National Aeronautics and Space Administration

FY24 Strategic Initiatives Research and Technology Development (SRTD)

Autonomous Systems Development for Decadal Mission Applications

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Strategic Focus Area: System-Level Autonomy Solutions and Testbed | **Strategic Initiative Leader:** Steven E Ardito

Objectives:

- Mature, validated and integrated set of system- and functional-level autonomy capabilities that we can confidently deploy in future missions, including core functions like automated planning, scheduling and execution, system health management, and autonomous navigation (Fig.1).
- Comprehensive, integrated system simulation and HIL testbed environments that are necessary to validate our autonomous system capabilities.
- Rigorous methods and tools to do architectural trade-offs involving autonomous capability, evaluated against metrics like science performance, cost, schedule, resilience, and risk.

Background:

Development of flight-ready spacecraft autonomy software is of strategic importance to JPL. Autonomy is defined as the ability of a system (e.g., spacecraft or rover) to achieve mission goals while operating independently of external control. A number of mission concept studies in the recent Planetary Decadal Survey highlighted the need for autonomy for various stages of their mission. However, to compete for and execute on future flight projects, we must evolve institutional development capabilities (methods, tools, and testbeds) and mature core system-level autonomy design concepts that have been developed under other R&D efforts. System-level autonomy enables missions that may not be possible with only functional autonomy applications by infusing reasoning engines that manage goal-based behaviors to achieve complex, coordinated operations.

Approach and Results:

Conops/Scenarios – We developed a set of compelling ConOps scenarios involving lunar mobility and communications, which framed our year-end integrated field demonstration on the ATHENA rover.

Core Algorithms – We developed powerful new flexible execution features for MEXEC, enabling it to, e.g., interrupt a drive to perform a high-priority downlink at the next available comm opportunity, then resume driving (Fig 2).

Integration and Demonstration – We developed a common software interface in the Robot Operating System (v.2) that connects the system-level autonomy algorithms (MEXEC) with functional autonomy algorithms (mobility and telecom) that are mission-specific. We integrated our system-level autonomy software with the autonomous rover navigation and drive control developed under the 4X autonomy SRTD Initiative, ground-based rover path planning from the 9X autonomy SRTD Initiative, and telecom behavior developed under our task. We completed multiple demo milestones, culminating in a validation of autonomous driving and telecom in a field test campaign (Figs. 3-4).

Simulation and Testbed – We developed a variable-fidelity environment for developing, testing and validating autonomy solutions, including a RoverSim simulation (based on the DARTS/DSHELL simulation framework) that allows for rapid testing of system-level autonomy, and a hardware-in-the-loop embedded avionics testbed (based on the Multi-Mission Autonomous Spacecraft Operations Testbed - MASCOT) with representative processor and communication hardware.

Architecture Evaluation – We developed a MissionSim system modeling and analysis capability to do architectural trades and design prototyping involving autonomous capability, and applied it to perform architecture trades for the Endurance mission.

Significance/Benefits to JPL and NASA:

Autonomy technology infusion risk is too high, and there is a general lack of readiness for flight. Furthermore, our mission formulation approach does not adequately address the impact of system autonomy in our mission architectures. Our core multi-mission autonomy architecture and testbed capabilities will address the prioritized needs and driving scenarios for the Endurance preproject, while maintaining broad applicability to other missions of strategic importance to JPL (e.g., Uranus Orbiter & Probe).

