs.
1.2	System shall analyze entire point cloud file for parts/assembly comparisons.
1.3	System shall create un-attributed, individual CAD-compatible parts/assemblies models from the point cloud data.
1.3.1	System generated parts/assemblies shall be CAD-neutral (i.e. STEP files) to be used or coverted for specific CAD software (i.e. CATIA)
1.3.2	System shall identify 50% CAD library objects for individual ship equipment/components for equivalent volumetric objects deduced from logical point clouds cluster.
1.3.3	System shall produce solid model geometry for 50% of structure and distributive systems present in point cloud.
1.4	System shall scan match models with library components based on library schema.
1.5	System shall match results back into engineering design space.

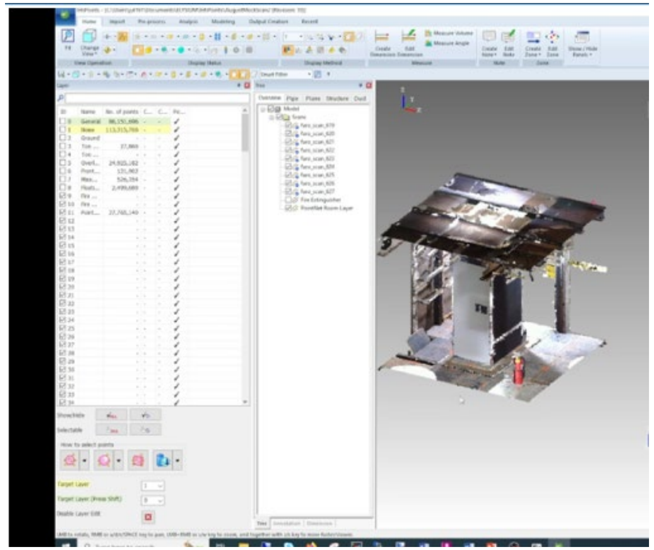
Task 4 Design Architecture & Development Plan

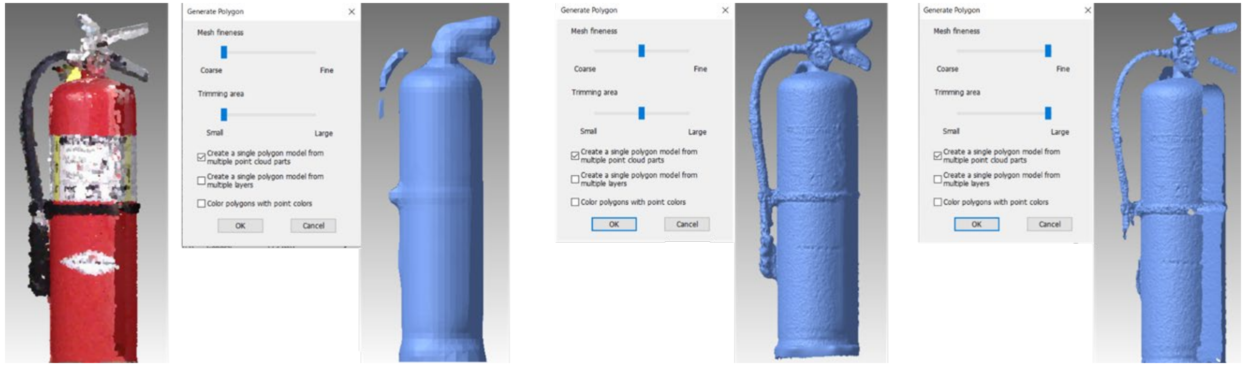
- System is comprised of software modules that reside on desktop workstation and VM CAD server.
- All software and data reside on premise within firewalled environment, no external connectivity required or desired.

