Trusted Distributed Autonomy Demonstration Experiment: Simulation Based Results

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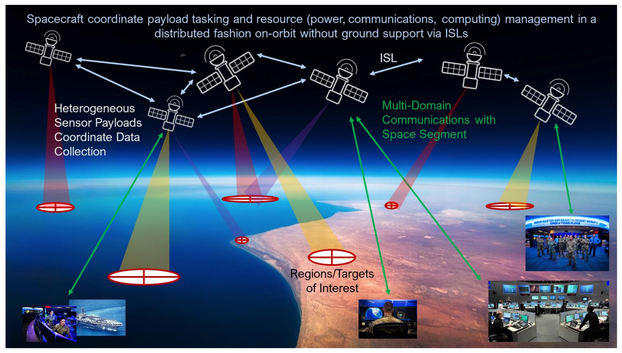
Trusted Distributed Autonomy Demonstration Experiment

- Distributed autonomy capabilities mitigate challenges of space battle management command and control (BMC2)
- Proliferated ISR missions need on-orbit:
  - Ultralow latency, high-speed, globally-available services
  - Constellation scale resource allocation
  - Management of a wide variety of heterogeneous payloads
  - Resilient against outages (without intervention)
  - Trusted autonomous operations

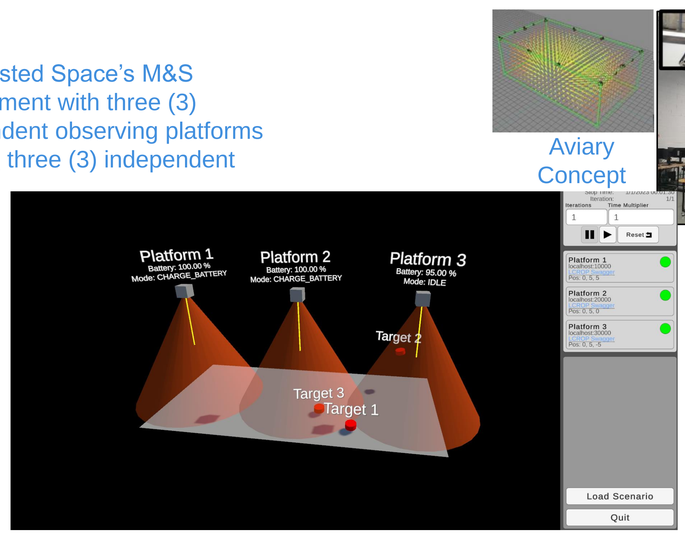


- The Air Force Research Lab experiments with advanced distributed autonomy concepts in the Local Intelligent Collaborative Networked Satellites (LINCS) Laboratory
- The goal of the Trusted Distributed Autonomy Demonstration Experiment (TDADE) is to develop and demonstrate a fully autonomous, distributed, trusted, and adaptive onboard autonomy software solution that enables resilient management of resources in *proliferated space* constellations, to meet complex *Missions at Scale*.

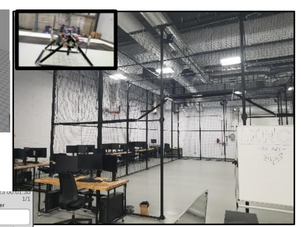
Digital Environment for Trusted Distributed Autonomy

- LINCS Laboratory implements collaborative autonomy algorithms on next-gen (adjacent) hardware for multiagent satellite cluster inspection and collaboration.

The Trusted Space's M&S Environment with three (3) independent observing platforms tracking three (3) independent targets



Aviary Concept



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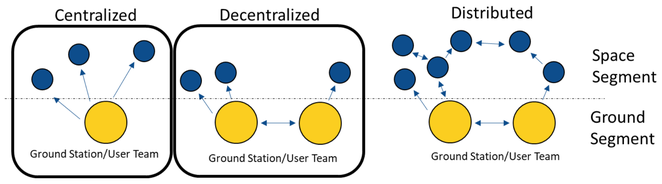
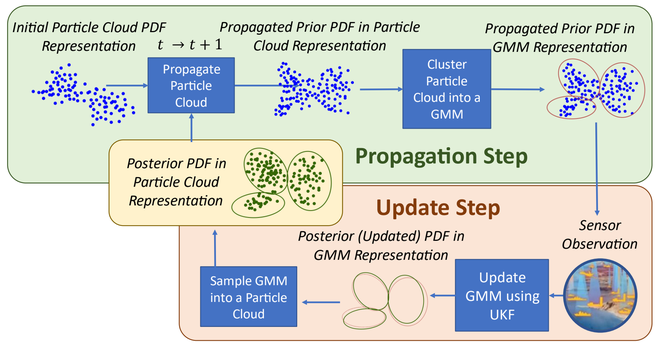
- TDADE seeks to develop and demonstrate benchmark distributed information fusion and decision-making algorithms that are trusted and adaptive.
- To support development of distributed autonomy solutions, we developed a M&S environment for the LINCS Laboratory.
- TDADE M&S environment end state = digital twin of the LINCS Lab.
- Scenario is relevant to space ISR design reference mission.

