INTELLIGENT TELEMETRY SIMULATOR FOR SPACE APPLICATIONS

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ABSTRACT

Ford Aerospace Corporation has been working for several years on Independent Research and Development (IR&D) that brings artificial intelligence technology to bear on space mission operations tasks. During this time, we have developed a flexible and sophisticated tool, called Paragon, that supports knowledge representation in a very intuitive and easy to maintain manner. As a fallout of our knowledge representation approach in Paragon, we get a simulation capability that supports testing and verification of the model. This same capability can be used to support various space operations training and readiness activities (1).

Recently, we became aware of the very flexible telemetry generation and display capabilities of the Loral 500 system, and found that we could combine our Paragon modeling and simulation capability with the Loral equipment to create an intelligent telemetry simulator that has the potential to dramatically reduce acquisition, development, installation, and maintenance costs for space system simulation.

This paper discusses the features and capabilities of the Paragon/Loral 500 Intelligent Telemetry Simulator (ITS) as well as the prototyping we have accomplished to date.

INTRODUCTION

Paragon was developed specifically to support research and development involving the use of artificial intelligence technology to increase satellite autonomy and to automate space operations tasks currently performed on the ground. The initial development started in 1984 on Xerox workstations to provide an environment for building model-based, intelligent systems. It included a structure for knowledge representation and a sophisticated user interface that allowed knowledge engineers to enter main knowledge in an intuitive manner that did not require programming expertise.

Over the past six years this environment was enhanced as necessary to support specific research. Recently, it was ported to Lucid Common Lisp to run on additional platforms including the SUN and MicroVAX.

Application model development requires no coding. The application developer works with a knowledge acquisition interface that allows the developer to think in terms of the concepts, attributes, relationships, and behavior descriptions that exist in the world or system being modeled (1). The interface takes care of translating the developers' input into Lisp. Extensions to the interface, or translation routines, will be necessary to convert the Lisp code to other high-level languages such as C or Ada.

The Loral 500 is an extremely flexible and powerful tool for real-time generation, processing, and display of telemetry. It handles a wide variety of telemetry formats and rates via custom boards that fit into slots in a modular chassis. This allows the user to easily configure the Loral 500 to meet specific application needs.

The Loral 500 includes a high-speed, programmable telemetry wavetrain simulator and associated software to generate a variety of patterns for particular telemetry parameters. It also can accept data from external models for inclusion in the output telemetry waveform. We exploit this feature for our Intelligent Telemetry Simulator (ITS). Paragon knowledge bases dynamically model and simulate system behaviors. A separate process monitors parameters in the knowledge base, which have been converted to PCM counts, and passes them to the Loral wavetrain simulator over an Ethernet link.

All hardware for the ITS is off-the-shelf. We are using commercial SUN, VAX, and DEC workstations and commercial Loral equipment. The hardware literally fits on a desk. There are no special power or cooling requirements. Communication between workstations is via Ethernet.

ITS PROTOTYPE

For the ITS proof of concept, we chose a representative Department of Defense (DoD) program. For this program , unclassified satellite design and operations information is readily available. The satellites are in subsynchronous orbit and are three-axis stabilized.

The ITS prototype includes detailed models of three satellite subsystems--the Electrical Power Subsystem (EPS); the Telemetry, Tracking, and Command (TT&C) Subsystem; and the Reactions Wheels System (RWS) which is part of the Attitude and Velocity

Control Subsystem (AVCS). Portions of other subsystems, including the Payloads and Thermal Control, were modeled where necessary.

EPS Simulation. For EPS simulation, the prototype includes 55 telemetered measurands and accepts 56 ground commands. This represents approximately 75% of the command and control functionality of the EPS for the satellite. Only the functionalities that are rarely exercised were left out of the model. Power balance behavior, eclipse behavior, battery charging/discharging behavior, wing behavior, automatic load shedding--just to name a few, are represented in the model. The EPS simulation also includes eight built-in anomalies for demonstrating ITS support for operations training and rehearsals. The eight anomalies are listed in Table 1. Figures 1 and 2 are representative displays of an EPS power balance anomaly. These displays are in color with "critical" and "warning" alarms shown in red and yellow, respectively. The System 500 is extremely flexible for telemetry display, allowing the user to easily tailor screens in ways appropriate for the domain.

