Session 2302

Satellite Artificial Intelligence Lab

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Abstract

The Spacecraft Artificial Intelligence Laboratory (SAIL) is a joint Navy / NASA / Industry/ Academia research and development project which uses existing facilities in the Department of Aerospace Engineering at the U.S. Naval Academy (USNA). The goals of the project are to test and evaluate automation and machine intelligence techniques for operating space systems. The SAIL project is unique because it uses the UHF Follow-On (UFO) Flight #1 spacecraft as an on-orbit test article, providing the means to qualify artificial intelligence (AI) applications for use in space. The laboratory is also used to support USNA classes and associated laboratories, as well as midshipmen and faculty research projects. This paper describes the SAIL project and how the Aerospace Engineering Department uses the project to support midshipmen education.

I. Introduction

Historically, operating space missions has been a labor-intensive endeavor. Spacecraft were designed as unique objects, and because of their operating environment, complexity on the spacecraft was minimized. This required the operators to be experts in both the operational procedures necessary to maintain the health and safety of the spacecraft, and also the engineering design of the spacecraft to properly respond to spacecraft anomalies. Two factors require us to re-think our approach to operating spacecraft. First, the number of operational spacecraft is increasing all the time. Second, breakthroughs in spacecraft design, especially in the area of miniaturization and on-board processing, allow us automate many of the operational functions on the spacecraft. Operators must now be able to monitor more spacecraft, know which operations functions are performed on the spacecraft, and understand how the spacecraft should respond to commands, both onboard and from the ground. Spacecraft design engineers must decide which functions can be controlled from the spacecraft onboard processor and which functions should be controlled by ground operations.

Before addressing the issue of automating space mission operations we need to define mission operations. Different countries, and different organizations within a country, define space mission operations differently. In this paper, mission operations includes actions needed to prepare for launch, activities that take place after launch, and activities required to maintain the infrastructure that supports space mission[1]. For the SAIL project, we focused primarily on the post-launch operation of the spacecraft. The mission operations concept describes how we will fly the spacecraft to accomplish mission objectives and get the required data to the user. The concept combines the people, procedures, hardware, and software necessary to support the mission into a set of tasks, or processes, for accomplishing the mission. From the mission operations concept we identify the functions operations must accomplish for a particular mission.

Boden and Larson describe thirteen functions typically associated with space mission operations[2]. These functions are shown in Figure 1.