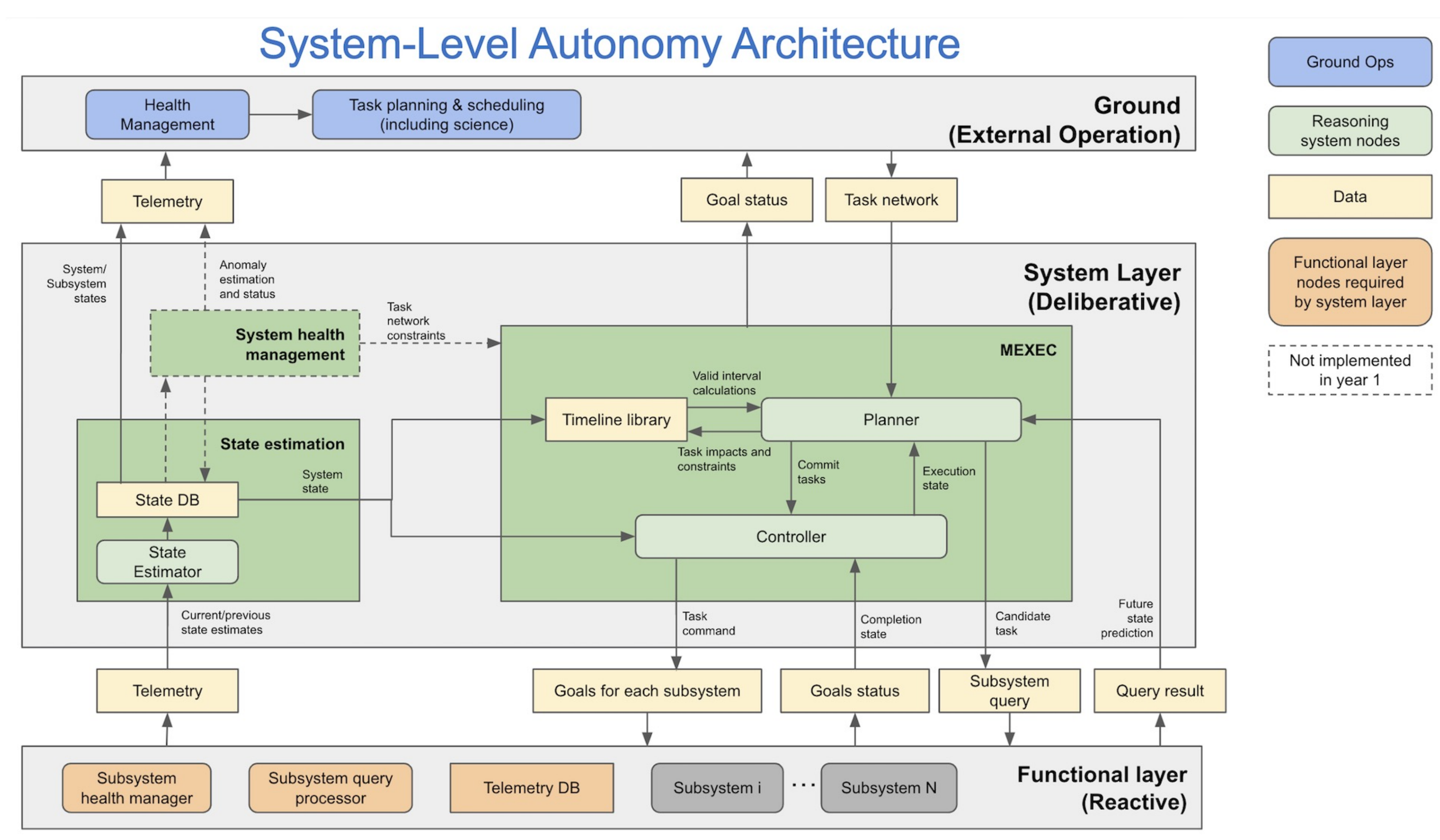

Fig. 1. System-Level Autonomy architecture diagram

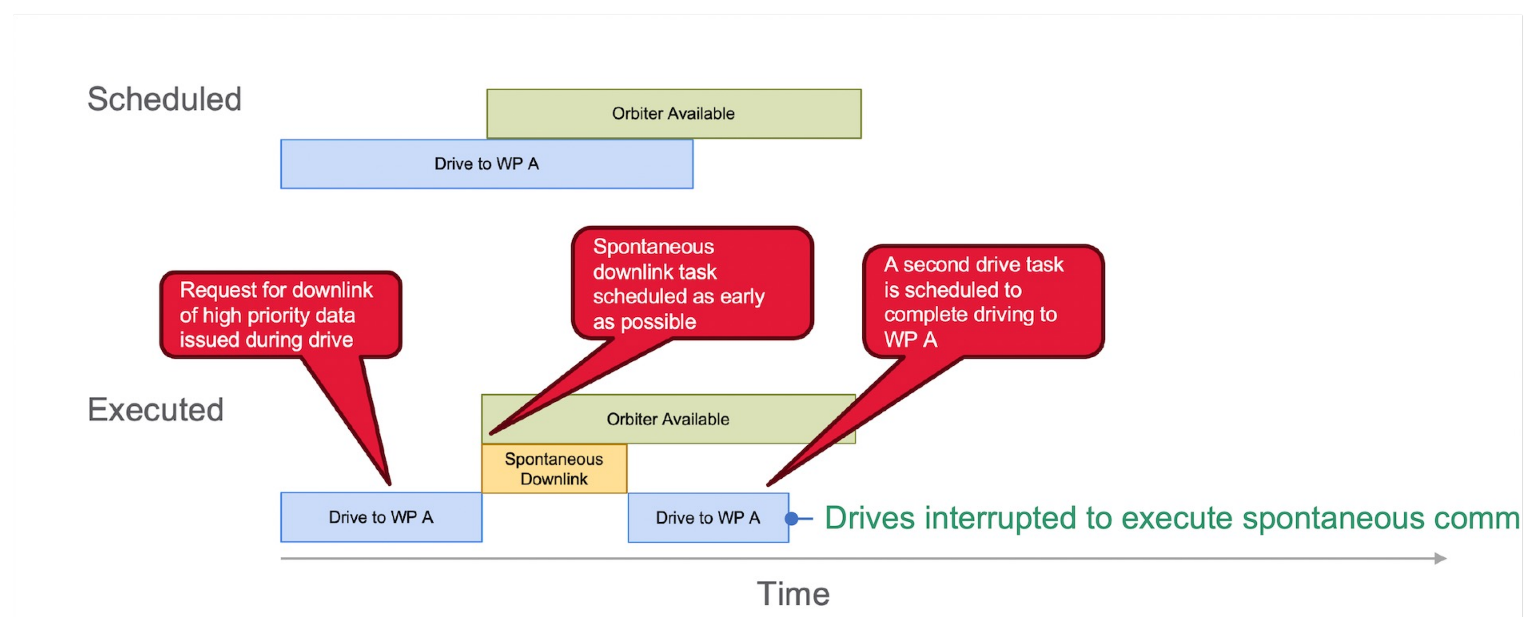

