



System of Systems at the Oceans-to-Space Interface

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Trends at the Oceans-to-Space Interface

▪ In Space

- A new generation of small satellites (<150 kg) is being developed and launched giving unprecedented opportunities for Earth Observation and communications
- ReCon: Earth Observation “on demand” by reconfiguring smallsat orbits using electric propulsion and unique repeating groundtrack orbits (RGT)
- New LEO communications satellite constellations, e.g. Starlink

▪ In the Ocean

- Robotic surface vehicles (e.g. sail drones) are becoming more frequent
- Autonomous Underwater Vehicles (AUVs) with increasing capabilities, endurance, sensors and on-board decision-making being deployed

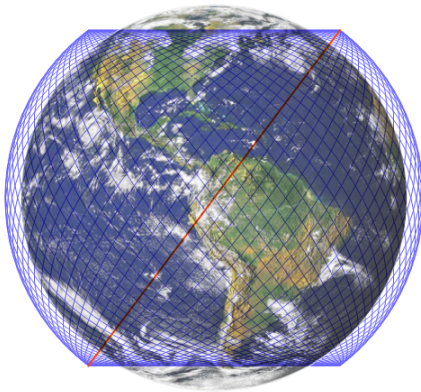
How to do we create a value added Oceans-to-Space System-of-Systems for support of ocean exploration, defense and developing the Blue Economy?



Example: Starlink Constellation (SpaceX)

- Low Earth Orbit (LEO) constellation as a high bandwidth internet service provider at Ku and Ka band
- Total Satellites Launched to date (7 August 2020): 597
- Mass: 230-260 kg each
- AFRL has already demonstrated 610 [Mbps] via Starlink in 2019

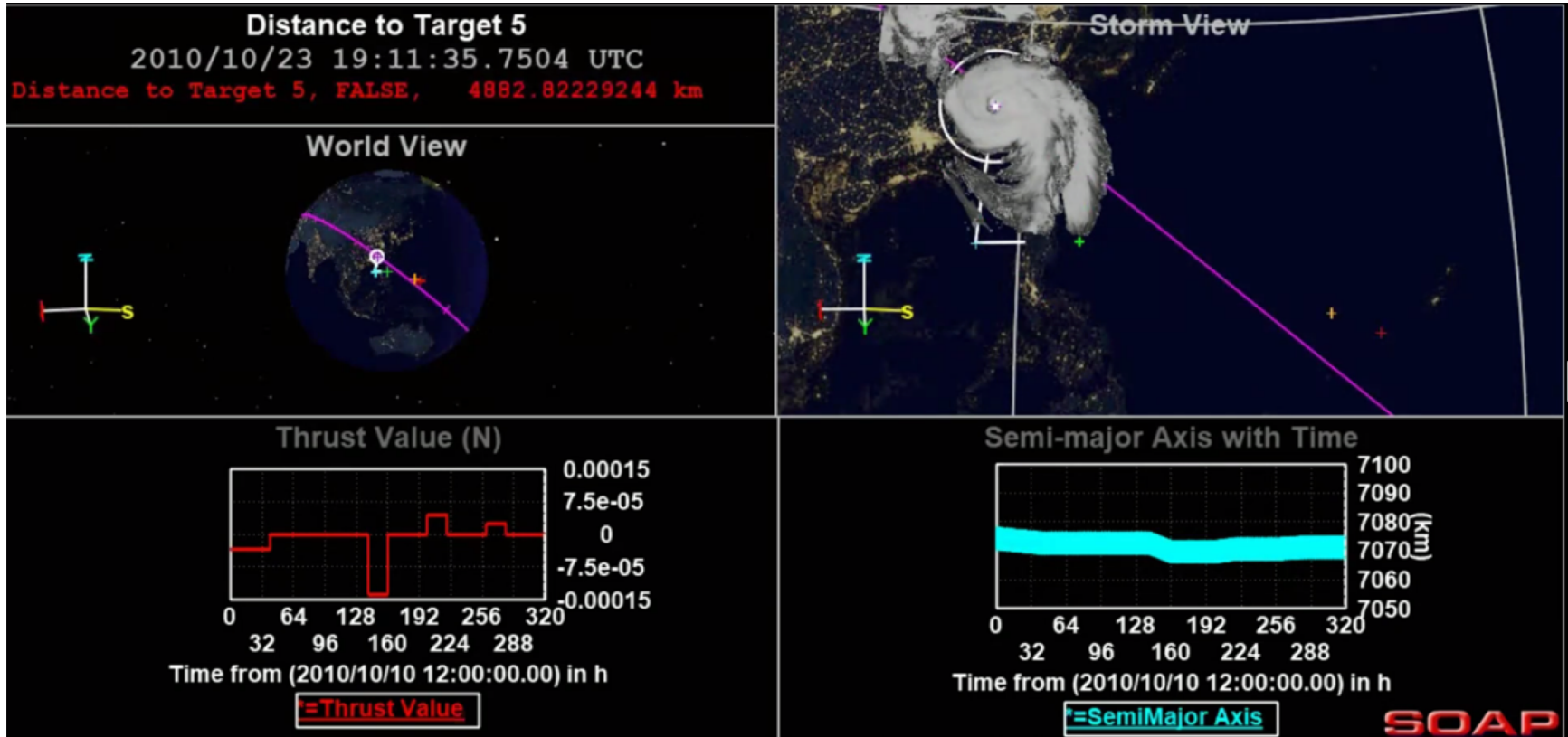
Starlink Initial Phase
1,584 satellites into 72 orbital planes
of 22 satellites each



