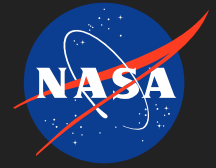


NASA Platform for Autonomous Systems (NPAS)

Active Technology Project (2016 - 2020)



Project Introduction

Autonomous operations are critical for the success, safety and crew survival of NASA deep space missions beyond low Earth orbit, including Gateway and Artemis. Future human spaceflight missions will consist of crewed and uncrewed spacecraft that will involve travel to distances beyond LEO, for significant extended periods of time, with limited to no communication with Earth. These facts introduce complex requirements and challenges associated with autonomous operations, which affect both human life as well as the health and life of the spacecraft. For the past 10 years, Stennis Space Center (SSC) has been developing and evolving 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). The main goal with NPAS is to enable reusable implementation of distributed hierarchical autonomous operations foundational capabilities in support of a Gateway and Artemis Program objectives. NPAS is developed using the G2 platform - a COTS product (a MIT derivative). NPAS provides the foundational technology and processes to affect a paradigm change 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, concepts of operations, and mission objectives. In this context, an autonomous system makes the best use of available resources to achieve the specified mission.

NPAS uniquely addresses and integrates primary functionalities for creating an integrated autonomy solution including: (1) autonomy strategies based on concepts of operation, while taking advantage of system attributes such as redundancy, persistence strategies such as repeating commands, and others; as well as comprehensive (real-time) operational knowledge models (beyond the comprehensiveness of SysML models) -capturing digital twin/digital thread information; (2) Integrated System Health Management (ISHM) strategies, for health assessment, anomaly detection, diagnostics and effects (FMEA), prognostics, and comprehensive awareness; (3) object libraries and infrastructure of system elements for electrical, mechanical, computer, and communications applications that can be used for a wide range of implementations to create knowledge models of applications (reusable); (4) infrastructure to create mission operations encompassing plans, schedules,



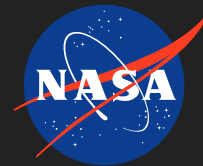
NASA Platform for Autonomous Systems

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execution and sequences; and (5) infrastructure to develop user interfaces providing comprehensive awareness for users, developers, and management. NPAS represents an innovative approach and technology to rapidly implement and deploy intelligent/thinking autonomous operations.

For FY20, NPAS, will leverage the integrated hierarchical distributed autonomy capability developed in FY19. For these FY19 projects, the NPAS, and corresponding engineering processes, rapidly achieved implementation of intelligent distributed autonomy encompassing a capability that is consistent with the current concepts of operations associated with Gateway.

NPAS top level project goal objectives includes the following activities:

- Advancing G2 autonomy software for cFS integration capabilities (G2 SBN Bridge) – Cooperative Agreement with Commercial Partner (Ignite Technologies)
 - NPAS will continue to develop integrated solution for NPAS/G2 and Core Flight Software (CFS) over the Software Bus Network (SBN) application. This solution involves a custom lightweight application (SBN Bridge), which will work as a middleware between NPAS/G2 and CFS applications running on the same or any other hardware connected via network. Demonstrate NPAS/G2 SBN Bridge seamless integration with CFS core Gateway applications
- Demonstrate NPAS/G2 SBN Bridge functionality and integration
 - Continued flight-like hardware integration for both NPAS and G2 SBN Bridge;
 - Port NPAS/G2 SBN Bridge to space flight computing processor
- Work with MSFC Engineering Process Group (EPG) to perform initial gap analysis for NPAS, and provide engineering process training to include, but not limited to CMMI (specifically associated with Level 3 rating).
 - NPAS will partner with MSFC EPG, leveraging EPG expertise in engineering processes to develop and define Software Process Improvement tasks for NPAS to advance from Class C to Class A, Safety Critical software.
 - Implement software process improvement, provide process improvement schedule, and conduct gap analysis for transitioning NPAS from Class C to Class A Safety Critical Software (meeting CMMI Dev 2.0 requirements for flight software)

Continued on following page.

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

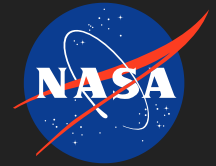
Co-Investigators:

Mark Walker

Jonathan A Morris

NASA Platform for Autonomous Systems (NPAS)

