N89-10078

AUTOMATION OF SPACECRAFT CONTROL CENTERS

Robert Dutilly
Goddard Space Flight Center

ABSTRACT

The objective of this paper is to describe the further automation of the Payload Operations Control Centers, specifically the Mission Operations Room, by using a series of expert systems interconnected together. The feasibility of using expert systems in the Mission Operations Room is presently being determined. The expert system under development is called the Communications Link Expert Assistance Resource (CLEAR) project. It is the first control center expert system being designed and implemented at Goddard. It will demonstrate the feasibility and practicality of expert systems in a real-time control center environment. This paper has a twofold purpose. The first is to briefly describe the present effort of the CLEAR expert system under development. The second is to describe how a series of interacting expert systems could be developed to almost totally automate the Mission Operations Room within the control center. This paper will describe how these expert systems would be put together and what functions they could perform in the control center. These efforts will provide a great deal of applicability toward the automation of the space station.

Keywords: Automation, Control Center, Expert System, Real-time

Purpose

The purpose of this paper is to describe the means by which automation software, specifically expert systems, can be developed for the spacecraft control centers at Goddard Space Flight Center. These control centers provide an excellent environment to test the feasibility and practicality of real-time expert systems. This paper will detail the control center environment, what work has already been started and how a series of interconnected expert systems will work together. Finally, summarizing this concept of expert systems in this real-time environment will provide the expertise necessary for both the ground system and onboard system of the space station.

Environment

There are two types of spacecraft control centers at Goddard. The dedicated control center, such as the Space Telescope, which handles only one mission and the

Multisatellite Operations Control Center (MSOCC) which supports a number of simultaneous missions. This automation effort that is proposed would work equally as well in either type of control center. The expert system presently under development will be used in the MSOCC for the Cosmic Background Explorer (COBE). This effort will be discussed later in this paper.

The control center environment is a combination of hardware and software. The hardware for the control center is made up of a front end computer system to frame synchronize the telemetry data; the main computer system which performs all of the processing on the telemetry data and commanding the satellite; and the workstations located in the Mission Operations Room (MOR). This main computer system is commonly called the Application Processor (AP). While the front end computer is called the Telemetry and Command (TAC) system. The function of the MOR is to provide a location where the Flight Operations Team works to monitor and control the spacecraft. The MOR contains workstations and stripchart recorders to display the data that has arrived at the AP. The software developed for the mission resides on all of the hardware systems used to support the satellite. Figure 1 provides a descriptive layout of the spacecraft to ground system.

There are several very important aspects that must be accounted for in this type of environment.

a. The control center receives a real-time flow of asynchronous data.

b. There is a large amount of data to process.

c. There must be a continuous performance assessment of the spacecraft and all of its subsystems in real-time.

d. The expert system must be on a separate computer system and receive all of the data electronically in real-time from the AP. The primary reason for a separate system is to avoid interfering with the existing real-time software and operations.

e. The expert system must be able to interact with the human analyst in real-time while receiving the data.

f. A time dependency is critical to this large amount of uncertain data.

What this last point means is that the expert systems are required to take into account what the short and long term trends are to the data. Consequently, the system must construct an internal history of the data to develop a trend analysis. This trend analysis will indicate how the spacecraft or instruments will be performing in the near

