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2023 Technology Showcase for Future NASA Planetary Science Missions

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Submitted by:

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1. Introduction

Emergent Space Technologies, Inc. is a U.S. owned Small Business that researches, develops, integrates, tests, deploys and operates advanced systems and software for civil, military, and commercial space missions. We are industry leaders in the development of FSW (FSW) and modeling and simulation (M&S) tools for autonomous satellite systems, including constellations, clusters and formations of small satellites. Our core competencies are systems engineering, I&T, GN&C, PNT, orbital mechanics, and flight and ground software design and development.

Our expert knowledge of modular, open systems architecture (MOSA) FSW for multi-satellite missions (MSMs) derives from NASA GSFC's Formation Flying Test Bed (2004-present) and its MMS (2012-2017) and OSAM-1 (2009-present) missions; NASA ARC's Starling mission (2019-present); DARPA TTO's System F6 (2011-2014) and Blackjack Pit Boss (2019-present) programs; the SDA's Tranche 0 Tracking Layer (T0TrL) and POET mission; two classified National Security Space (NSS) cluster flight missions [CFM1 (2017-present); CFM2 (2021-present)]; a DoD Rapid Innovation Fund (RIF) contract with USSF SSC and numerous SBIR contracts.

Through these missions and technology development projects, we have gained valuable experience in many of the key technical areas relevant to NASA's future planetary science missions.

2. Technology Proposed:

2.1. Technology Description:

Our experience in FSW architecture, design, and development for technology relevant to NASA's future missions. Emergent has developed a suite of FSW applications and surrounding technology that provides enabling capabilities to many of the proposed missions, including navigation and control for spacecraft, reactive autonomous execution, faulty management, and onboard networking, storage, and distributed computation. Our applications are deployed on top of our FSW integration and infrastructure framework, Gear, that enables them to be deployed on top of different MOSAs, including NASA's Core Flight System, based on customer needs. These applications have been deployed piecemeal for different customers based on their individual mission needs, but as a suite they would provide a baseline infrastructure for future advanced mission concepts. This would enable a new paradigm for mission software development resembling smart phone applications. Apple and Google have been highly successful in selling smartphones because of their iOS and Android OS, respectively. Both have well-defined application programming interfaces (API) and kits (APK). Both have programs for certifying 3rd party applications ("apps") for deployment to their platforms. Both have on-line stores to purchase and download these apps, some for free, and install them for instant use with just a few clicks of a mouse. All of this is combined to create a thriving industry of app developers that has revolutionized mobile telecommunications and computing.

Emergent Space Technologies, Inc. (Emergent) proposes to apply similar technology and business practices applied to FSW. The challenge lies in providing the features of the smartphone without developing an entirely new, custom-built OS. The aerospace industry is growing, driven by new customer demand and fueled by the small satellite revolution and that is evident in many of the proposed concepts, but it is not consumer product-driven with hundreds of millions of customers like the smartphone industry. The infrastructure that emergent has developed provides a iOS/Android-equivalent for FSW (**Exhibit 3-1**) leveraging our Gear infrastructure and our existing FSW applications. The Emergent FSW application suite will provide the equivalent of the smartphone infrastructure and API providing reusable advanced capabilities through a defined message set. This will enable the rapid development of FSW for new mission capabilities by letting mission developers to focus on the new FSW needs of their mission as opposed to having to reengineer the capabilities that already exist within the suite.