Table 1. ITS Prototype EPS Anomalies

1. SUN SENSOR FAILURE:	Solar wing cannot track the sun due to a zero error being returned by a failed sun sensor.
2. PWR A FAILURE:	Solar wing cannot track the sun due to a System A power source failing to that wing.
3. ELECTROSTATIC DISCHARGE:	Solar wing cannot track the sun due to an electrostatic discharge phenomenon placing the wing in the hold mode without ground commanding.
4. TRACKING FUNCTION FAILURE:	Solar wing is unable to track the sun due to a tracking circuitry failure.
5. BATTERY OVERTEMPERATURE:	Battery 1, 2, or 3 overheats due to a battery heater A-string problem.
6. BATTERY SHORTED CELL:	Battery 1, 2, or 3 exhibits shorted cell characteristics.
7. LOAD SHED 1 TIMR FAILS:	The load shed 1 timer begins ramping up without the proper conditions being present.
8. LOAD SHED 2 TIMER FAILS:	Same as 7 above but for Timer 2.

When an anomaly is selected, the ITS telemetry responds accordingly. There is no need for a rehearsal team to predetermine a "correct" command plan solution and account for it in the "data base" since the model (or knowledge base) is dynamic and will respond to any correct or incorrect commanding automatically. When the operations personnel try a commanding sequence, the model responds accordingly and the ITS telemetry stream will dynamically reflect the actual satellite behavior.

TT&C Simulation. For TT&C simulation, the ITS prototype includes 85 telemetered measurands, 50 discrete commands, and 136 magnitude commands. This represents approximately 90% of the command and control functionality of the TT&C subsystem for the satellite. No anomalies are "built-in" for this subsystem, but they can be added for almost any desired TT&C related problem. Anomalies can be modeled in such a way as to be selectable. With this approach, nominal behavior (in the telemetry stream) is present until an anomaly is selected.

The TT&C model includes the automated, onboard, bypass commanding and crosstrapping modes, in addition to approximately 90% of the ground commanded configuration possibilities. The automatic turn-on and command turn-on modes are also supported.

RWS Simulation. For RWS simulation, the ITS prototype includes 36 telemetered measurands and 31 discrete commands. Sixteen of the commands involve solar wing rotations since rotating a wing causes attitude transients for the satellite. The RWS on the satellite uses four reaction wheels for precise attitude control. Three wheels are adequate for attitude control and the model supports the various 3-wheel configurations. Stiction (a term used for degraded reaction wheel performance) can be induced for any of the four wheels to simulate performance degradation. Transient attitude perturbations can be simulated randomly through user selection. Figures 3 and 4 are representative displays of typical attitude perturbation data. Again, the displays are in color with "critical" and "warning" alarms shown in red and yellow.

CONCLUSION

The ITS includes the Paragon knowledge-based modeling environment that allows for model development, test, validation, modification, and maintenance through a user-friendly graphics interface. This environment supports rapid prototyping as well as full system (space vehicle) modeling. In addition, the ITS includes a dynamic and flexible telemetry wavetrain generation capability which is configurable via a friendly user interface. User displays are easy to define using a variety of graphical display tools. Also included is user programmable telemetry preprocessing.

In conclusion, the ITS provides a powerful, flexible, and easy-to-use environment for building dynamic, model-based telemetry wavetrain simulations that can be used to support a variety of test, training, and readiness activities.

BIBLIOGRAPHY

(1) Blasdel, A. N., 1989, Simulating Satellite Telemetry, International Telemetering Conference.

