An Autonomous Agent Framework for Constellation Missions: A Use Case for Predicting Atmospheric CO_2

DSM / EDP
Event Driven Planning

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Agent Framework is an autonomous decision-making agent that takes in multiple subsystems over multiple spacecrafts and generates decisions and a plan of action.

Abstract

Distributed systems missions (DSM), also known as swarm or constellation missions, is an upcoming class of mission design that is changing the current landscape. Swarms enable multipoint observations and higher fidelity science data collection. Autonomy is a critical feature that DSM will require in order to run successfully, especially beyond earth-centric missions and in dynamic environments due to increased delays between ground and space.

Demo

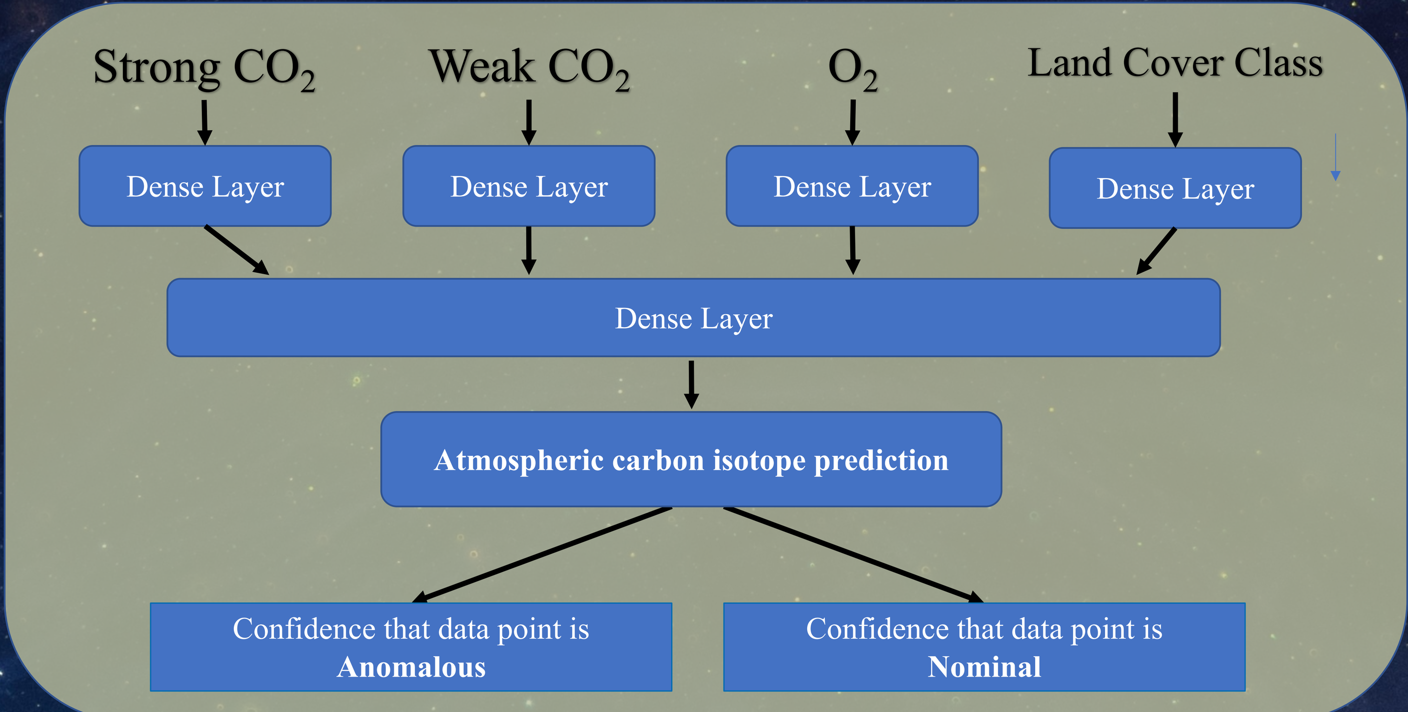
We demonstrate our Agent Framework architecture by utilizing data from OCO-2. We analyze OCO-2 data using a neural network (NN) trained on CO_2 strong, CO_2 weak, and O_2 spectral data from spacecraft measurements by OCO-2 and ground-based measurements by the National Ecological Observatory Network (NEON). The NN predicts ground-based isotope measurements of CO_2 using OCO-2 spectroscopic inputs – a novel use of these data and a powerful tool in carbon cycle science. An OCO-2 Instrument Agent collects CO_2 data and uses the NN to intelligently predict in situ atmospheric conditions to understand atmospheric cycling, while also identifying anomalies (e.g., from wildfire, or pollution). When the NN model denotes these readings as an anomaly, the OCO-2 Instrument Agent flags and communicates such to a Meta Agent. Then, the Meta Agent determines the importance of investigating the anomaly further. If the Meta Agent adds the anomaly investigation to the schedule, other spacecraft are employed to make more observations. Once the anomaly is observed, the constellation plans to route the data to the ground station in the most optimal manner, thus ensuring the most salient information is downlinked and flagged rapidly. Throughout the whole process, faults are being intelligently remedied, ensuring longevity of spacecraft.

