



# Framework for System-Level Autonomy

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**Jet Propulsion Laboratory**  
California Institute of Technology

# Changing How We Look At Autonomy

*3 years and ~\$3M to change the way we look at spacecraft*



Mission Architecture

Defining components

Design requirements

Systems Engineering

Tasknet Definition

V&V

Tasknet Development

Operations

**Autonomy represents a paradigm shift in how spacecraft are designed, built, and operated. Adopting autonomy will require evaluating these aspects – not just writing the software.**



# A Flexible Framework for Autonomy

*A framework requires many components to come together*

## “Tasknet” Framework

Planning & Execution

MEXEC

On-Board Fault Diagnosis

MONSID

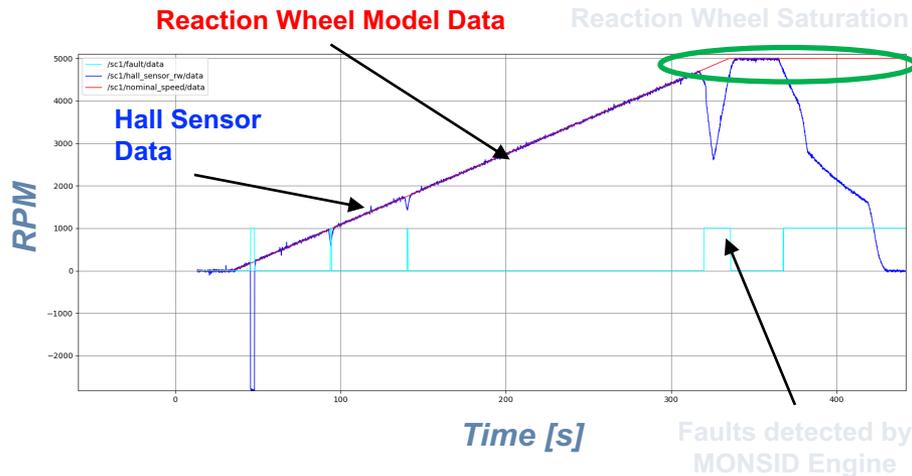
FSW Framework

F Prime  
ROS

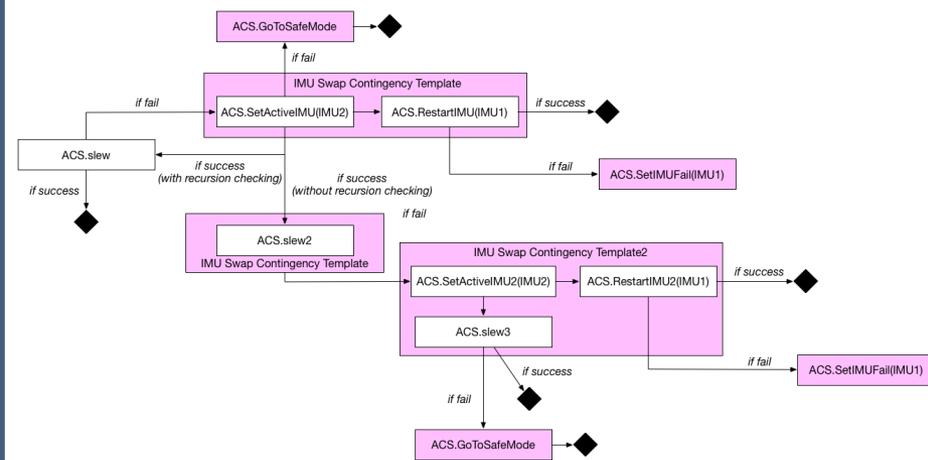
Tools

Autonav (on-board)  
Tasknet Development  
Validation & Verification

### CAST integration of MONSID with RWA (S. Lupu)

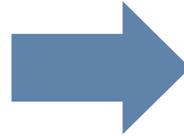


### Theoretical Study of Contingencies for IMU Failure

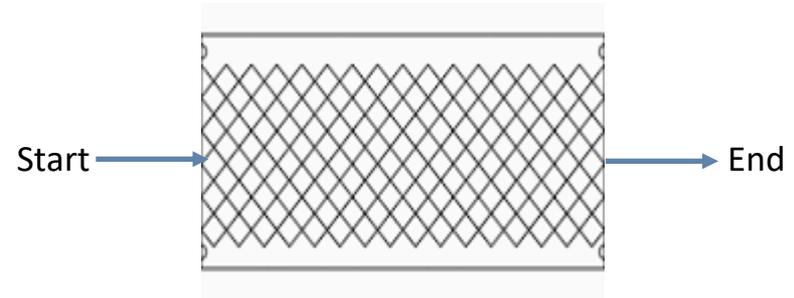


# What Are Tasknets?

*Sequences are fragile*



*Tasknets are robust*



- Sequences provide one execution path and do not provide flexibility to respond to current conditions. Unexpected events stop the sequence.
- Task-level commanding enables the space asset to determine order and timing of activities based on current conditions – traversing a net to achieve successful path
- Tasknets check preconditions and postconditions of tasks and enable simpler commanding and more robust on-board execution.
- Contingencies and other functions offer the spacecraft multiple approaches to maintain and restore nominal operations.

# Building Confidence in Autonomy

## Demos

- **In space!**
  - ASTERIA operations
- **In CAST**