Start of Commercial
Operations: early 2021

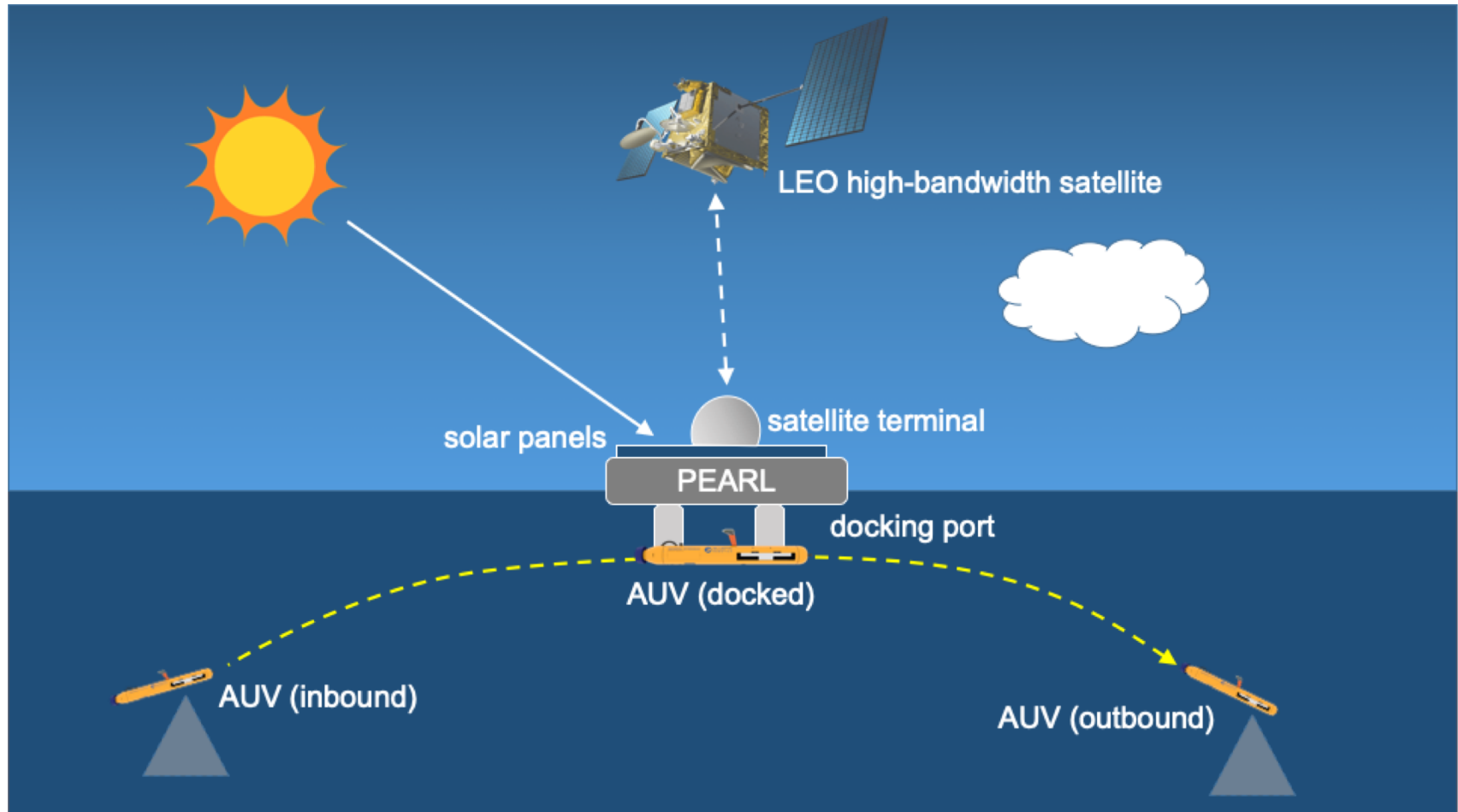


Reconfigurable Earth Observing Sat Constellations



Sarah J. Morgan , Ciara N. McGrath , and Olivier L. de Weck, "Mobile Target Tracking Using a Reconfigurable Low Earth Orbit Constellation", AIAA ASCEND 2020 Conference, Las Vegas, November 2020