Distributed Fusion and Decision-Making

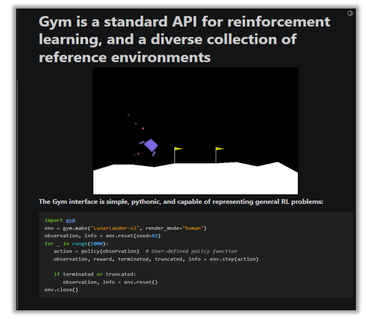
TDADE develops *distributed* Autonomy Solutions for Proliferated Space Systems

What are distributed satellite systems?



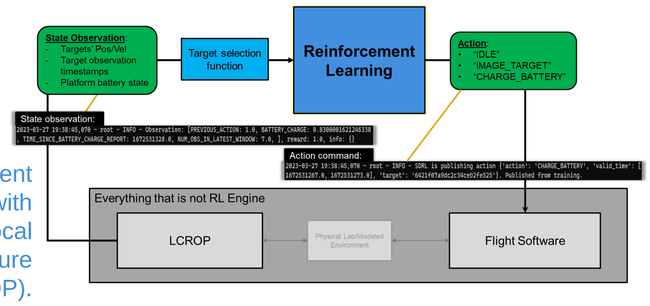


Machine learning based on Stable-Baselines3 [3] is implementable with OpenAI gym.



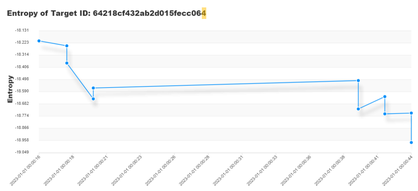
Single agent Probabilistic Admissible Region-Particle Gaussian Mixture Model Filter (PAR-PGMF) advanced tracking and filtering algorithm[1,2].

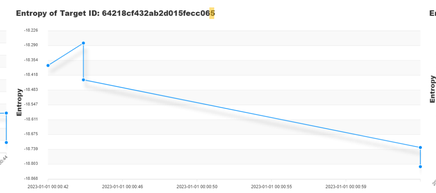
The Shielded Deep Reinforcement Learning [4] algorithm interacting with simulated platform and distributed Local Common Relevant Operating Picture (LCROP).

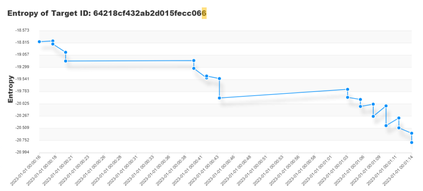


Ongoing Work

- Simulation results indicated expected behaviours.







- Early distributed PAR-PGMF tracking shows the information state of individual targets (see entropy charts) is improving upon every observation. Tracks were initialized using the PAR.
- Reinforcement learning approach implements a distributed ISR mission-conserves battery while dynamically balancing target collections.
- Distributed autonomous collaboration enabled through Local Common Relevant Operating Picture (LCROP).
- Adding fidelity to M&S environment in sync with LINCS hardware capabilities.

References:

1 D. Raihan and S. Chakravorty, "Particle Gaussian Mixture Filters I & II", Automatica, V. 98, pp. 331-348, 2018.

2 I. Hussein, et al., "Probabilistic Admissible Region for Multi-Hypothesis Filter Initialization," J. Guidance, Control and Dynamics, Vol. 41, No. 3, 2017.

3 A. Raffin, A. Hill, A. Gleave, A. Kanervisto, M. Ernestus, N. Dormann, "Stable-Baselines3: Reliable Reinforcement Learning Implementations," journal of Machine Learning Research 22 (2021)

4 A. Harris and H. Schaub, "Spacecraft Command and Control with Safety Guarantees using Shielded Deep Reinforcement Learning" AIAA SciTech Forum, Orlando, Florida, Jan 6-10, 2020.