Recent JPL Results Supporting Automation of Ground and Flight Systems

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EXTENDED ABSTRACT

Introduction

This paper will survey three software systems in development at JPL which are the product of many years of research and development in artificial intelligence and related disciplines. These systems each provide a framework for automation of ground data systems in the Deep Space Network and spacecraft autonomy.

Mission Data System

To address the challenge of designing reliable software that will expand mission capabilities, support autonomy, and be reused in effect mission scenarios, JPL initiated the Mission Data System (MDS) project. The objective of the project was to rethink the mission software life cycle and to develop software architectures that accommodate the complexities of future mission requirements.

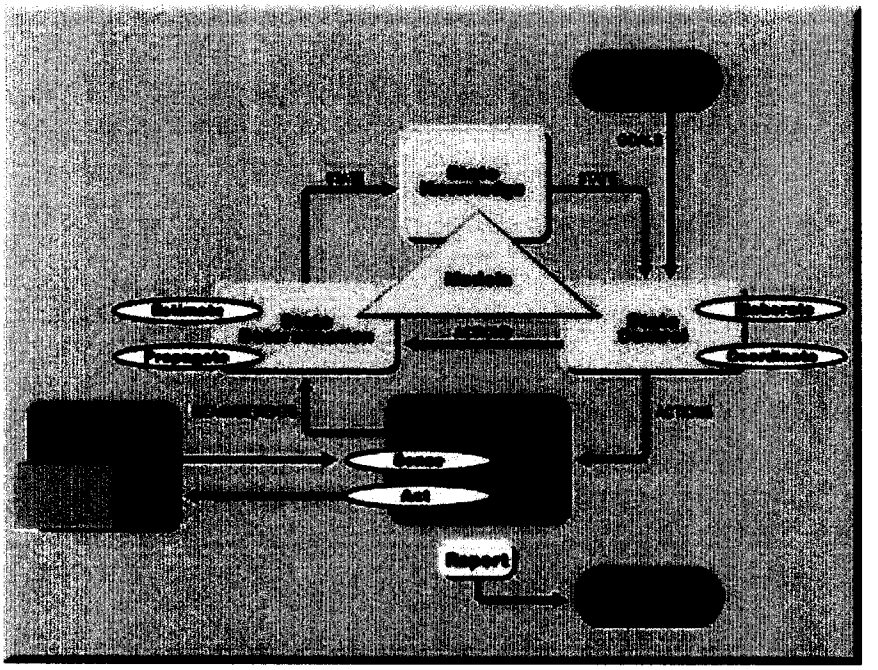

Figure 1: Generalized MDS Architecture

The project has produced a unified flight, ground, and test data system architecure that is revolutionary in scope and vision. It is a component-based, object-oriented design that assimilates and codifies years of JPL's domain knowledge in the areas of spacecraft and ground software.

The MDS core product is a unified architectural framework for building end-to-end flight and ground software systems. This framework includes the necessary elements for building goal-oriented, autonomous commanding; intelligent data management and transport, integrated guidance, navigation , and control, and most other capabilities needed for mission software. Design patterns provided with MDS enable adaptation of the framework for mission-specific software functions.

Fault Diagnostics and Prognostics for the DSN

An on-going objective of research and technology development at JPL is the creation of a framework of automated tools and techniques for reducing operational and maintenance costs in the NASA's Deep Space Network (DSN). A recent product of this research has been a demonstration of fault diagnostics and prognostics for ground systems during DSN tracking operations, specifically, the new DSN Full Spectrum Processing Array configuration located at the Goldstone Deep Space Communications Complex (GDSCC).

The demonstration was based on a Fault Detection and Isolation (FDI) framework developed at JPL that provides a DSN-compatible infrastructure for seamless integration of heterogeneous, intelligent tools for the purpose of DSN FDI analysis. For this demonstration, the framework was integrated with the DSN's new Network Monitor and Control Subsystem.

The resulting system integrated two mature JPL-developed tools, Beacon-based Exception Analysis for Multi-missions (BEAM) and Spacecraft Health Inference Engine (SHINE). BEAM is used as a highly advanced prognostic state estimator and SHINE is being used for hard real-time diagnostics and interpretation of the system state output by BEAM. These technologies provide new insights into system visibility that were not previously possible using channel-based diagnostics techniques. The integrated systems enable raw sensor data and software-derived data to be simultaneously fused in real-time. This automatically abstracts system physics and information invariants (constants). This enables the system to be ultra-sensitive to degradation and changes, and to isolate significant events in both time and space to specific sensors.

The full paper will include an overview of the BEAM and SHINE technology, and a discussion of the results of this demonstration.

Autonomous Ground Station Controller

The Deep Space Station Controller (DSSC) is a state of the art ground station control architecture being develop at the Jet Propulsion Laboratory (JPL). The DSSC has been designed for robust closed loop control of ground communication stations utilized for communications with and commanding of NASA's deep space exploration missions.

The operation of the DSN is a very difficult task due to the extreme sensitivity of the equipment, the volume of data collected, the number of missions operated, and the frequency of service that must be provided. In an attempt to reduce cost and increase operations reliability, the DSN has looked towards automation.

The new Deep Space Station Controller (DSSC) architecture under research and development is designed to be modular and extendable. While initially this architecture is being considered for station controller, it has been designed so that the same architecture and much of the same code can be used as a complex controller and as a sub-system controller. This general-purpose solution is being referred to as the Common Automation Engine (CAE).

The DSSC/CAE is built around two powerful state of the art technologies developed at JPL. CLEaR (Closed Loop Execution and Recovery) is a reasoning and controlling component used for selecting, executing and monitoring commands as well as re-planning recovery scenarios. The second is the fault detection and isolation (FDI) framework presented earlier in the discussion of diagnostics and prognostics demonstration for the DSN Full Spectrum Processing Array. Recall, this framework integrates the Beacon-based Exception Analysis for Multi-missions (BEAM) and Spacecraft Health Inference Engine (SHINE).

The full paper will provide an overview of the DSSC/CAE architecture being developed for the Deep Space Station Controller to provide ground communication antenna station automation for NASA's Deep Space Network. The paper will also include a presentation of CLEaR as well as how the component intelligent systems fit together in the solution of a general purpose software controller for autonomous operations in a number of domains.

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