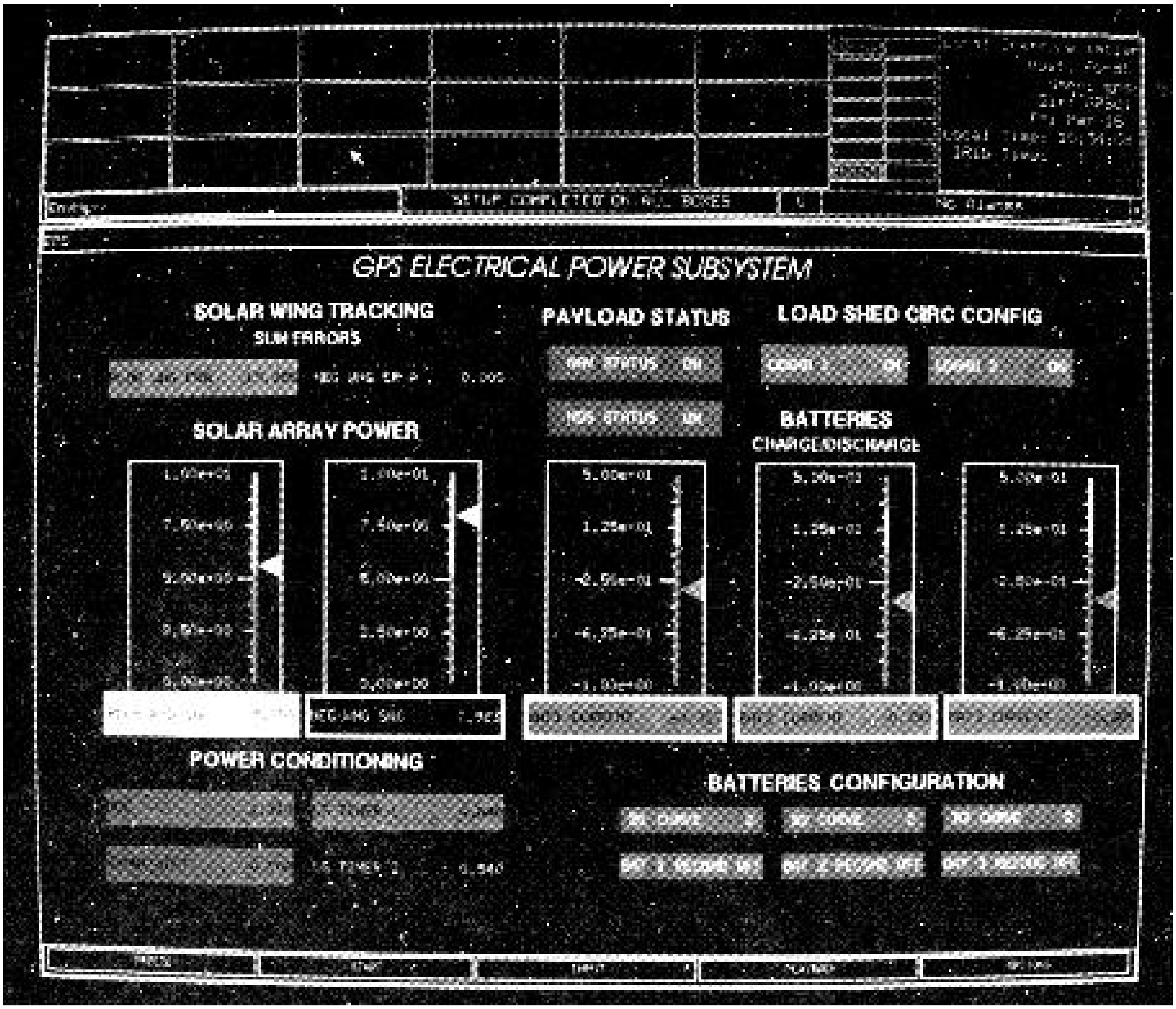

Figure 1. Example display screen showing an EPS power balance anomaly.