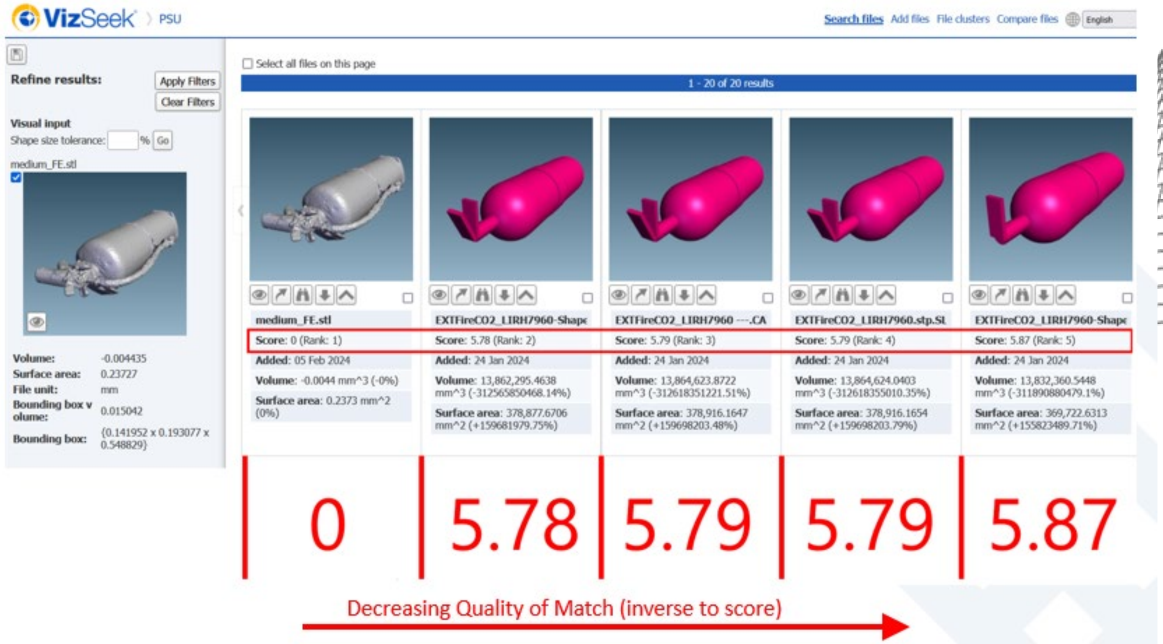


Task 5 Develop Prototype

- Phase I concluded with a proof-of-concept



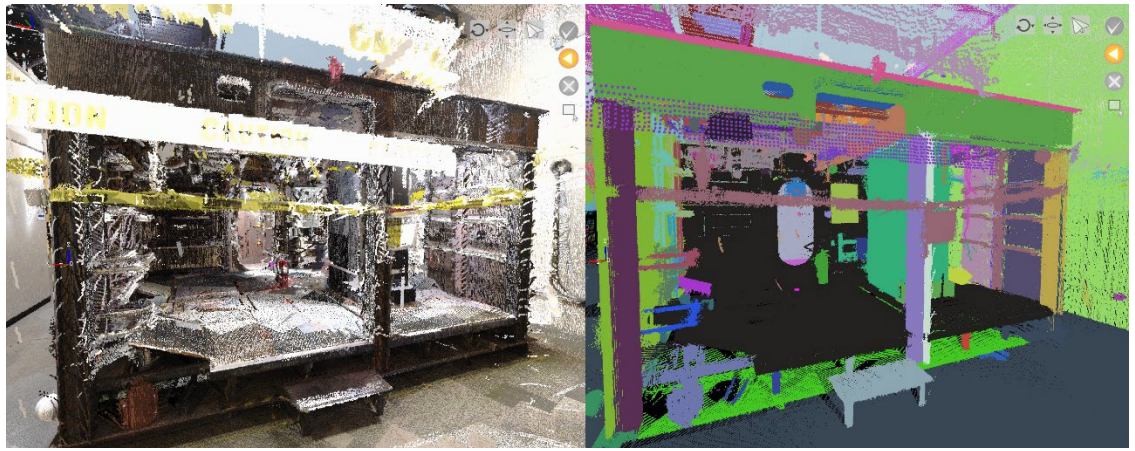


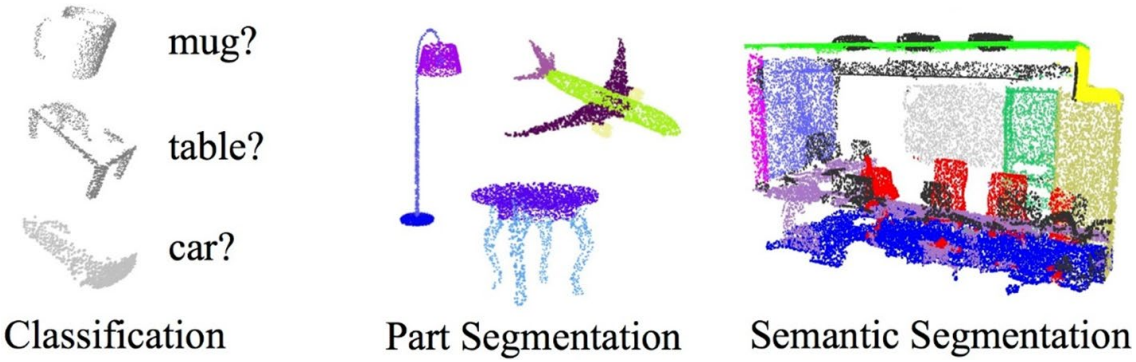


VizSeek is a *visual search* tool that can be hosted on-prem. It loads a database of known CAD objects and the user can upload a new image/object and find *similar* entities in the database. Here we have a number of objects and the point cloud reconstructed fire extinguisher (top left) for comparison.

Task 7–11 Development

- Classifying point clouds into homogeneous regions
- Deep learning can be applied to segmentation, aid in overall identification, and define raw point cloud data