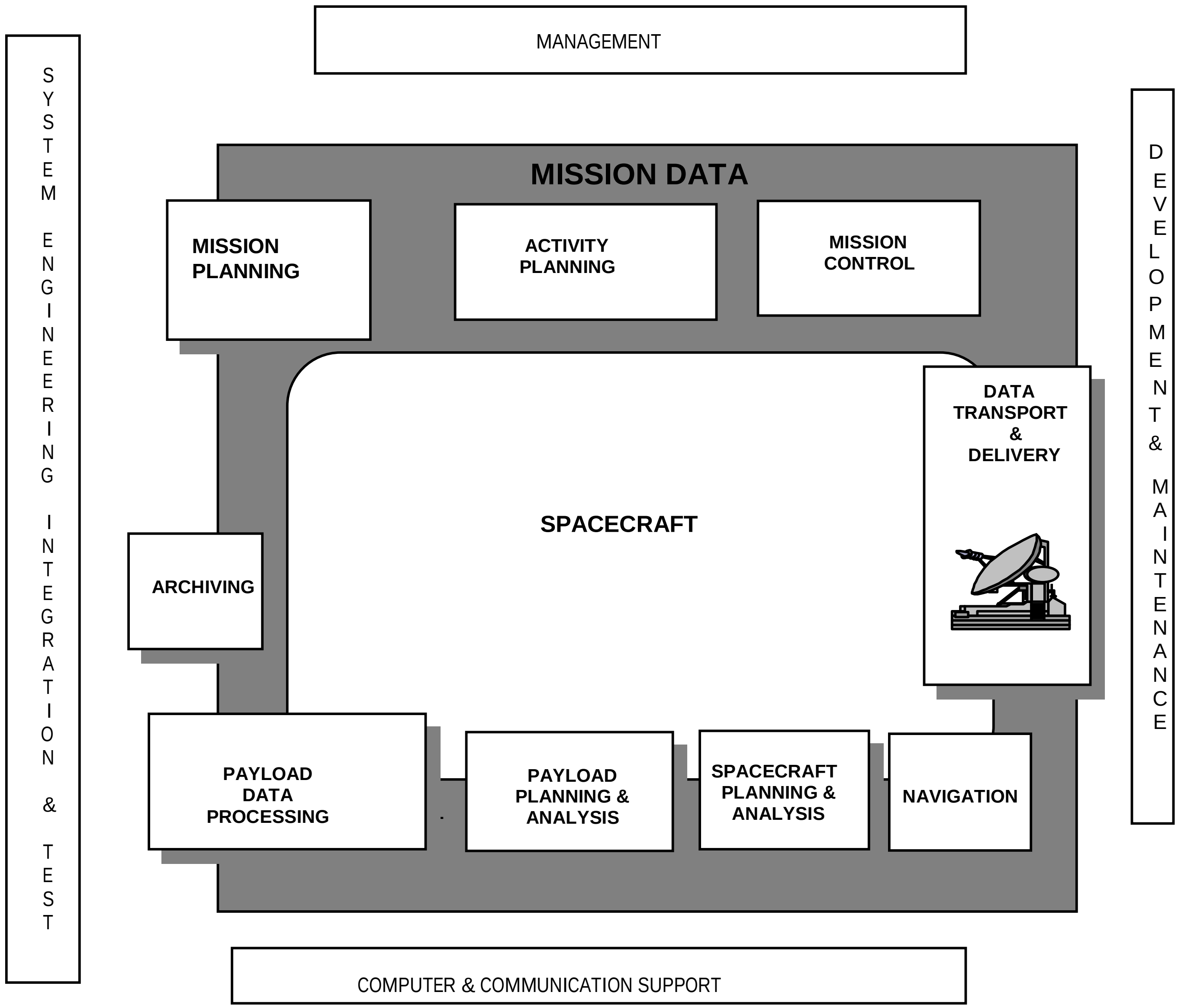

Figure 1. The thirteen functions within the Mission Operations System[2].

These functions can be combined in different ways depending on the type and complexity of the mission, the spacecraft, and the payload. Combining functions can take place in the spacecraft, the ground data system, and the operations organization. As the number of spacecraft increases and the processing ability onboard the spacecraft improves, more and more of the functions can be migrated to the spacecraft for autonomous operation. One goal of the SAIL project is to identify which functions we can accomplish onboard the spacecraft, prepare algorithms for automating the functions, and then test our approach.

II. SAIL Project Description.

Figure 2 shows the data flow for the SAIL project, from the Navy UHF Follow-On Flight-1 Satellite (UFO-1), to our 12 meter tracking antenna, and finally to our electronic classroom.