Fig. 2. MEXEC Capability: interrupting tasks in response to high-priority task

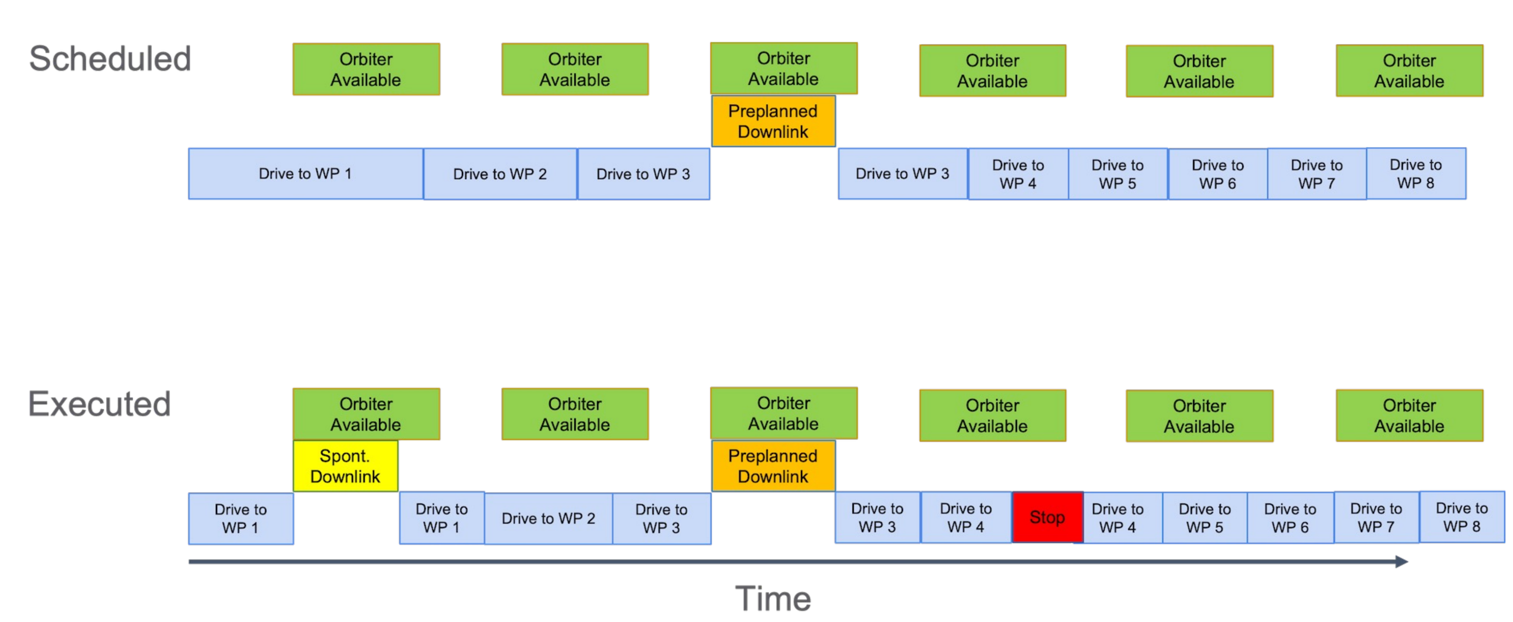

Fig. 3. End-of-year Field Test scenario (task network)