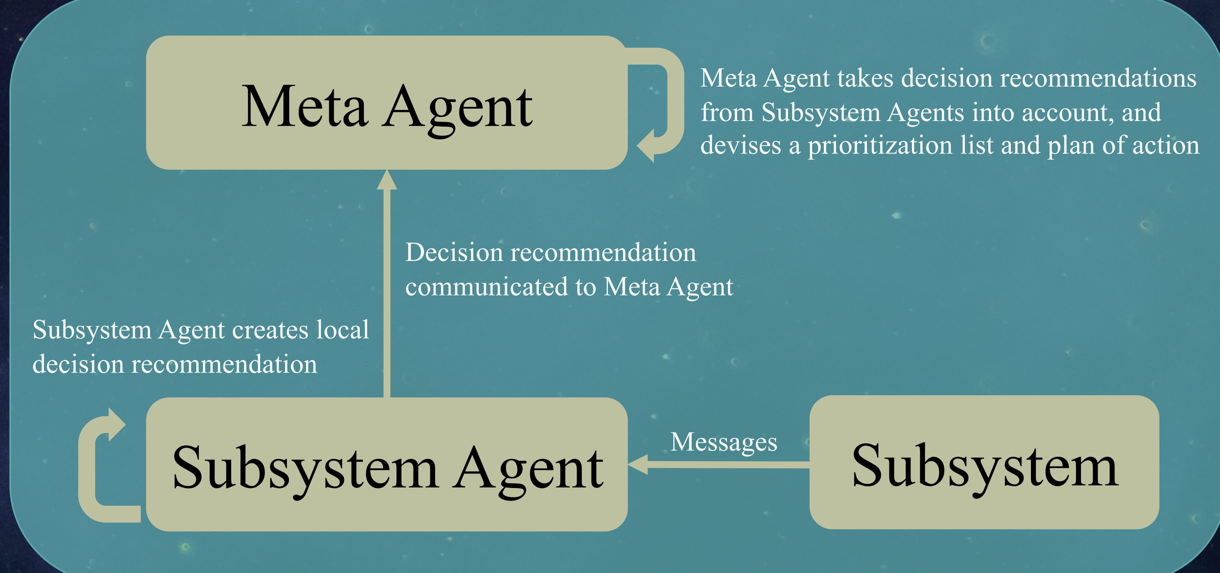
Conclusion

Our Agent Framework is an autonomous decision-making and fault-detection architecture that reads environment data, intelligently detects phenomena using on-board machine learning models, and deploys communication and planning techniques to enable multipoint observations using swarms. Our framework has a modular structure, such that specific capabilities can be included as desired, which promotes use across a variety of space-based missions.