System of Systems: Platform for Expanding AUV exploRation to Longer Ranges (PEARL)

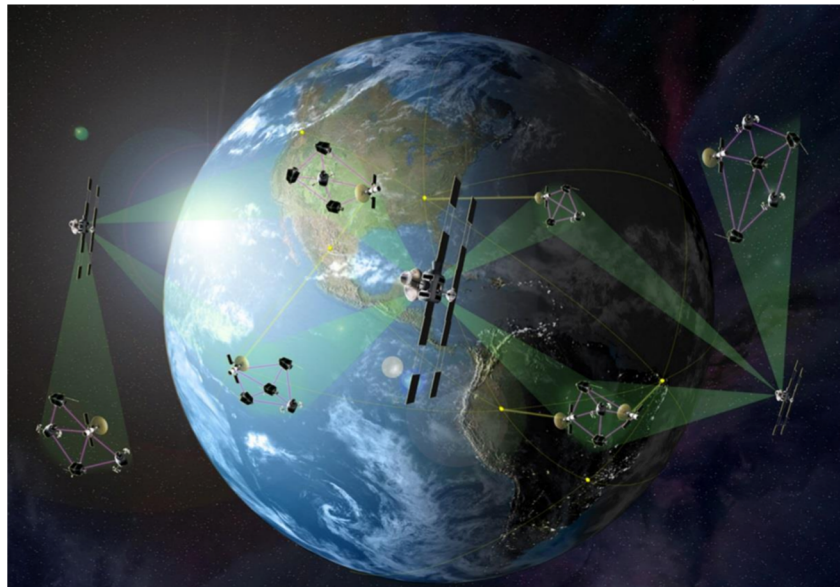


New Methods for System-of-Systems

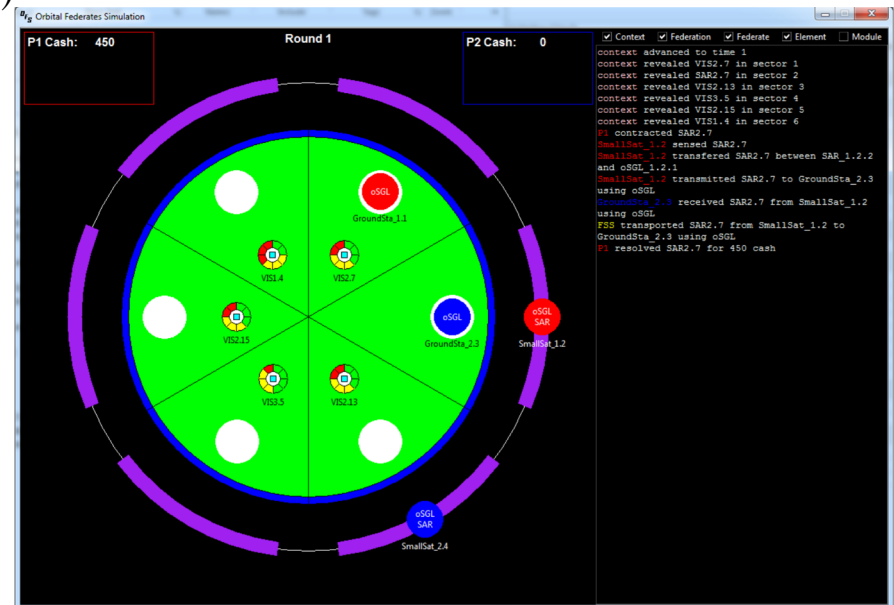


- Agent-based-Modeling
- Discrete Event Simulation
- Multi-Player Gaming

Federated Satellite System (FSS)



Orbital Federates Game and Simulation



Grogan, Paul T., Koki Ho, Alessandro Golkar, and Olivier L. De Weck. "Bounding the value of collaboration in federated systems." In *2016 Annual IEEE Systems Conference (SysCon)*, pp. 1-7. IEEE, 2016.