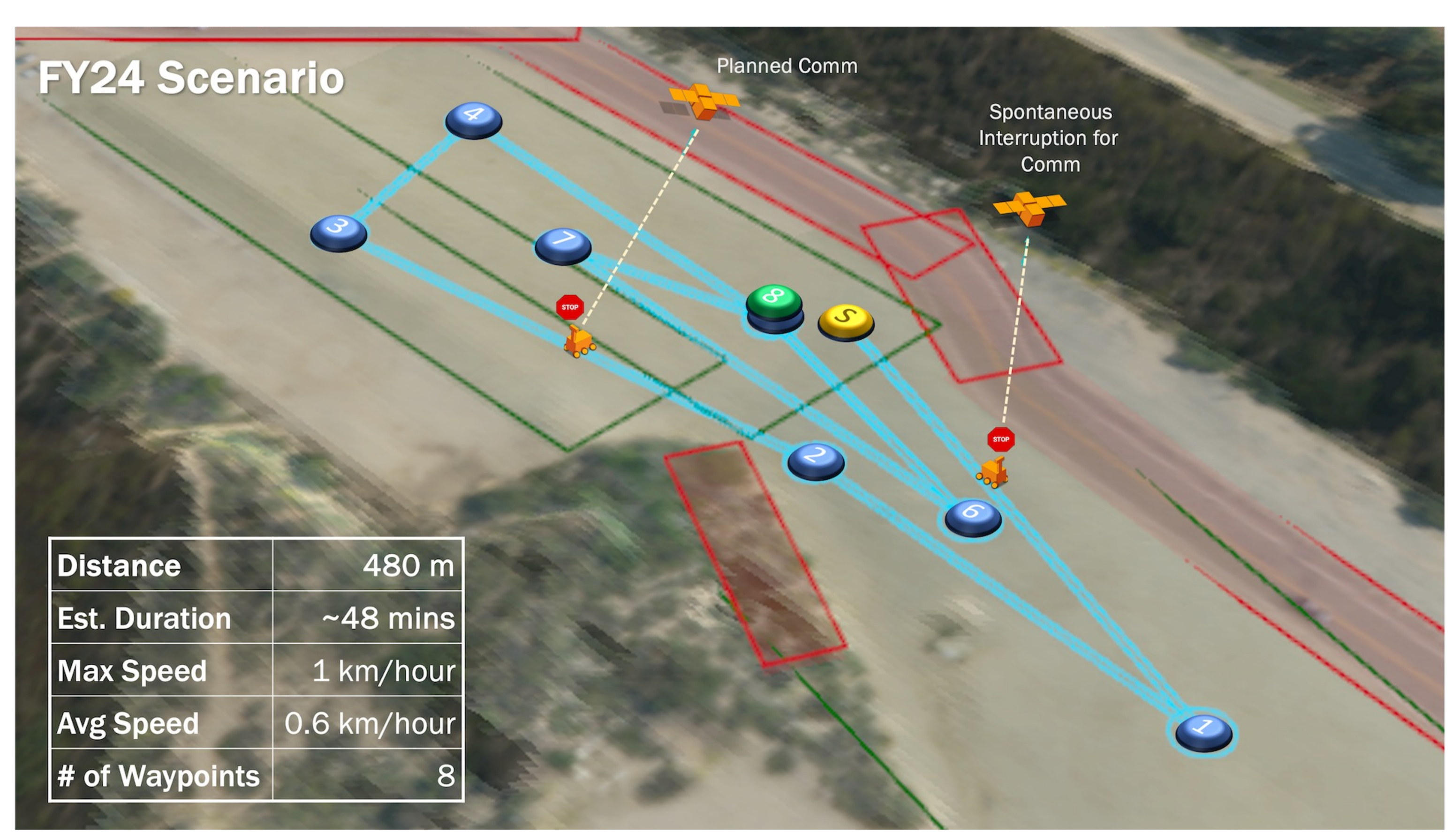

Fig. 4. End-of-year Field Test scenario

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Publications:

Ingham, M., Hasnain, Z., Amini, R., Ardito, S., Bandyopadhyay, S., Bocchino, R., Gaut, A., Mestar, L., Rabideau, G., and Rouquette, N., “Onboard planning and execution of mobility and telecommunications for the Endurance lunar rover”, Proceedings of AIAA ASCEND 2024, Las Vegas, NV, July 2024.

Bandyopadhyay, S., Gaut, A., Rouquette, N., Jain, A., Amini, R., Hasnain, Z., Goel, A., Davis, A., Elliott, J., Kornfeld, R., Nesnas, I., Ardito, S., and Ingham, M., “Endurance Mission-level Simulation Architecture for Autonomy Development”, Proceedings of AIAA ASCEND 2024, Las Vegas, NV, July 2024.

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