Proliferated LEO Autonomy Architecture for Capability with Scalability

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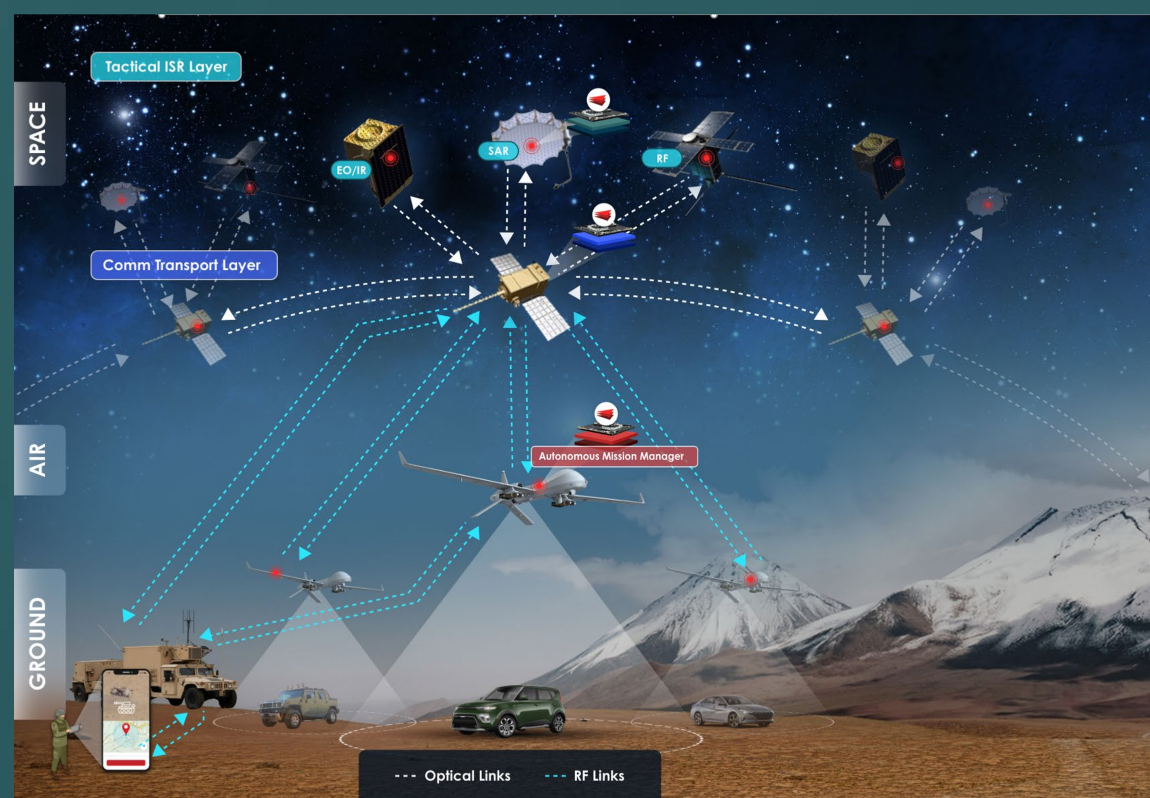