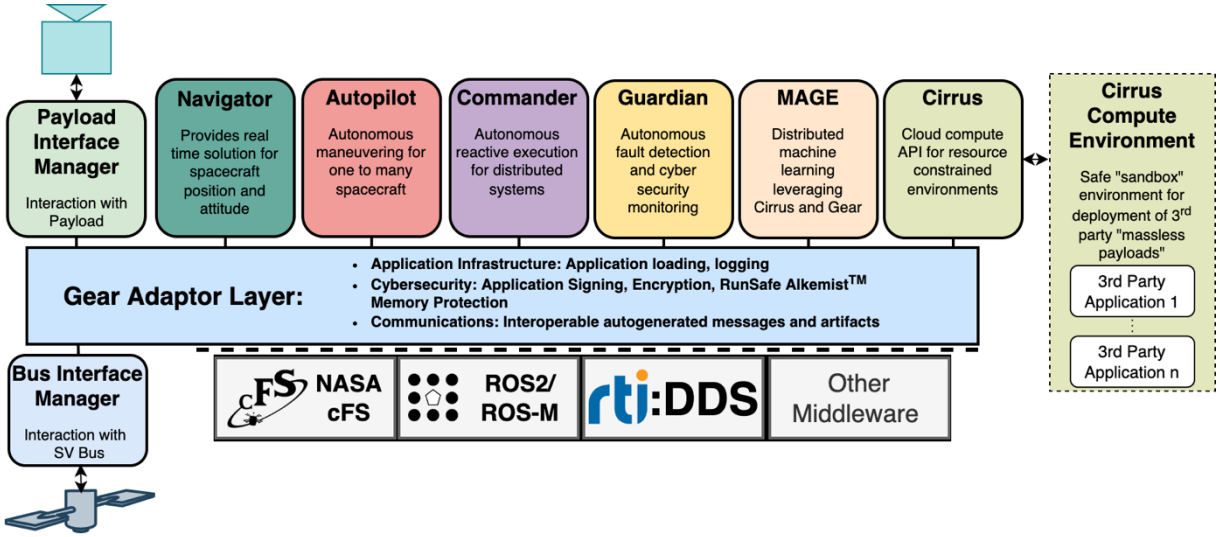

Exhibit 2-1: Emergent's Flight Software Application Suite deployed using our Gear infrastructure

2.2. Technology Readiness Level (TRL):

Emergent's different products have achieved varying levels of TRL through various contracts and missions where they have been deployed. These respective TRL and associated mission applications are described in **Exhibit 2-2.**

Exhibit 2-2: Emergent Product TRL List

Product	TRL	Customer / Mission / Project	Path-To-Market
Navigator	9	DARPA F6, NSS #1, AFRL/RV RAPID, SDA POET, SDA T0TL	Bid in various DARPA, DoD and IC proposals and awarded contracts for adaption, mission integration, test support, along with product licensing sales and follow-on support.
Autopilot	9	DARPA System F6, NSS #1, NSS #2, AFRL/RV RAPID, NASA Starling 1.5	
Guardian	9	AFRL/RV RAPID, NSS #1, NSS #2, SDA T0TL	
Commander	6[1]	AFRL/RV RAPID, NASA Starling 1.5, SDA POET	Development and integration with Starling
Cirrus	5 [2]	AFRL/RV RAPID, NSS #2, SDA T0TL	Development and integration with T1TL
Gear	8	AFRL/RV RAPID, NSS #2, SDA T0TL, Starling 1.5	Development and integration with T0TrL and NSS missions

[1] Components of Commander are currently operating in flight, but the full suite has only been demonstrated in simulation

[2] Components of Cirrus have been validated and is being integrated into a flight system, but the full suite has only been demonstrated in simulation

Ascent	9	DARPA Blackjack, AFRL/RV RAPID, NSS #1, NSS #2, USSF SSC SIAMMS, SDA T1TL, SDA POET, NASA Starling 1.0 & 1.5	Bid in proposals and awarded subcontracts for adaption, mission integration, test support, along with product licensing sales and follow-on support.
Summit	9	AFRL/RV RAPID, NSS #1, NSS #2, USSF SSC SIAMMS, SDA T1TL, NASA Starling 1.5	
GMAT Visualization	9	NASA missions, U.S. Space Rapid Capabilities Office (SpRCO)	Various NASA SBIR Phase III contracts, GSA support contracts

3. Applications to Proposed Missions:

A combination of Emergent's Navigator and Autopilot will be demonstrated on the upcoming NASA Starling mission. This mission is being funded by the Space Technology Mission Directorate and Navigator and Autopilot will be used to prove out autonomous navigation and maneuvering capabilities that will be required for future planetary science missions. Emergent's Commander has been selected to enable greater general cooperative autonomy during the Starling extended mission (Colloquially referred to as Starling 1.5). The capabilities that this suite of software has demonstrated as part of previous classified efforts and will be demonstrated for NASA Starling are highly relevant to several of the proposed missions.