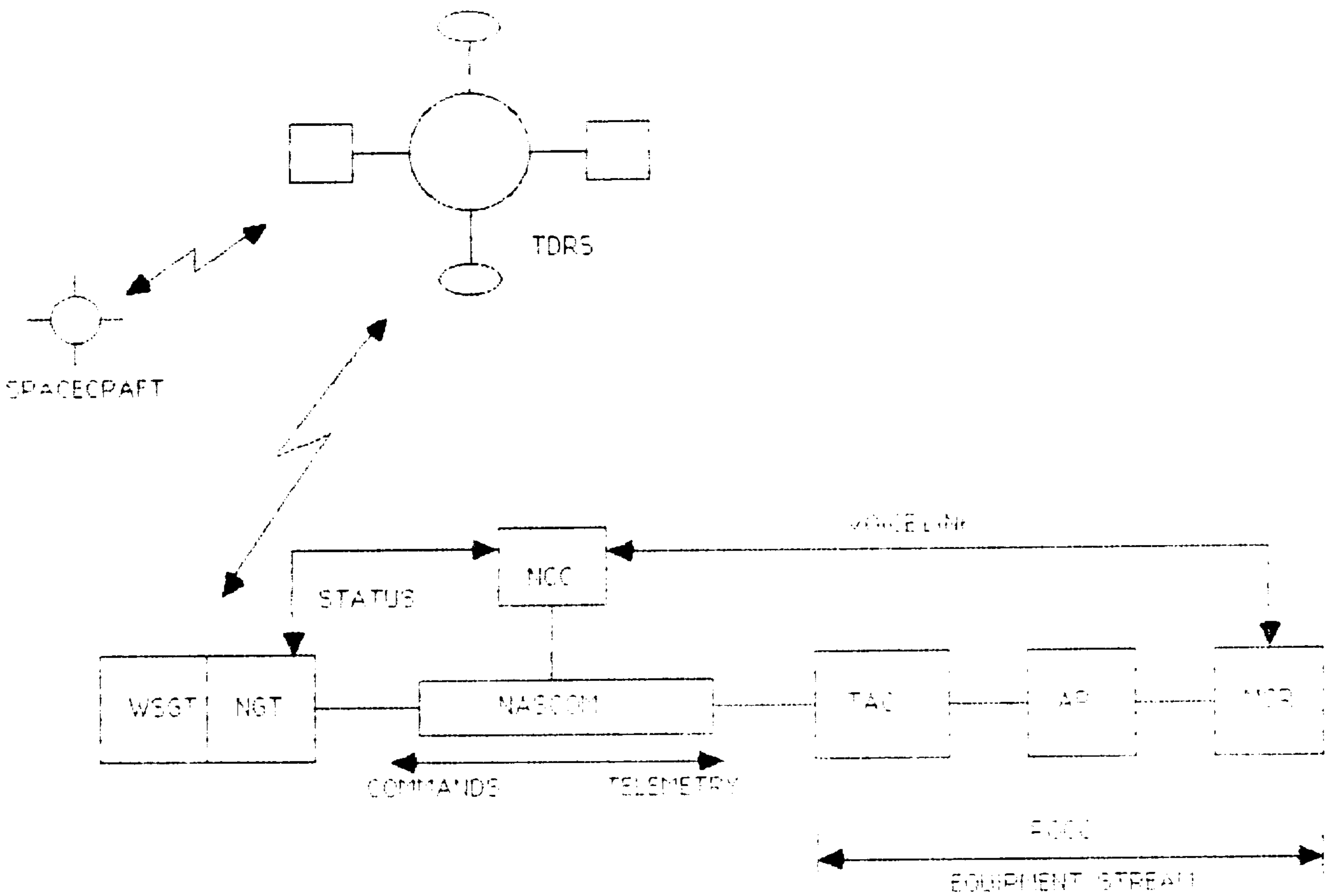

Figure 1 Descriptive Layout of a Satellite to Ground System

ORIGINAL PAGE IS
OF POOR QUALITY

term. The expert systems must also be able to relate the data from different areas. This capability will provide a multi-focus analysis of the incoming information. This is similar in nature to the human information gathering capabilities in which pieces of disparate information forms a whole concept. This would be the meta-knowledge required to develop the generalities for the system to use in determining problems with the spacecraft. This meta-knowledge will provide the expert system with the overall concepts on how the spacecraft and its subsystems should operate together. It will provide some capabilities for the expert system to draw conclusions about the health and safety of the spacecraft. Finally for this type of environment, there are three types of systems that can be developed.

a. Passive system -- This expert system acts only as a recommender of actions for the spacecraft analyst. This system does not take any actions and is not provided that capability. This is the type of system that must initially be developed for control centers.

b. Active system -- This type of expert system provides all of the capabilities of the passive system. It also can be directed by the spacecraft analyst to actually take positive action to correct problems. After expert systems have proven their capabilities to find and solve problems, then an active system may prove to be worthwhile.

c. Autonomous system -- As this term indicates, this system would perform all actions in finding, solving and correcting problems. It would operate independently of the spacecraft analyst and would only present the problem and actions taken both during and immediately after the event.

