

## **ASTRA – Autonomous Satellite Technology for Resilient Applications: A Technology Demonstrator**

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ASTRA is an on-orbit technology demonstrator establishing a new paradigm for implementing on-board “thinking.” ASTRA is a system-level autonomy capability (including digital twins, anomaly detection, diagnostics/prognostics and mission management) enabled by an innovative technology, NPAS - NASA Platform for Autonomous Systems. NPAS is developed by NASA Stennis Space Center (SSC) Autonomous Systems Laboratory (ASL) with support from NASA Exploration Systems Development Mission Directorate (ESDMD) Advanced Exploration Systems and Mars Campaign Office. ASTRA leverages NPAS for on-board “thinking” autonomy. ASTRA also includes advances in avionics required for implementing autonomy. ASTRA Flight Software (FS) is running on commercial hardware that provides the computational and memory resources required for on-board autonomous behavior and operations. ASTRA’s autonomy capability is being validated as a payload rider on-board LizzieSat-1 (LS-1), a commercial satellite launched and operated by Sidus Space. LS-1 satellite avionics includes 3 on-board processors: an SP0 processor running the LS-1 operations implemented in Core Flight Software (cFS) and two NVIDIA General-Purpose Computing Graphics Processing Unit (GPGPU) processors running Linux. One GPGPU hosts multiple payloads managed by Sidus, and the second GPGPU is dedicated to NASA SSC’s ASTRA.

ASTRA’s implementation is containerized and demonstrates a hierarchical distributed autonomy architecture. ASTRA FS includes two autonomous system managers that coordinate work to achieve mission objectives: a Vehicle System Manager and an Electrical Power System manager. In this way, ASTRA is a uniquely configured payload that can operate LS-1 when enabled. Furthermore, software uploads/updates enable ASTRA to evolve. For example, ASTRA Flight Software (FS) version 1.0 includes core capabilities required to validate communication, command, and control. Then, ASTRA FS version 2.0 is designed to monitor and manage the LS-1 onboard EPS, including load-shedding non-essential power under low power generation conditions. ASTRA FS operations are coordinated with LS-1 using NPAS’ Software Bus Network (SBN) bridge (SBN bridge enables ASTRA FS integration with LS-1 cFS applications). SBN publish/subscribe capabilities enables transmission of telemetry from LS-1 systems (e.g. power) to ASTRA, as well enabling ASTRA commands to change satellite EPS onboard state. Data flow from LS-1 to ASTRA includes ground operations performed at the ASTRA ASL Payload Operations Command Center (POCC). First, LS-1 data is transmitted to Sidus Mission Command Center (MCC) via ground stations Sidus leases daily from commercial providers. Then, prescribed telemetry stream(s) are transmitted from LS-1 to Sidus MCC. Finally, all data collected at Sidus’s MCC is pushed (encrypted) to the SSC ASL POCC via UDP connection. Telemetry data is streamed immediately to ASTRA POCC during each successful LS-1 communication pass. Throughout the LS-1 mission, ASTRA, in addition to autonomous operations, represents a dual testbed for NASA SSC’s ASL: (1) on-board the LS-1 satellite on-orbit and (2) on the ground using flight telemetry, processed through a flight equivalent engineering unit. The ASTRA FS technology demonstrator on-orbit has the potential to enable development, test, and validation of autonomous operations on-orbit (e.g. satellites, spacecraft) and autonomy capabilities required for future Moon-to-Mars missions.