Exhibit 3-1: NASA Starling Spacecraft which will Demonstrate Emergent's Autopilot and Navigator in 2023 and Commander in 2023

The challenge of "Formation flying of CubeSats at low lunar altitudes" for the SelenITA mission is the exact CONOPS the Starling demonstration is intended to pave the way for. This software suite would also be highly valuable for missions with autonomous coordinated constellation operations such as those proposed in the MACAWS and Mars-WeatherComm-Infrastructure abstracts. The proven station keeping capabilities are particularly relevant to the aerostationary orbit station keeping required for MACAWS.

NASA is also currently investing in extending the autonomy capabilities of our Commander product through a Phase II SBIR. This effort is expanding the autonomous planning capabilities of Commander and demonstrating it for applications such autonomous management and tasking of constellations around moons or planets and managing interactions with communications relays. This effort would be directly applicable to many of the proposed space based missions. It could support the tasking and management of the Titan Orbiter and the communication relay proposed in the Rideshare2OuterPlannets. Commander's framework for distributed autonomy could also be extended to support distributed rover missions such as that proposed in the The-Lunar-Geophysical-Network.

Finally, Emergent FSW infrastructure tools Gear, Cirrus, and Guardian would be broadly applicable to the FSW needs for any of the proposed missions. Gear provides reusable infrastructure for the deployment of modular FSW components and Cirrus integrates with Gear to provide networking, storage, and compute sandbox capabilities. This combined infrastructure is being deployed for the Space Development Agency as part of their Tranche 0 Tracking layer to enable the rapid development and deployment of FSW applications. This infrastructure and the associated Software Development Kit (SDK) would help the missions develop software and enable the reuse of that software for future missions. Cirrus complements Gear by adding a constrained compute environment for running software that wouldn't traditionally be safe to run in a flight environment. This facilitates concepts like running Python onboard as proposed in Mars-Stationary-Orbiter-MSO. The final infrastructure component, Guardian, provides Fault Detection Isolation and Recovery (FDIR) capabilities that have been demonstrated as part of multiple classified efforts. This FDIR capability will enable the proposed missions to autonomously detect and recover from system faults which is highly valuable for the proposed missions at outer planets with long communications delays.

4. Technology we Bring to the Showcase:

Emergent regularly builds out Software-in-the-Loop and Processor-in-the-Loop simulation capabilities for our mission development efforts. We will bring a Processor-in-the-Loop demonstration of our FSW products and modeling, simulation, and visualization capabilities, similar to what his shown in Exhibit 4-1, for scenarios relevant to the missions indicated above.

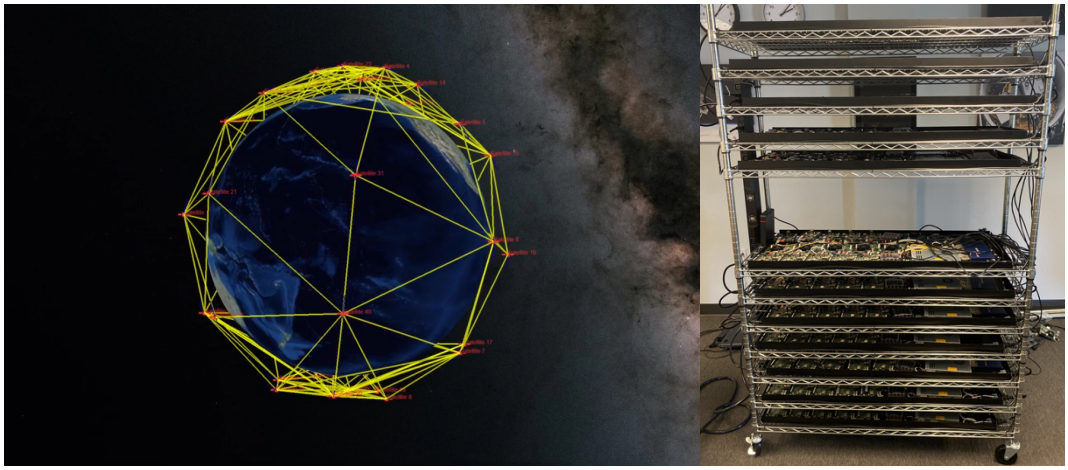

Exhibit 4-1: Examples of Emergent's Processor-in-the-Loop Simulation and Visualization for Constellations