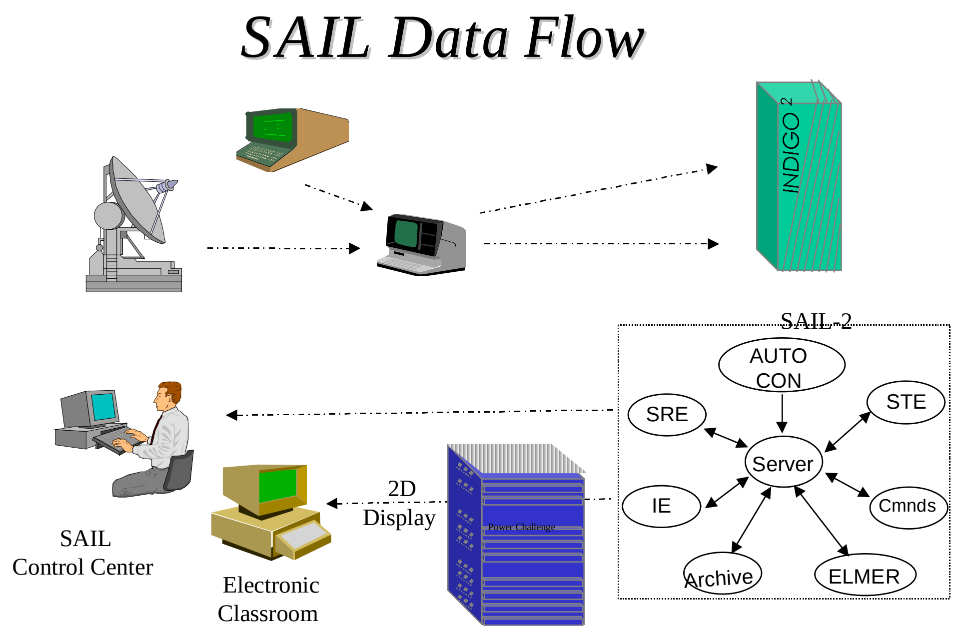

Figure 2. SAIL Project Data Flow

SAIL uses the UFO-1 spacecraft as an on-orbit test bed. UFO-1 was launched on March 23, 1993, but did not achieve an operational orbit and had to be placed in a super-synchronous orbit. The inclination of the orbit is 28 degrees. Since its fuel reserve was expended in this effort the spacecraft was never placed in an operational status. Because UFO-1 is not operational, we have access to the satellite's telemetry whenever the satellite is in view of our ground station.

Currently, our ground station is fully capable of receiving and displaying the UFO-1 engineering telemetry. We receive the data via our 12-meter tracking dish shown in Figure 3. This consists of the spacecraft engineering status and system parameters such as temperatures, pressures, currents, and voltages. We input the telemetry (either live or in playback mode) to the Altair Mission Control Software (AMCS). AMCS was developed by Altair Aerospace and provides the ability to monitor the UFO-1 subsystems using dynamic, graphical displays of the telemetry. Displays include the following systems: electrical power, attitude control, communications, propulsion, and thermal control subsystems. AMCS is designed to allow other Artificial Intelligence tools to plug-in to the UFO-1 telemetry and test their algorithms by feeding information between the various programs. The AMCS uses a state recognition engine to examine numerous parameters and report the state of a subsystem. Operators and AI tools have access to both raw parameters and system states.

Figure 3. USNA 12-m Tracking Dish

In addition, SAIL supports our electronic classroom used by first class midshipmen in our Space Systems Laboratory Course. AMCS drives the displays on individual workstations in the classroom. Midshipmen view two-dimensional graphical displays of the subsystems, obtain technical descriptions of components, and query sensors for real-time telemetry data. In one example laboratory, midshipmen observe the electrical power system as the spacecraft moves into eclipse. They monitor falling voltages and currents from the solar panels, as well as falling temperatures in the spacecraft. Midshipmen are also exposed to the data transport and data processing functions of mission operations. They learn first hand how data is received and processed to provide usable engineering information. During the Space Systems Laboratory course midshipmen also conduct hands-on laboratory exercises to enhance the experience with the actual satellite data. The focus here is on communications, electrical power, thermal control, and structural dynamics.

III. Future Work

Future plans for SAIL include development of a virtual environment spacecraft using UFO-1 as a model. The model will be built and connected to the live telemetry stream, allowing an operator or a student to go inside the spacecraft and observe the current state of the spacecraft. The model will also support collaborative engineering from geographically displaced locations.

We also hope to receive a high-fidelity UFO-1 simulator to support the project. This allows us to create several types of scenarios. One requires the student to either predict the future state of the spacecraft based on some initial input and running the simulator to check their solution. Another is to input an anomaly or fault into the simulator and require the student to observe the telemetry stream and identify the anomaly or fault using fault detection and analysis tools. A final scenario requires the student to generate a command file, predict the performance of the spacecraft, and then send the command file to the simulator and compare actual performance with predicted performance.

The SAIL project at the Naval Academy enhances the education of our students by providing hands-on experiences with a functioning, state-of-the-art spacecraft. Students apply what the learn in the classroom to a real spacecraft to gain additional insight into space systems engineering.

Bibliography
1. Boden, D. & Larson, W., *Cost-Effective Space Mission Operations,* McGraw-Hill, NY, 1996, Pg. 31
2. Ibid., Pg. 33.

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