Completed Project (2011 - 2014)

Autonomous Systems: Autonomous Cryogenic Loading Operations Project

Game Changing Development Program | Space Technology Mission Directorate (STMD)

ABSTRACT

Multi-center team will develop and demonstrate new, state-of-the-art control architecture that enables next generation of health management techniques, intelligent devices and autonomous control technologies to perform autonomous control of a cryogenic propellant loading system.

ANTICIPATED BENEFITS

To NASA funded missions:

Reduces the dependance on a large workforce to conduct system operations by automating and integrating the fault diagnosis, isolation and recovery functions with a supervisory control function. Increases availability of cryogenic systems to support operations. Enables reduced development, operations and maintenance costs.

To NASA unfunded & planned missions:

Enables variable levels of autonomy and supports objectives to rapidly adapt to and supportoperations for multiple system and subsytem architectures in both ground and a microgravity environments.

DETAILED DESCRIPTION

The main objectives are to develop and integrate Integrated Systems Health Management (ISHM) tools and component technologies into a seamless health management architecture and to create an autonomous cryogenic loading capability. ACLO components will be developed for mission-relevant cryogenic platforms/environment (i.e., ground-based and micro-g in-space capability) and demonstrated against the KSC Cryogenic Test Facility's Simulated Propellant Loading System, a.k.a, the Cryogenic Testbed. The autonomous cryogenic loading capability and component technologies developed under the ACLO Project Element will be used to help mature concepts

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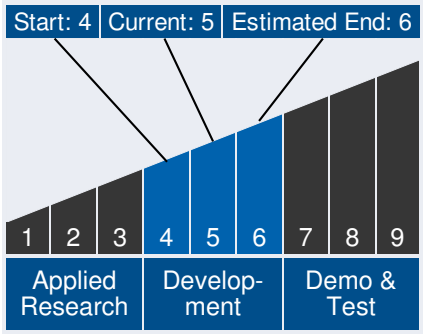
Technology Maturity



Management Team

Program Executive:

- Ryan Stephan

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for variable levels of autonomy and will enable NASA to rapidly adapt to and support various launch concepts with multiple vehicle types in a multi-use launch pad or an in-space environment. The ACLO Project Element will continue to build on capabilities and concepts developed and/or demonstrated in FY13 under ACLO and previous ground autonomy and health management efforts: Systems Autonomy Demonstration Program: Knowledge-based Autonomous Test Engineer (KATE), which proved the feasibility of using high-fidelity physics models and simulations to enable integrated system health, status and control for autonomous tank loading operations Constellation pathfinder demonstrations and trade studies: Ares I-X Ground Diagnostic Prototype & Fault Detection, Isolation and Recovery Architecture Prototype, which developed a certifiable configuration and approach for integrated health management for ground and launch operations AFRL Future Responsive Access to Space Technologies Program: Rapid Propellant Loading Project, which developed concepts for distributed launch operations and cryogenic loading operations using KATE and the Hybrid Diagnostic Engine

Management Team *(cont.)*

Program Manager:
- Stephen Gaddis

Project Manager:
- Barbara Brown

Principal Investigator:
- Robert Ambrose

Technology Areas

Primary Technology Area:
Ground and Launch Systems (TA 13)
- Operational Life-Cycle (TA 13.1)
  - On-Site Production, Storage, Distribution, and Conservation of Fluids (TA 13.1.1)
    - Higher-Efficiency Transfer of Cryogens Using Active Means (TA 13.1.1.5)

Secondary Technology Area:
Robotics and Autonomous Systems (TA 4)
- System-Level Autonomy (TA 4.5)

Ground and Launch Systems (TA 13)

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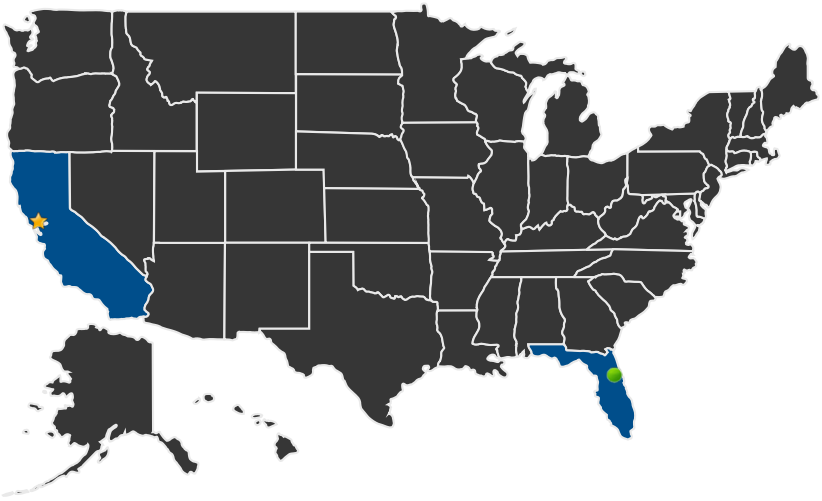
U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Ames Research Center

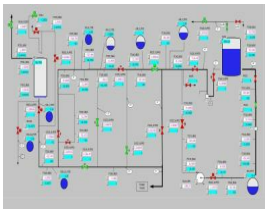
Supporting Centers:

- Kennedy Space Center

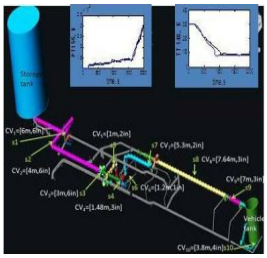
Other Organizations Performing Work:

- ABACUS / ITSS
- Stinger Ghaffarian Technologies (SGT)

IMAGE GALLERY



KATE Display of Cryogenic Testbed



Physics Model of Cryogenics Test Bed

Technology Areas *(cont.)*

Thermal Management Systems (TA 14)
- Thermal Protection Systems (TA 14.3)
  - Ascent/Entry TPS (TA 14.3.1)
    - Self-Repairing Thermal Protection System Materials (TA 14.3.1.6)

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DETAILS FOR TECHNOLOGY 1

Technology Title

Autonomous control software for cryogenic loading operations

Technology Description

This technology is categorized as complex electronics software for engineering, design, modeling, or analysis

The health management capability will identify conditions representing current or impending failure/degradation and will both automatically and autonomously try to overcome these problems through reconfiguration, bypassing failed components or redefining control points.

Capabilities Provided

High-fidelity, 2-phase flow model and physics-based simulation of the Simulation Propellant Loading System at KSC's Cryogenics Test bed Laboratory.

C++ version of the autonomous control software system, called the Knowledge-based Autonomous Test Engineer (KATE).

Potential Applications

Diagnostics and autonomous control for ground or migro-g cryogenic systems. The capability can also be applied to other electro-mechanical or fluid systems (HVAC, power, etc.)

Performance Metrics

Metric	Unit	Quantity
Percentage of fault modes covered	%	75
Percentage of known fault modes for which intended system function can be maintained or restored	%	30
Percentage of faults detected and correctly isolated	%	80