Modeling, Design and Operation of Robotic Tether-Net Systems for Reliable Capture of Targets

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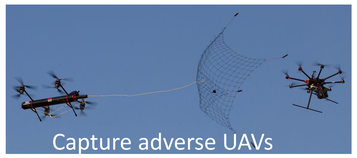
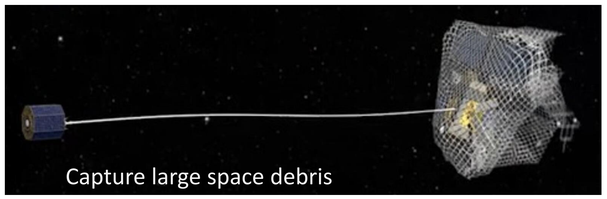
23000+ tracked debris pose severe threat to spacecraft, satellites and orbital assets

Capturing debris is difficult → **A generalizable, reliable, low-cost solution needed**

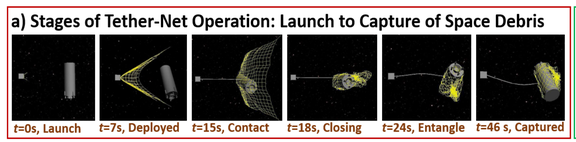
CHALLENGE: Advance scientific understanding of how to autonomously capture flying targets under environmental uncertainties using robotic tether-net systems launched from aircraft or spacecraft.

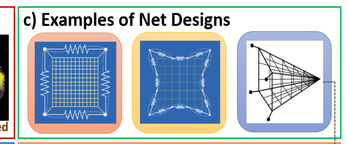

Capture adverse UAVs

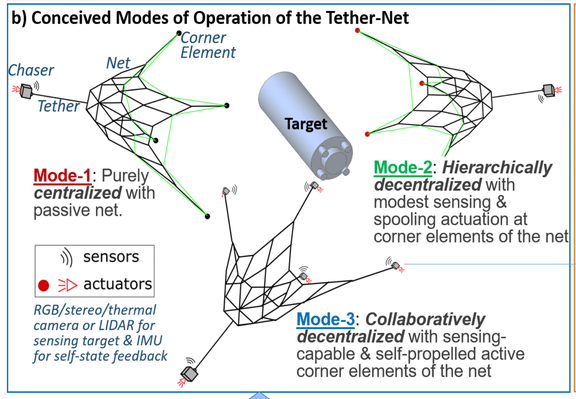

Capture large space debris

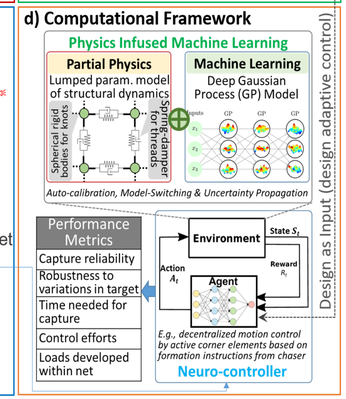
SCIENTIFIC IMPACT: CPS

- Learning-based control of flexibly-constrained multi-node systems.
- Fast yet generalizable prediction of dynamic systems using PIML.









KEY INNOVATIONS & CONTRIBUTIONS:

1. Physics-infused machine learning (PIML) to auto-calibrate net dynamics and contact models with computing-cost/fidelity trade-offs that are suitable for learning and deploying controllers.
2. Develop, test and compare centralized vs. novel decentralized formation control approaches to regulate launch, maneuver and closure.
3. Reliability-based optimization with design-adaptive neuro-control to identify optimal net designs that are effective across wide range of uncertainties in the state of the target object and sensing quality.

BROADER IMPACT ON SOCIETY

Effective tether-net based solutions to space debris capture will enable safe exploitation of commercial orbits, which will:

- Benefit satellite operators, national agencies, the public who rely on earth observation.
- Help strengthen U.S. leadership in space.

BROADER IMPACT: EDUCATION & OUTREACH

- Broaden participation of women in STEM, particularly robotics, through hands-on experiences in robotics research.
- Promote exposure of engineering students to the emerging technologies of net-based robotics and learning based control.

BROADER IMPACT:

- New ROS and OpenAI libraries.
- Two graduate students / two rotating engineering undergrads.
- Panel sessions at flagship conferences.
- Experimental setup and best practices for autonomous net-based target capture.

2022 NRI & FRR Principal Investigators' Meeting
April 19-21, 2022

Award ID#: 2128578

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