  - On-board fault diagnosis with hardware
  - MEXEC-ROS integration
  - Docking
- **In DARTS environment**
  - Fundamental behaviors
  - Autonav/orbit determination
  - Nominal science operations
  - Off-Nominal science operations
- **In “paper” environment**
  - Existing and future mission operations

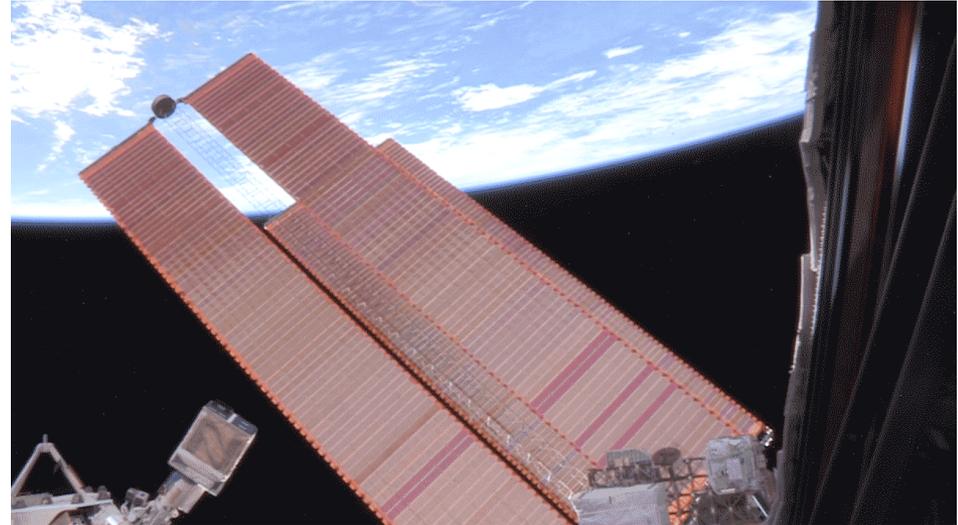
## Products

- **Framework Compliance Best Principles**
- **Framework requirements document (DOORS)**
- **MEXEC-ROS distribution**
- **Ground Tooling**
  - Ground tool
  - V&V
  - Domain-specific languages

# Flying Autonomy on ASTERIA

## *Arcsecond Space Telescope Enabling Research In Astrophysics*

- 6U CubeSat built, tested, operated by JPL
- Collaboration with MIT's Sara Seager, PI
- Demonstrated pointing stability of  $<0.5$  arcseconds RMS over 20 minutes
- Demonstrated pointing repeatability of 1 milliarcsecond RMS from orbit to orbit
- Demonstrated focal plane thermal stability of  $\pm 0.01$  K over 20 minutes



### ASTERIA Demo Goals

- Demonstrate onboard orbit determination in Low Earth Orbit (LEO) using autonomous navigation (Autonav) without GPS.
- Demonstrate a fully independent means of spacecraft orbit determination for Earth orbiters with only passive imaging using ASTERIA camera.
- Enable future missions to navigate in GPS-denied environments and with a more robust sensor suite.
- **Learn lessons to close the experience-development loop for autonomy!**

# Collaborating for Success

NASA JPL

- Framework theory
- ASTERIA
- MEXEC
- F Prime
- Autonav
- DARTS/Paper demos
- Ground Tool
- Tasknet V&V

Caltech CAST

- **Hardware demos**
- **MONSID**  
integration
- **MEXEC-ROS**  
integration

Okean  
Solutions

- **MONSID**
- **FSW Development**

*CAST provides JPL an excellent venue for hardware demonstration and immediate outreach to academic autonomy work*





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