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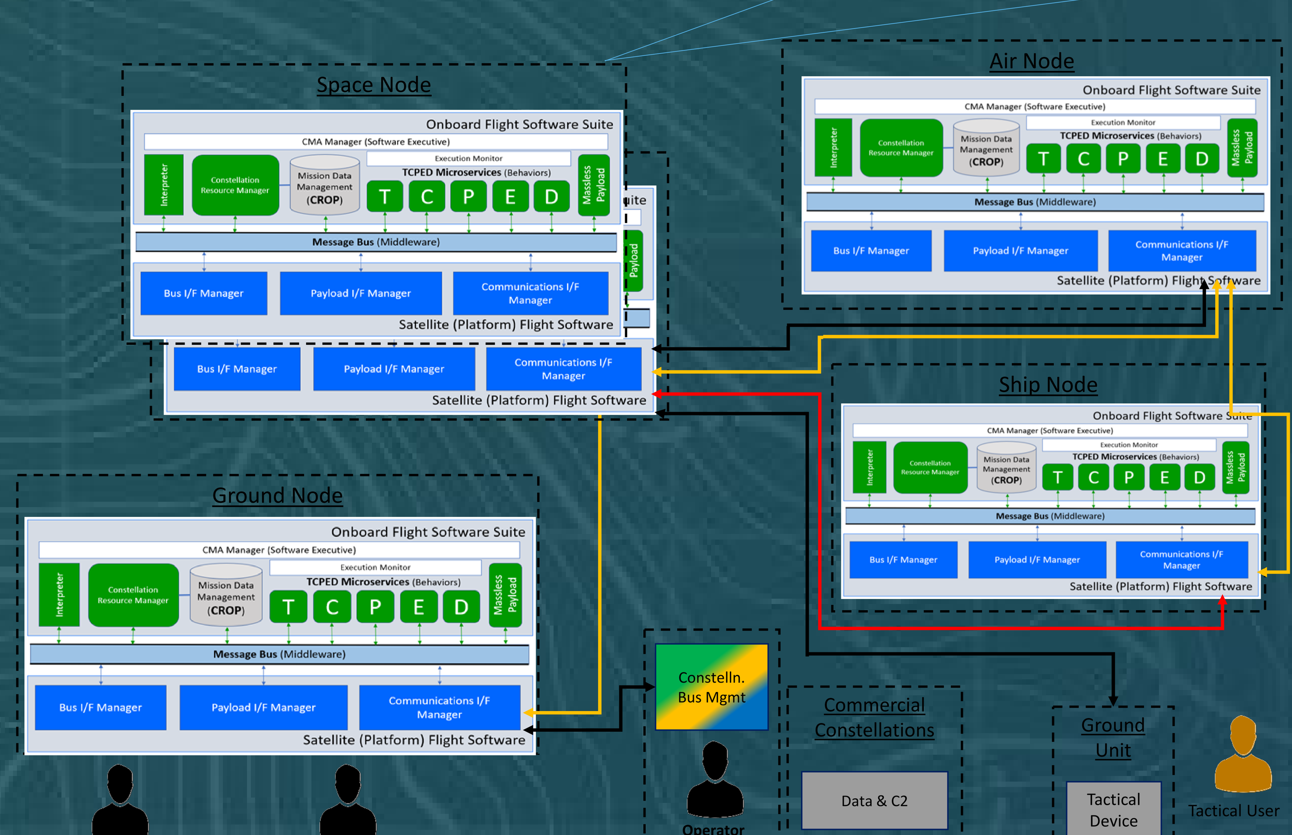
BACKGROUND

A next generation space architecture focused on proliferated low-Earth Orbit (p-LEO) constellations holds the promise of improved situational awareness, responsiveness, and resiliency.

A variety of proliferated space constellation efforts are underway in the National Security Space Arena, all demanding innovations in ubiquitous satellite command, control, and communications.

Whether communications, science, or defense missions, the expansion into PLEO constellations drives new demands upon autonomy, software, and communications architectures.

Previous groundbreaking autonomy work was performed on the Deep Space 1 mission, which eventually led to NASA Mars and Earth Observing-1 autonomy. In Autonomous Rendezvous, Proximity Operations, and Docking (ARPOD), Defense Advanced Research Projects Agency (DARPA)'s Orbital Express and the Air Force XSS-10 mission helped establish the state of the art. While similarities exist, mission autonomy for these individual spacecraft missions fundamentally differs from PLEO constellations in their demands and constraints.



The CMA architecture support flexible instantiation in platforms across multiple domains. It enables truly scalable Machine-to-Machine collaboration with processing at the edge

