## Project Introduction

Autonomous operations are critical for the success, safety and crew survival of NASA deep space missions beyond low Earth orbit, including Gateway. For the past 10 years, Stennis Space Center (SSC) has been developing, and has demonstrated an innovative software platform, along with expertise and processes for implementation of autonomous operations.

The current version is called NASA Platform for Autonomous Systems (NPAS). NPAS is developed using the G2 platform - a COTS product (a MIT derivative). NPAS provides the foundational technology and processes to evolve from traditional "Brute-Force Autonomy" (BFA) towards innovative "Thinking Autonomy" (TA). NPAS applications encompass comprehensive SysML-like live-models that permit model-based real-time analysis and operations. NPAS uniquely extends the paradigm of model-based systems engineering (MBSE) beyond static models, into live models for real-time thinking autonomous operations that can be rapidly and affordably implemented, deployed, re-used and evolved.

NPAS supports the concept that achieving autonomous operations, beyond developing algorithms for dealing with specific cases that warrant an autonomous response (or reaction), must address implementing strategies for autonomy that are guided by combination of requirements that include, policy, operations procedures, mission objectives. In this context, an autonomous system makes the best use of available resources to achieve the specified mission.

NPAS uniquely addresses autonomous operation requirements and integrates primary functionalities including: (1) autonomy strategies based on concepts of operation, while taking advantage of system attributes such as redundancy, and persistence strategies such as repeating commands; (2) Integrated System Health Management (ISHM) strategies, for anomaly detection, diagnostics and effects (FMEA), prognostics, and comprehensive awareness; (3) object libraries and infrastructure to create knowledge models of applications (reusable); and (4) infrastructure to create mission operations encompassing plans, schedules, and sequences.

A primary goal of the current NPAS project is to integrate with other Advanced Exploration Systems (AES)/HEOMD projects at Johnson Space Center's (JSC's) Integrated Power Avionics and Software (iPAS) "habitat" test article. NPAS was used to demonstrate a deep space autonomous habitat operation, exhibiting integrated hierarchical distributed autonomy capability, encompassing 3 autonomous systems (vehicle manager, power, and avionics). The demonstration addressed autonomous nominal and off-nominal operations and responses taken jointly by multiple subsystems to mitigate anomaly effects (from flight computers and the power system) on the mission objectives. NPAS was also used to develop graphical user interfaces (GUI's) for autonomy and shared-autonomy operations. Each NPAS application ran from a networked



NASA Platform for Autonomous Systems

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single-board computer.

For this project, the NPAS, and corresponding engineering processes, rapidly achieved implementationof intelligent distributed autonomy encompassing subsystems of a reference space habitat module application, and validated NPAS as an efficient, cost-effective, integrated, and unique autonomous operation software capability.

Currently, NPAS includes autonomy strategies, ISHM strategies and libraries of system elements for electrical, mechanical, computer, and communications applications that can be used for a wide range of implementations

NPAS represents an innovative approach and technology to rapidly implement and deploy intelligent/thinking autonomous operations. NPAS encompasses tools for creating an integrated autonomy solution: comprehensive (real-time) operational knowledge models (beyond the comprehensiveness of SysML models) –capturing digital twin/digital thread information, health assessment, diagnostics, anomaly detection (FMEA), autonomous operational strategies, mission plan scheduling and execution.

## Anticipated Benefits

NPAS software is being cultivated as a paradigm shift in the way NASA develops autonomous operation software that will enable cost effective, comprehensive, "thinking", and evolutionary autonomy for future space and ground systems.

NPAS has reusable core capabilities

- Leverageable – system elements and modelling code applies to a wide range of system applications (reusable)
- Sustainable (modular, knowledge-base that enables systematic changes, inherent integration that is maintained throughout the life cycle of NPAS applications).
- Scalable within each autonomous application and across networked distributed autonomous applications
- Affordable – long term cost savings
- Reduced delivery time
- Evolvable

NPAS has cross-cutting relevance for autonomy across multiple applications, including ground test and launch systems, space systems, satellite systems, Deep Space Network, aeronautics, and science. NPAS software developers are targeting NPAS implementation processes to meet NASA Advanced Exploration System's (AES's) current avionics architecture requirements for Deep Space Gateway, Deep Space Transport and space habitat modules.