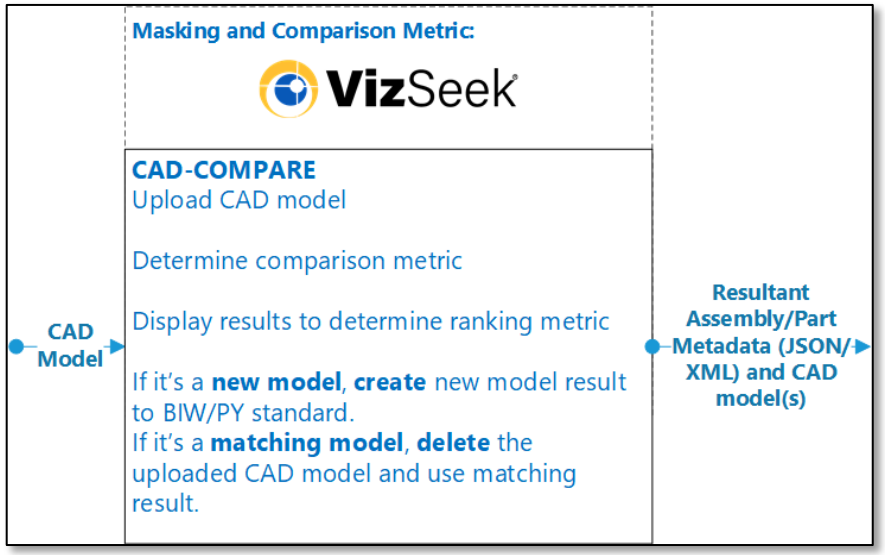


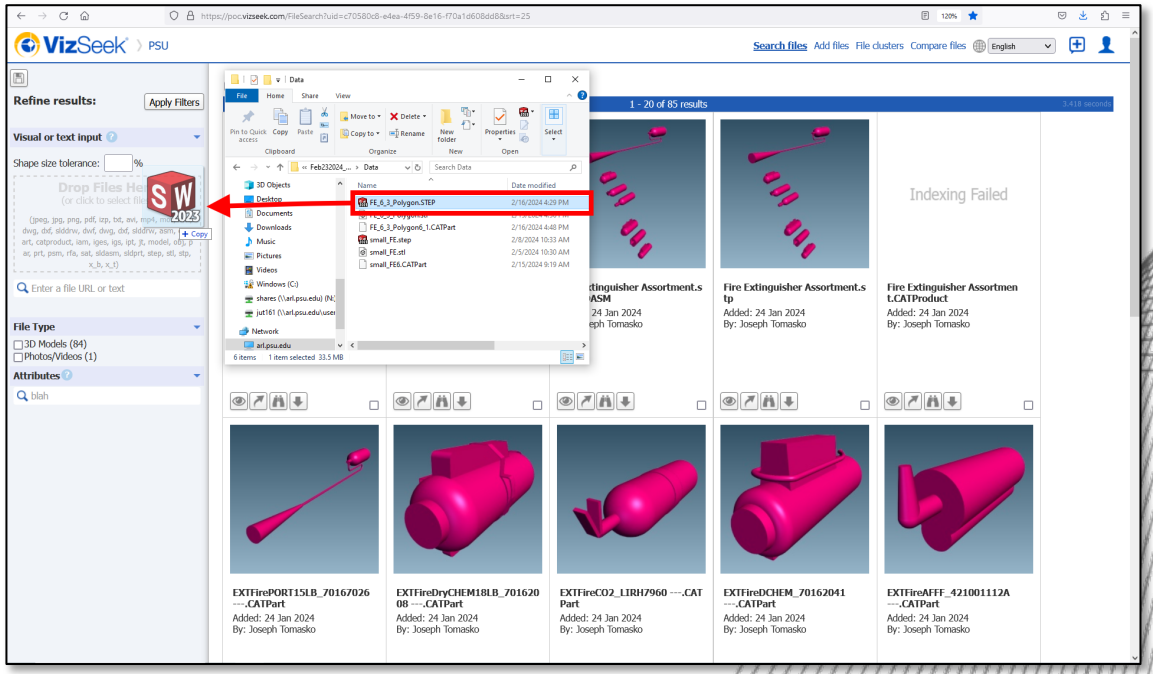


- Shape Classification
  - Based on trained shapes and their scores, find the best match
- Part Segmentation
  - Fine-grained object parts instead of generic object labels
- Semantic Segmentation
  - Each point is associated with a label or category

Task 7–11 Development

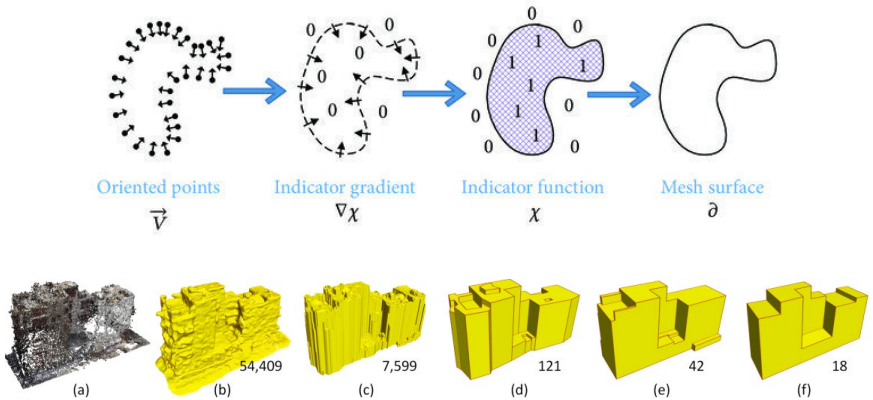
- Visual search is a technique of comparing 2D and 3D objects and identifying the “best” match against a database of objects.
- Using a known CAD database, users can upload an object (i.e. image, mesh) and find entities in the database.
- Metrics and scoring criteria are based on visual cues, meta-data, and user-defined functions.