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TECHNICAL CHALLENGES

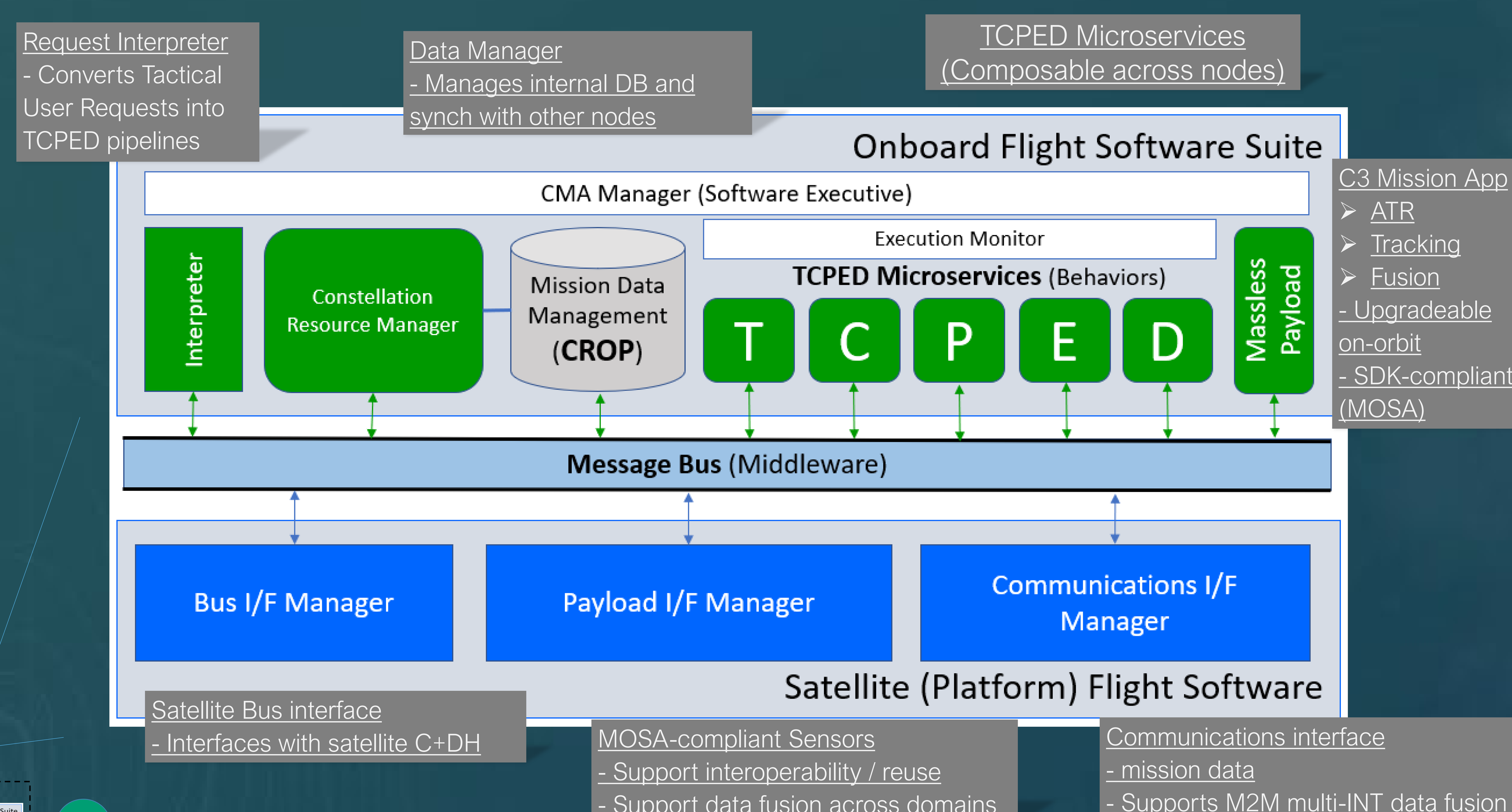
New demands on PLEO mission autonomy systems include:

1. Integrating heterogenous assets with varying capabilities and availability,
2. Adapting to evolving missions,
3. Overwhelming volumes of time-sensitive data,
4. Abstracting mission autonomy from low-level functions,
5. Performing machine-to-machine satellite coordination, and
6. Providing an application layer interface to ground users.

These capabilities must be ***scalable and*** must be ***resilient*** amid unreliable communication links and to resource failure or loss.

In addition, rapidly evolving missions and technologies demand on-orbit assets to be capable of software updates to fix defects and add capabilities. Maintaining utilization on relevant timelines demands moving computation onboard for decision making and data exploitation. These demands strongly discourage centralized architectures.