Agent Framework Design

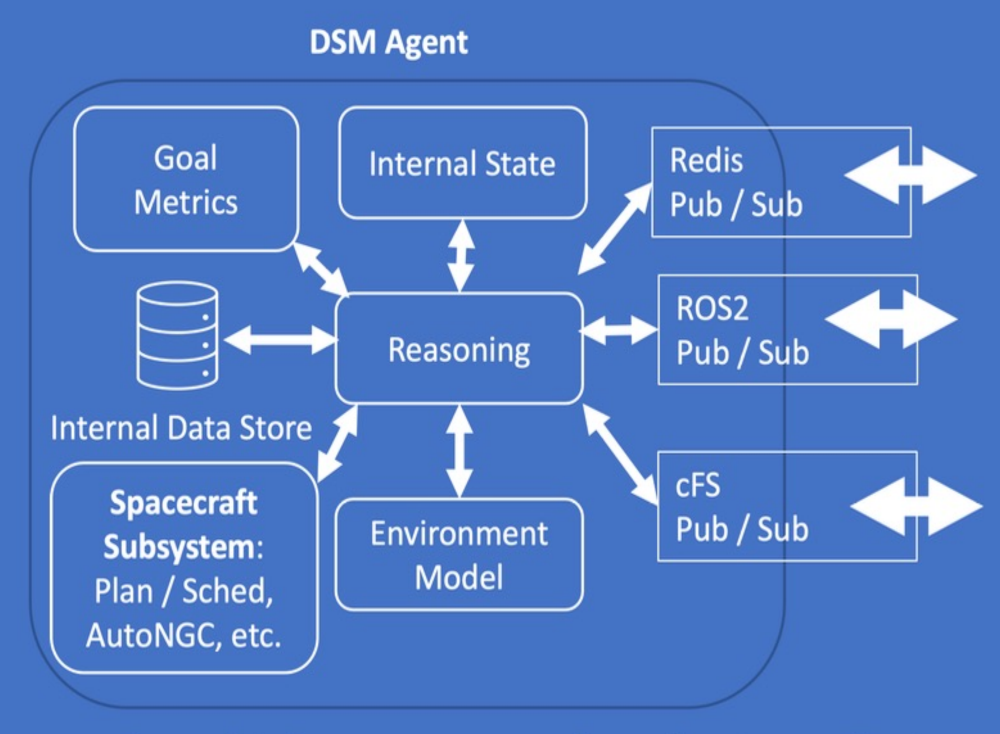
- Agent Framework architecture is comprised of two main types of autonomous systems called Agents: Subsystem Agents and Meta Agents.
- Subsystem Agents control relevant spacecraft subsystems (e.g., power, thermal).
- Meta Agents coordinate the Subsystem Agents running on the spacecraft.
- All Agents use machine learning and scheduling techniques to fulfill their relevant tasks, as well as facilitate both inter and intra spacecraft communication using Robotic Operating System 2 (ROS2) or Core Flight System (cFS) depending on application.
- Uses the publish-subscribe messaging pattern, allowing it to remain platform-agnostic and facilitates integration with future platforms or subsystems.



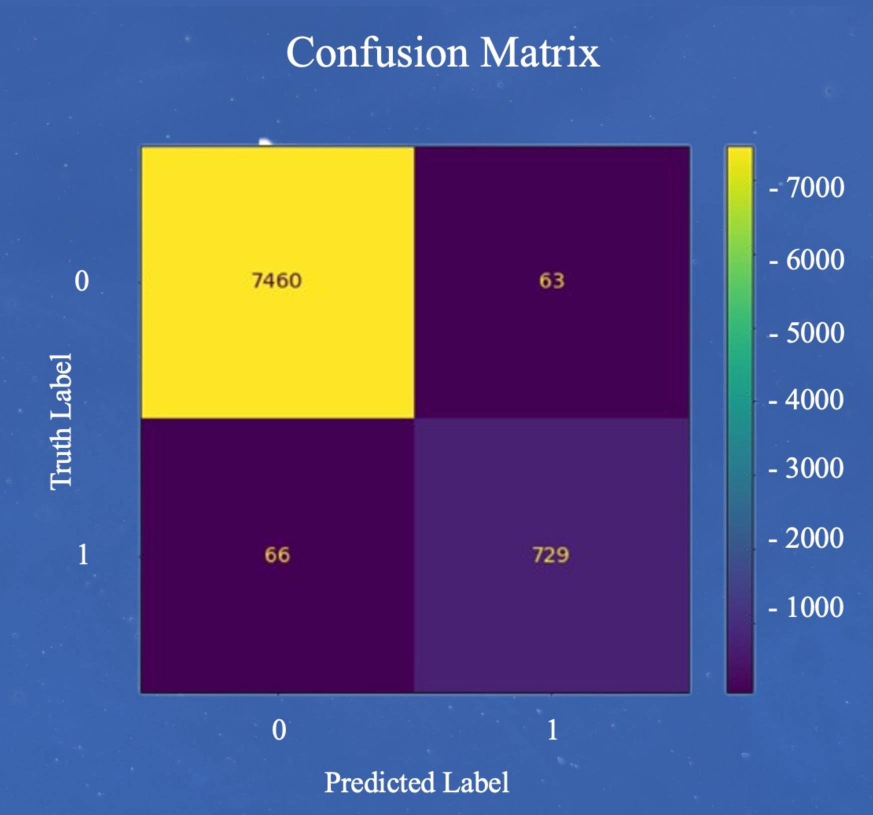


Event Driven Planning (EDP)

Agent Framework for constellation-wide event-based planning, real-time instrument reconfiguration, Resource deconfliction



Coordinates on-board Subsystems as well as the Constellation as a whole



Future Work

- High-fidelity virtual simulation environment
- Field testing during the Network for Assessment of Methane Activity in Space and Terrestrial Environments (NAMASTE) campaign
- Further intelligence and subsystem management/integration