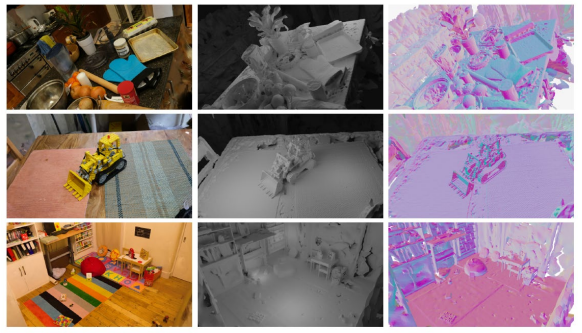


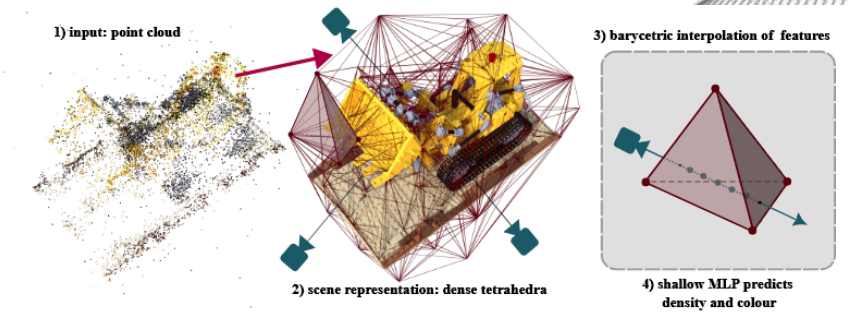
Task 7–11 Development

- Classic methods generate shapes for comparison and new CAD object generation
- Surface Reconstruction techniques, RANSAC, Primitive Fitting, etc., produce data that can be compared for the visual search engine routines



- Modern tools such as NeRF and Gaussian Splatting explored to create image and mesh objects
- Images used for visual search
- Meshes used for visual search and new/updated CAD design





Current Project Status

- Working Tasks 9-11
- Functionality improvements with InfiPoints
  - Provide a tool or function that allows the user to select a segment from the Segment View within InfiPoints and export it to a directory on disk or allow the user to “Export all segments” from the Segment View to a specified directory on disk as individual segmented point cloud files.

  - InfiPoints exported files are being converted into CAD Models and iteratively passed into VizSeek for comparison and matching to library parts.

Current Project Status

- Actual DDG-51 PC and CAD data provided to project.
- Working on VizSeek attribute mapping to all CAD data (CPC and parametric).
- Integrating library code for improved classification and for Gaussian splatting/mesh object creation from PC.
- First User Assessment (UA) was 4 Nov at BIW with senior PY designers and BIW IT.
- Second UA and testing will be at Penn State ARL.

Transition/Implementation

- Transition Event:
  - ManTech Deliverable: Point Cloud System Specification & Installation Guide and Point Cloud Application Software (March 2025)

- Implementation / Implementation Funding:
  - Target: GDBIW PY / IT
  - Time Period: Q3 2025
  - Implementation Funding Estimate, Source(s), and Status:
    - Hardware: $6,000
    - Infrastructure: $20,000
    - Professional Service Agreement preparation: $10,400
    - Process & Training Documentation: $61,600
    - Legacy data conversion: $44,000
    - Software licenses: $406,000 (will depend on terms of purchase)

Next Steps

- Finish development of key capability and test
  - Refine software integrations – implement software to algorithmically pass identified objects into VizSeek
  - Broaden test components and perform user testing on full environment
- Deliver all remaining technical deliverables and deliver final report by end of May.