Constellation Collaborative Mission Autonomy – Node Architecture



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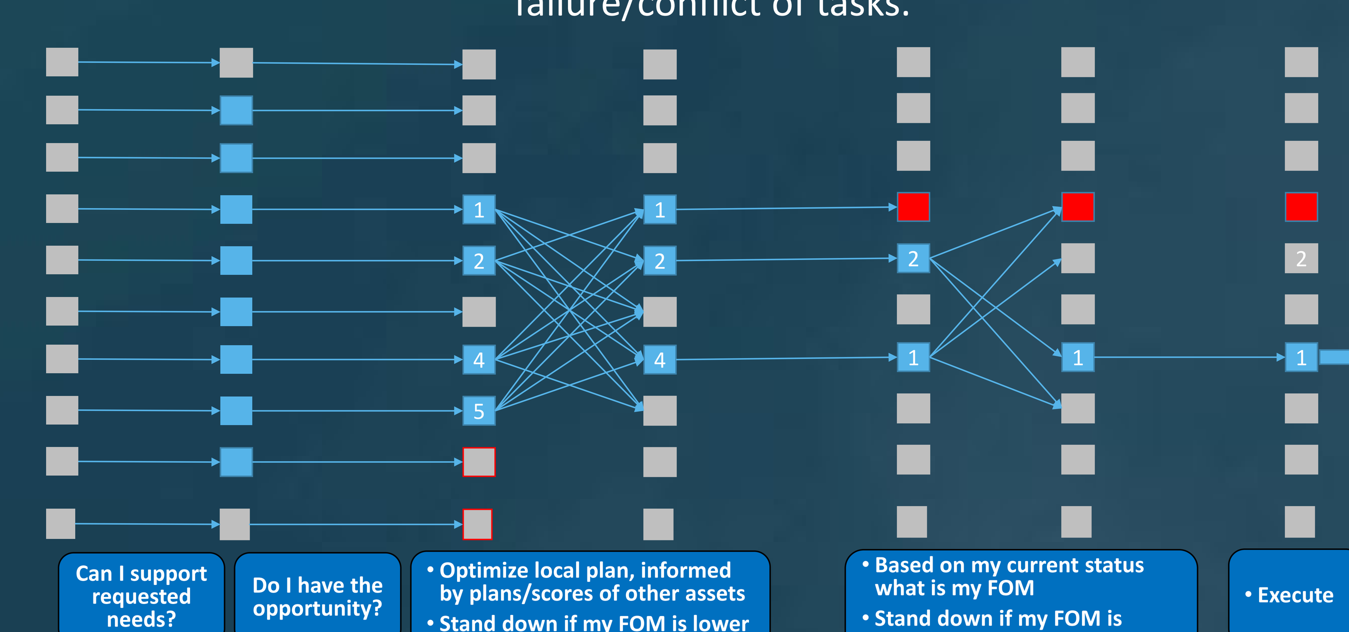
SOLUTION

SSCI's processor-agnostic Collaborative Mission Autonomy (CMA) is a decentralized architecture & implementation for onboard planning and execution that is being developed to address the identified needs of PLEO operations supporting TCPED execution.

The architecture aims to enable lightweight data synchronization to maintain a common relevant operating picture (CROP) across the constellation and enable decentralized decision making which underpins resilience and graceful degradation.

The architecture performs self-tasking via a receding horizon local plan with local scoring, and conduct onboard processing and exploitation. All this orchestrated within a microservice framework that allows SDK-based, modular, uploadable software plugins. An essential architectural element is to enable the use of software translation layers which abstract mission autonomy away from bus- and payload-specific interfaces & platform autonomy software.

Redundant fully decentralized self-planning with reactive execution.
Redundancy supports collaborative execution and robustness to failure/conflict of tasks.