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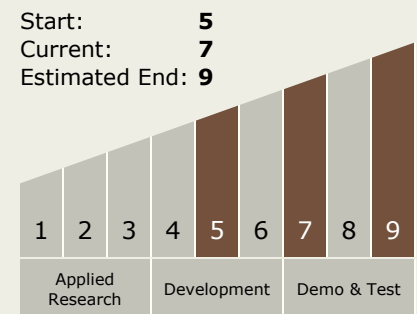
- Support autonomous avionics risk reduction test activities that include demonstrating an NPAS VSM, MSM, and SM for a prototype Gateway module
 - Autonomous Avionics Risk Reduction Activities - a developmental project focused on autonomous avionics for deep space human exploration. This activity is being implemented through a Space Act Agreement in combination with a Lockheed Martin Internal Research and Development effort to elevate the maturity of autonomy via command, control, and fault management for Artemis missions at the Gateway.
 - This activity also supports the NPAS project efforts to demonstrate a distributed hierarchical autonomy implementation for potential use in Gateway and other elements of the Artemis missions as an efficient, cost-effective, integrated, and unique autonomy software capability
 - Rapidly evolve and validate NPAS (advance TRL) as a platform for intelligent distributed hierarchical autonomy capability as a Gateway Vehicle System Manager (VSM)-lite, (Module System Manager) MSM-lite, and system manager (SM) for a prototype for space habitat module including demonstrating integration with VSM.
 - Coordinate NPAS MSM implementation with Gateway autonomy Interface Control Documents (ICDs), Flight Software Con-Ops, and requirements
- AES FY21 Moon to Mars eXploration Systems and Habitation (X-Hab) Academic Innovation Challenge
 - Proposal Title: Voice Interaction Management of Gateway, included as a project for RFP <https://spacegrant.org/wp-content/uploads/2020/02/M2M-X-Hab-Challenge-Solicitation-2021.pdf>

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

Technology Maturity (TRL)



Technology Areas

Primary:

- TX10 Autonomous Systems
 - └ TX10.3 Collaboration and Interaction
 - └ TX10.3.3 Goal and Task Negotiation

Target Destinations

Earth, The Moon, Mars

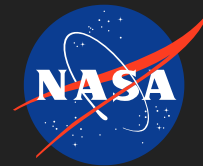
Supported Mission

Type

Planned Mission (Pull)

NASA Platform for Autonomous Systems (NPAS)

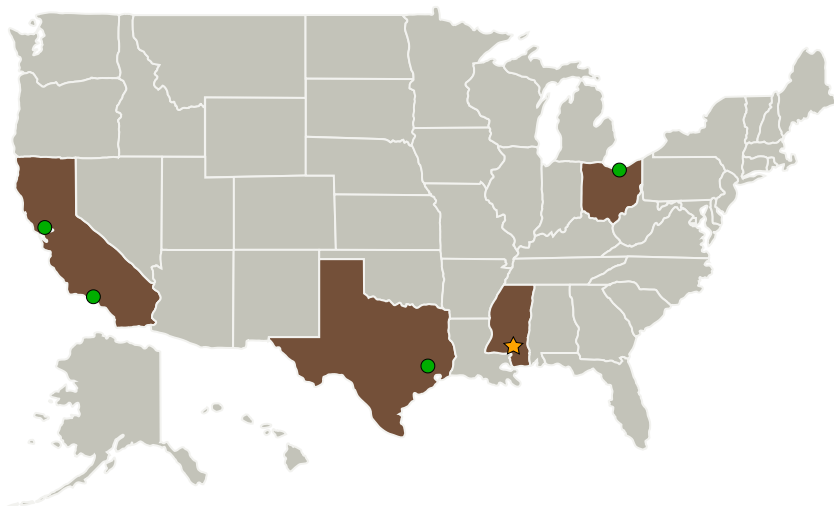
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- Leverageable – system elements and modelling code applies to a wide range of system applications (reusable)
- Sustainable (modular, knowledge-base that enables systematic changes, inherent integration that is maintained throughout the life cycle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

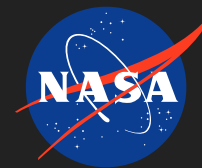
NPAS has cross-cutting relevance for autonomy across multiple applications, including ground test and launch systems, space systems, Lunar and Mars surface systems, In-Situ Resource Utilization (ISRU), satellite systems, Deep Space Network, aeronautics, and science. NPAS software developers are targeting NPAS implementation processes to meet NASA AES's current avionics architecture requirements for Gateway, Artemis and space habitat modules, and continue to provide benefit to commercial space industry partners.

Primary U.S. Work Locations and Key Partners



NASA Platform for Autonomous Systems (NPAS)

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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	Moffett Field, 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

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

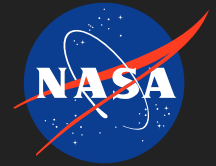
Primary U.S. Work Locations	
California	Mississippi
Ohio	Texas

Images

**Autonomous Systems Lab**

SSC Autonomous Systems Lab

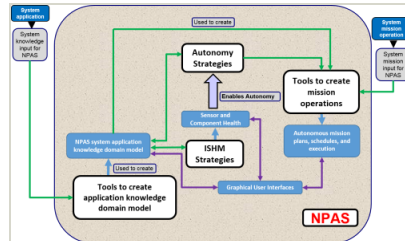
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NPAS

NASA Platform for Autonomous Systems

(<https://techport.nasa.gov/image/39649>)



NPAS Functional Architecture

NPAS functional architecture overview

(<https://techport.nasa.gov/image/39646>)



NPAS Roadmap

NPAS Roadmap - autonomous operation from ground to space applications

(<https://techport.nasa.gov/image/39645>)

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>