As previously indicated, the first expert systems to be installed in a control center will be of the passive type. All actions will be taken by the analyst on a separate workstation in the MOR. Eventually, after expert systems have been proven, an active system can be implemented. The autonomous system will take a great deal of time and effort to develop. It must not only be proven to be safe for the spacecraft but also be accepted by the operations personnel.

Present Development

The expert system that is presently being developed is called the Communications Link Expert Assistance Resource (CLEAR). CLEAR will operate in the Mission Operations Room during real-time passes of the COBE spacecraft. This is the first expert system to be put into an operational control center environment at Goddard. The purpose of this system will be to monitor and help solve communications problems between the COBE spacecraft and the Tracking and Data Relay Satellite (TDRS). CLEAR is a passive system that advises the spacecraft analyst when an event has occurred which indicates the COBE-TDRS communications link is degrading or failed. The analyst is provided with possible solutions to the problem. It is the analyst who decides what should be done and uses a voice link with NCC and the workstation to solve the problem. A detailed description of CLEAR is provided in another paper.

Proposed Development

Now to describe how a series of real-time expert systems could be installed into the MOR. These expert systems would be executing on a separate system from the AP. Figure 2 provides a functional layout on how this system would operate. The basic concept is that the AP would be providing a continuous stream of data to the expert systems during the real-time pass of the spacecraft. The main classes of data that would be provided to the expert systems are:

a. The spacecraft subsystem data such as attitude, power or electrical.

b. The spacecraft instrument data for health and operability.

c. Any communications information from the Network Control Center.

The control center is concerned with the health and safety of the spacecraft and the onboard instrumentation. So the specific purpose of this system is to monitor the data sent to it by the AP and to assist the spacecraft analyst in solving problems that occur. This indicates to you that the system must initially be passive so that the human remains in total control. The main requirements of this system are:

a. It must be designed in a modular fashion so that lower level expert systems may be added or deleted easily.

b. Each of the systems must be able to handle multiple faults.

c. Each of the systems must be able to handle any reconfigurations of the spacecraft subsystems.

d. The systems should be able to develop estimates on when a component, instrument or subsystem is failing based on trend analysis.

e. This system must be able to accept information into the data base from the spacecraft analyst via the user interface.

