Enhanced Space Object Characterization

Automated solution for pose, shape, and density estimation of space objects

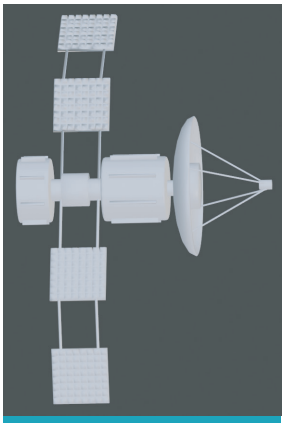
Intelligence Agencies face a rapidly increasing workload to characterize space objects.

Riverside Research is using AI to develop automated approaches to 3D reconstruction of the object to estimate shape, pose, mass/density, and component-level identification. We aim to increase throughput and quality of object characterization capabilities across EO and Radar imagery of space objects regardless of prior known object shape.

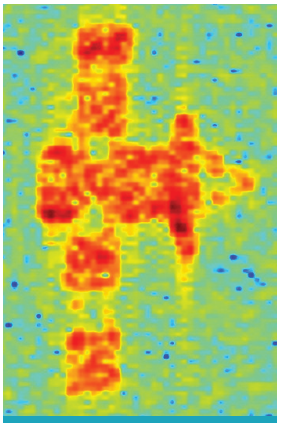
Process

We created a synthetic space object data pipeline to assess initial feasibility of deep learning model's ability to estimate pose and shape of input radar images. We then developed a deep learning model in Pytorch to estimate pose and shape of the object given a sequence of radar images.

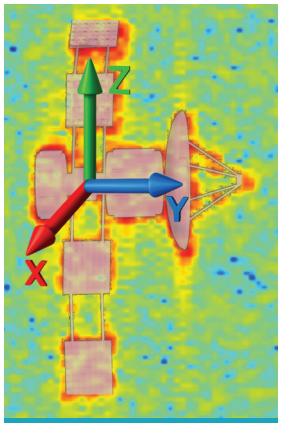
From there we leveraged foundation models, SAM 2.1, Visual Geometry Grounded Transformer (VGGT), to perform image segmentation and 3D shape estimation to provide accurate prior conditions for the deep learning model.



Satellite Model



ISAR Image



Calculated Pose

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Key Features

- Automated pose estimation
- Automated shape estimation
- Automated mass/density estimation

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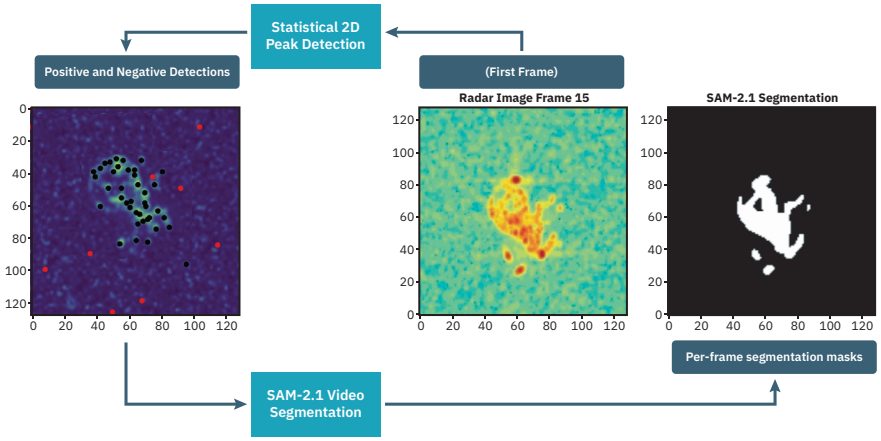
Observations

This solution leverages a deep learning model to create a physics-informed, temporally aware, deep learning model for automatically reconstructing 3D space objects' shape and estimating motion from radar data over time.

The current process for space object characterization is manual and involves various agencies and tools. The proposed enhanced space object characterization solution will expedite the process and can more readily adapt to an increased workload that stakeholders face.



Enabling robust ISAR target segmentation supporting existing simultaneous shape and motion estimation algorithms from prior A&AS work.

Next Steps

Our next step is to leverage existing, real wideband imagery sequences (both ISAR and EO) to validate our approach. We have procured classified image data that can be used to validate the deep learning and foundation models currently used for the synthetic data.

More specifically:

- Fine-tune the model architecture to improve performance
- Investigate the feasibility of component-level segmentation of the space objects—current research is focused on object-level segmentation and characterization
- Research and prototype mass and density estimation approaches that are informed from the shape and pose estimation

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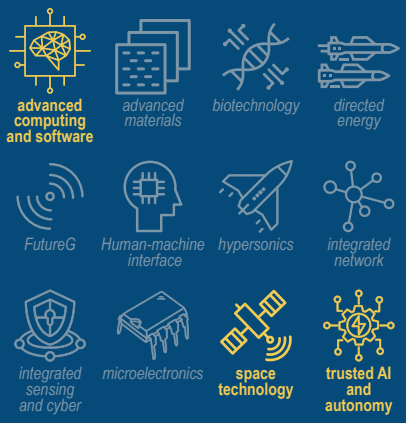
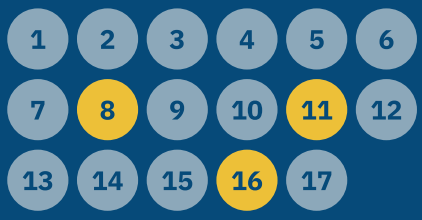
Critical Tech Areas



DoD Priorities



1. Southwest Border Activities
2. Combating Transnational Criminal Organizations in the Western Hemisphere
3. Audit
4. Nuclear Modernization (including NC3)
5. Collaborative Combat Aircraft (CCAs)
6. Virginia-class Submarines
7. Executable Surface Ships
8. Homeland Missile Defense
9. One-Way Attack/Autonomous Systems
10. Counter-small UAS Initiatives
11. Priority Critical Cybersecurity
12. Munitions
13. Core Readiness, including full DRT funding
14. Munitions and Energetics Organic Industrial Bases
15. Executable INDOPACOM MILCON
16. Combatant Command support agency funding for INDOPACOM, NORTHCOM, SPACECOM, STRATCOM, CYBERCOM, and TRANSCOM
17. Medical Private-Sector Care