## Organizational Responsibility

**Responsible Mission Directorate:**

Human Exploration and Operations Mission Directorate (HEOMD)

**Lead Center / Facility:**

Stennis Space Center (SSC)

**Responsible Program:**

Advanced Exploration Systems Division

## Project Management

**Program Director:**

Christopher L Moore

**Project Manager:**

Lauren W Underwood

**Principal Investigator:**

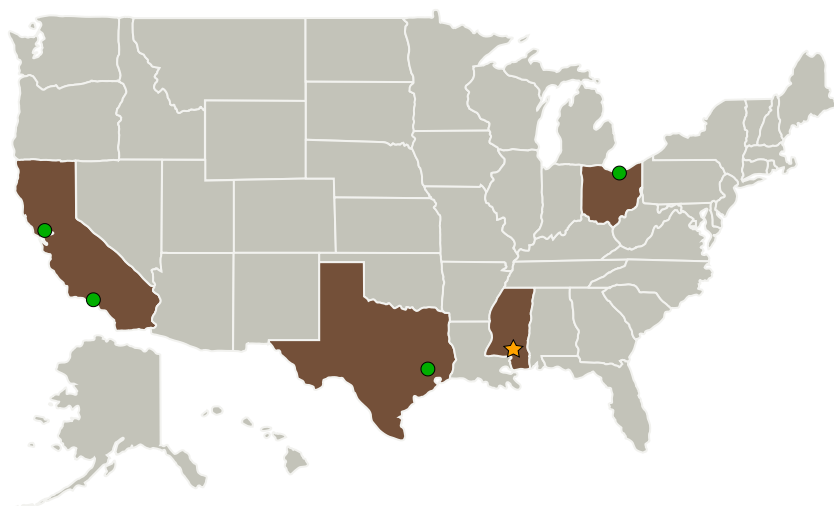Fernando Figueroa

**Co-Investigators:**

Mark Walker
Jonathan A Morris

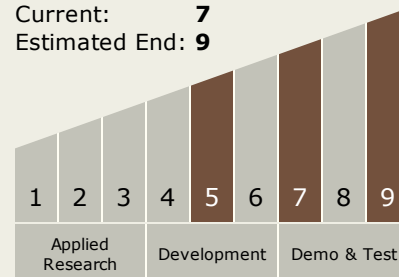## Primary U.S. Work Locations and Key Partners



| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| ⭐ Stennis Space Center(SSC) | Lead Organization | NASA Center | Stennis Space Center, MS |
| 🟢 Ames Research Center(ARC) | Supporting Organization | NASA Center | Mountain View, CA |
| 🟢 Glenn Research Center(GRC) | Supporting Organization | NASA Center | Cleveland, OH |
| 🟢 Jet Propulsion Laboratory(JPL) | Supporting Organization | NASA Center | Pasadena, CA |
| 🟢 Johnson Space Center(JSC) | Supporting Organization | NASA Center | Houston, TX |

## Technology Maturity (TRL)

Start: **5**
Current: **7**
Estimated End: **9**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Applied Research | | | Development | | | Demo & Test | | |

## Technology Areas

**Primary:**

- Robotics and Autonomous Systems (TA 4)

**Other/Cross-cutting:**

- Human Health, Life Support, and Habitation Systems (TA 6)
- Human Exploration Destination Systems (TA 7)
- Ground and Launch Systems (TA 13)

## Target Destinations

Earth, The Moon, Mars

## Supported Mission Type

Planned Mission (Pull)

| Co-Funding Partners | Type | Location |
|---|---|---|
| Office of the Chief Technologist(OCT) | NASA Office | |
| Space Technology Mission Directorate(STMD) | NASA Mission Directorate | |

| Primary U.S. Work Locations | |
|---|---|
| California | Mississippi |
| Ohio | Texas |

## Images



**Autonomous Systems Lab**
SSC Autonomous Systems Lab



**NPAS**
NASA Platform for Autonomous Systems



**NPAS Functional Architecture**
NPAS functional architecture overview

**NPAS Roadmap**
NPAS Roadmap - autonomous operation from ground to space applications

## Links

SSC Autonomous Systems Lab
*(https://technology.ssc.nasa.gov/techdev/autonomous-systems/autonomous-systems-lab.asp)*

SSC Partnership - G2 for Spaceflight Computers
*(https://technology.ssc.nasa.gov/techdev/autonomous-systems/autonomous-systems-lab.asp)*

## Project Website:

https://technology.ssc.nasa.gov/techdev/autonomous-systems/npas.asp