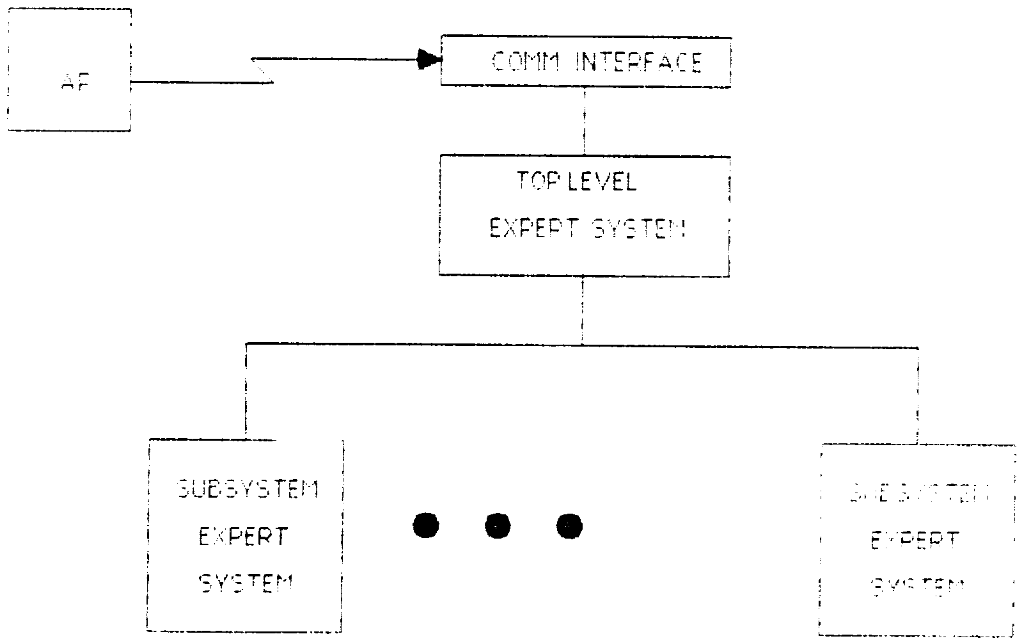

Figure 2 Functional Layout of the Total System

The software architecture for this integrated system is shown in figure 3. What stands out immediately is the main inference engine providing messages to a blackboard and the lower level expert systems obtaining those messages addressed to them. Each expert system has its own Knowledge Base provided for that subsystem. Also available to all the expert systems are the Data Base, the Data Tables and the Logging Facility. The Data Base contains the information about the spacecraft, the instruments, the different telemetry formats and all of the information about the data itself, for example, the limits. The Data Tables contain all of the incoming data, similar in nature to the telemetry table in the AP. As shown in figure 3, the blackboard shown will be a circular file with the main system notifying each subsystem of a problem. The subsystems periodically "wake up" on a short time span and check the blackboard for a message. If a subsystem locates a message, it will read and erase the entry on the blackboard. That subsystem will then access the data table looking for its specific information and use its detailed knowledge base to try to determine the problem or event that occurred. It will then access the user interface to provide this information to the spacecraft analyst. The reason for this hierarchy is to minimize the number of subsystem expert systems from competing for the computer's resources.

Several other points need discussing at this time. This integrated system will require meta-knowledge; the ability to solve problems by combining the data and knowledge from several sources. This is one of the most difficult areas to develop since the system designer must be able to glean from the spacecraft analyst all of the factors involved in making critical decisions. It is not enough to have rules checked based on a telemetry point. The system must be given a "higher" knowledge about how the spacecraft and its subsystems operate together and also how to "reason" about the telemetry data. This leads into the second point on how to work with the uncertain data. The most popular ways today is using probability techniques and fuzzy logic theory to help assist the inference engine in determining if a problem exists. The third point is the testing of this system. With the hierarchy of systems as designed, the testing will be able to focus in on each part. While not perfect, at least this will provide a structured technique that is in use today for testing large systems. Finally, the most important point is to remember to keep the human "in the loop". The human will be able to assist the expert system and correct any false conclusion that had been reached.