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DEVELOPMENT STATUS

Flight Implementation

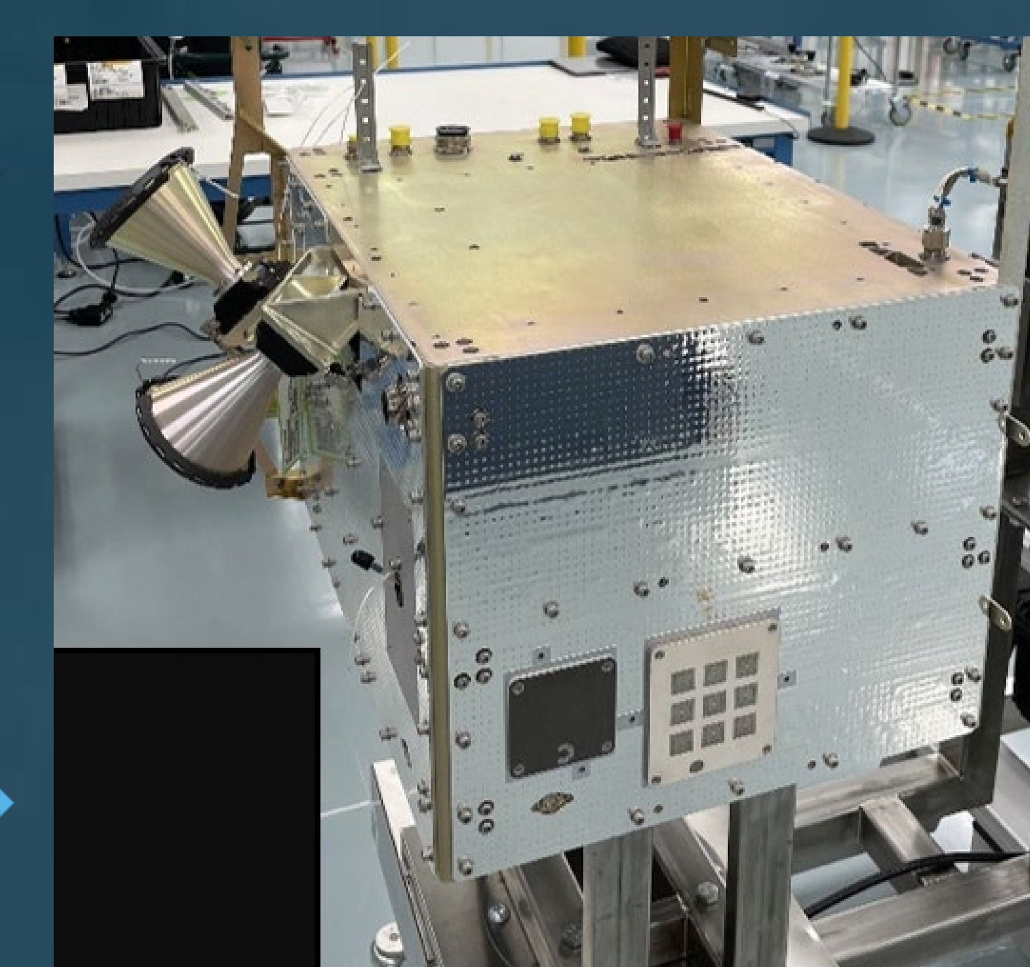
SSCI is leading a DARPA-funded team launching a mission in June 2021, dubbed Sagittarius A*, implementing an instantiation of this architecture. (see conference paper by Royer et al.)

The system will fly on Loft Orbital's YAM-3 shared LEO satellite mission, and includes SSCI's onboard autonomy software suite running on an Innoflight CFC-400 processor with onboard Automatic Target Recognition (ATR). The autonomy payload has attitude control authority over the spacecraft bus and command authority of the imaging payload, and performs fully-autonomous onboard request handling, resource & task allocation, collection execution, ATR, and detection downlinking. The system is capable of machine-to-machine tip-and-cue from offboard cueing sources via cloud-based integrations. Requests for mission data are submitted to the satellite throughout its orbit from a tactical user level via a smartphone application, and ISR data products are downlinked and displayed at the tactical level on an Android Tactical Assault Kit (ATAK) smartphone. Follow-on software updates can be sent to the autonomy suite as over-the-air updates for on-orbit testing at any time during the on-orbit life of the satellite.

The CMA architecture enables true machine-to-machine collaborative mission execution, with the ability to orchestrate operations across domains, exploit data onboard and provide tactical users the ability to task from and receive information at the tactical edge.

As the Sagittarius A* mission becomes available as an on-orbit testbed implementing CMA with the aforementioned capabilities, new missions and mission management software, modules and algorithms can be deployed and tested in-orbit within days if not hours.

CMA is providing a proof-of-concept of a new architectural paradigm for TCPED execution that significantly enhances responsiveness, scalability and tactical capabilities.



Sagittarius A* mission implements CMA for a ISR TCPED with automated object detection