#	Task	Deliverable	Responsible	Type	Expected Due Date/Cadence
1	1.2	Baseline Spend Plan	GDBIW ARL/PSU	Project Management	Actual 1 May 23
2	1.2	Master Schedule	GDBIW	Project Management	Actual 1 May 23
3	1.3	Telecon Presentations	GDBIW	Project Management	Bi-Weekly
4	1.4	Kickoff Meeting Presentation and Minutes	GDBIW	Project Management	Actual 1 May 23
5	1.6	Quarterly Review Presentation	GDBIW ARL/PSU	Project Management	Quarterly
6	1.6	Quarterly Report	GDBIW ARL/PSU	Project Management	Quarterly
7	1.7	Project Technical Presentation	GDBIW ARL/PSU	Project Management	Actual date?
8	1.8	ManTech Program / Tech Transfer Presentation	GDBIW ARL/PSU	Project Management	Semi-Annual
9	1.9	Signed Technology Transition Plan	GDBIW	Project Management	60 days after subcontract award, ECD 20 Jul '23
10	1.10	Phase I Review / Gate Review Presentation	GDBIW	Project Management	End of Task 5
11	1.11	Phase I Report	GDBIW	Project Management	End of Task 5
12	1.12	Material/Equipment Disposition Plan	GDBIW ARL/PSU	Project Management	Quarterly
13	2.1	Detailed Process Description	GDBIW	Technical	19 May 23
14	2.2	Future State Vision	ARL/PSU	Technical	20 May 23
15	3.1	Requirements Document	ARL/PSU	Technical	14 Jul 23
16	3.2	System Design Concept	ARL/PSU	Technical	ECD 19 Jul 23
17	4.3	System Design Document	ARL/PSU	Technical	End of Task 4
18	5.3	Initial Functionality Test Release	ARL/PSU	Technical	End of Task 5
19	6.1	Baseline Spend Plan	GDBIW ARL/PSU	Project Management	30 Calendar days after option exercise Phase II
20	6.1	Master Schedule	GDBIW	Project Management	30 Calendar days after option exercise Phase II
21	6.2	Telecon Presentations	GDBIW	Project Management	Bi-Weekly
22	6.3	Quarterly Review Presentation	GDBIW ARL/PSU	Project Management	Quarterly
23	6.3	Quarterly Report	GDBIW ARL/PSU	Project Management	Quarterly
24	6.4	Project Technical Presentation	GDBIW ARL/PSU	Project Management	6 Months after option exercise Phase II
25	6.5	ManTech Program / Tech Transfer Presentation	GDBIW ARL/PSU	Project Management	Semi-Annual
26	6.6	Updated Technology Transition Plan	GDBIW	Project Management	60 calendar days after option exercise Phase II
27	6.7	Final Review	GDBIW	Project Management	5 business days prior to Subcontractor PoP
28	6.8	Draft Final Report	GDBIW	Project Management	45 calendar days prior to Subcontractor PoP
29	6.8	Signed Final Report	GDBIW	Project Management	5 business days prior to Subcontractor PoP
30	6.9	Material/Equipment Disposition Plan	GDBIW ARL/PSU	Project Management	Quarterly
31	7.5	Phase 'A' System Development Report	ARL/PSU	Technical	End of Task 7
32	8.6	Phase 'A' Integration Report	ARL/PSU	Technical	End of Task 8
33	9.2	Initial Release Candidate Software (Code, deliverable to shipyard only)	ARL/PSU	Technical	End of Task 9
34	9.4	Phase A User Identified Gaps and Suggested Modifications Document	GDBIW	Technical	End of Task 9
35	10.3	Installation Directions and BIWIT Compliant Software	GDBIW	Technical	End of Task 10
36	11.1	Point Cloud System Test Plan	GDBIW	Technical	End of Task 11
37	11.4	UAT Results	GDBIW	Technical	End of Task 11
38	11.5	IT & DXC Architecture Presentation and Minutes	GDBIW	Technical	End of Task 11
39	12.1	Point Cloud System Specification and Installation Guide	ARL/PSU	Technical	End of Task 12
40	12.1	Point Cloud Application Software (Code, deliverable to shipyard only)	ARL/PSU	Technical	End of Task 12