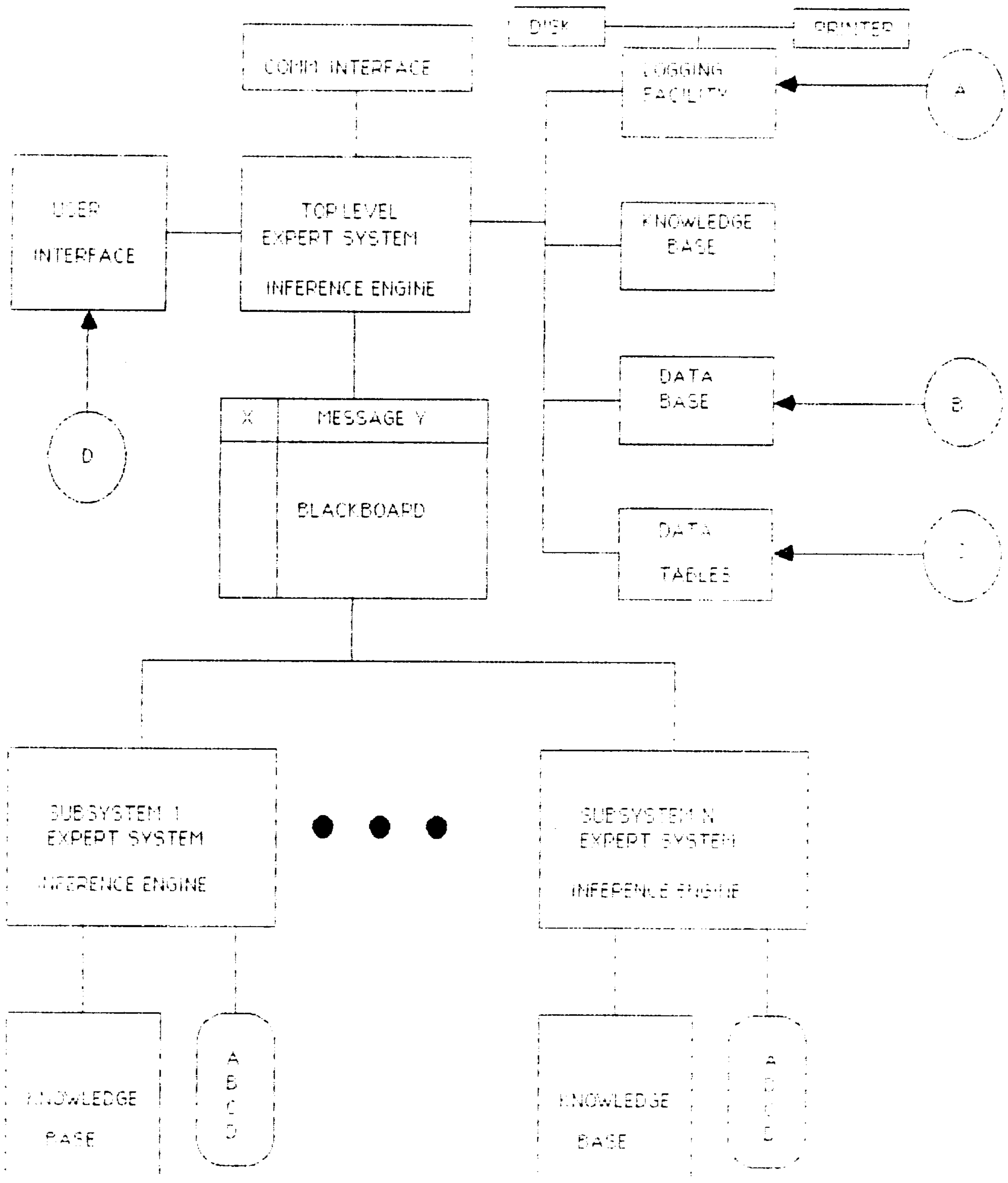

Figure 3 Architecture of the Total System

Summary

As was indicated at the beginning of this paper, chaining together expert systems to form one integrated system will automate many of the functions of a control center. This will also reduce the complexity of analyzing all of the data by the spacecraft analyst. If this concept proves to be both feasible and practical and can actually be implemented to work properly in the real time environment of a control center, the use of expert systems would have definite applicability for space station support. The control center could serve as the initial test environment on how expert systems would be developed and installed in the space station and any attendant ground control system.

GLOSSARY

AP	Applications Processor; The computer system that sends command data to the spacecraft and receives the telemetry data, decommutates the data and sends that data to the MOR.
CLEAR	Communications Link Expert Assistance Resource; This is the first expert system being developed for use in the control center. It will be used for the COBE spacecraft.
COBE	Cosmic Background Explorer; This spacecraft will be the the first at Goddard to use an expert system in the control center.
Control Center	The hardware and software real time environment that controls the spacecraft and monitors its health and safety.
MOR	Mission Operations Room; That part of the control center in which the Flight Operations Team works. It contains the workstations, displays and strip chart recorders to display the data from the AP.
NCC	Network Control Center; This facility provides the management for allocating and regulating network resources to support network users.
TAC	Telemetry and Command System; The front end computer system that frame synchronizes and time tags the incoming telemetry data before sending it to the AP. It receives the command data from the AP and sends it out to NASCOM.
TDRS	Tracking and Data Relay Satellite; This is the communications satellite which communicates with the spacecraft and White Sands.

Section C

Data Processing/Analysis
Expert Systems