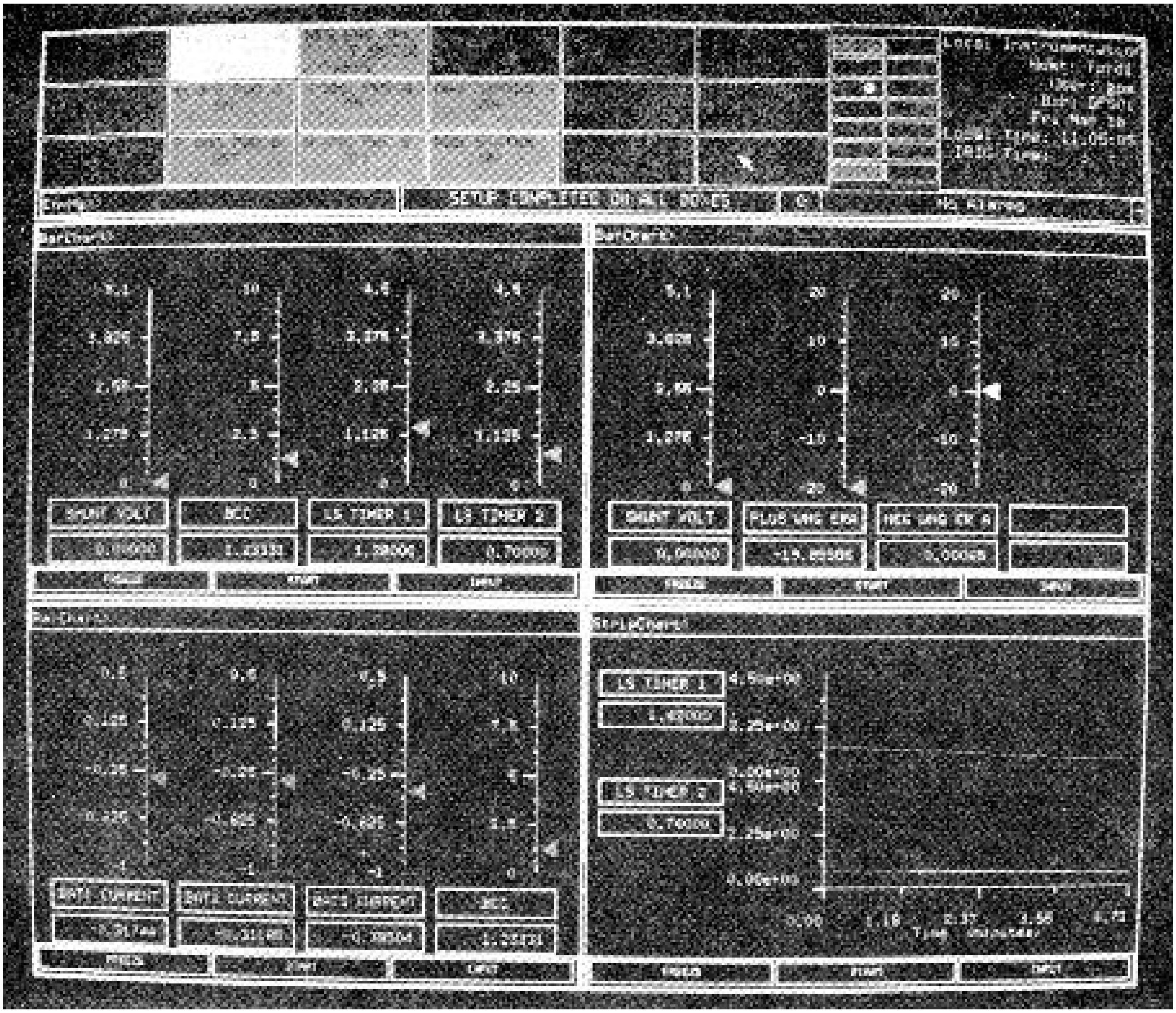

Figure 2. Example display screen showing an EPS power balance anomaly.

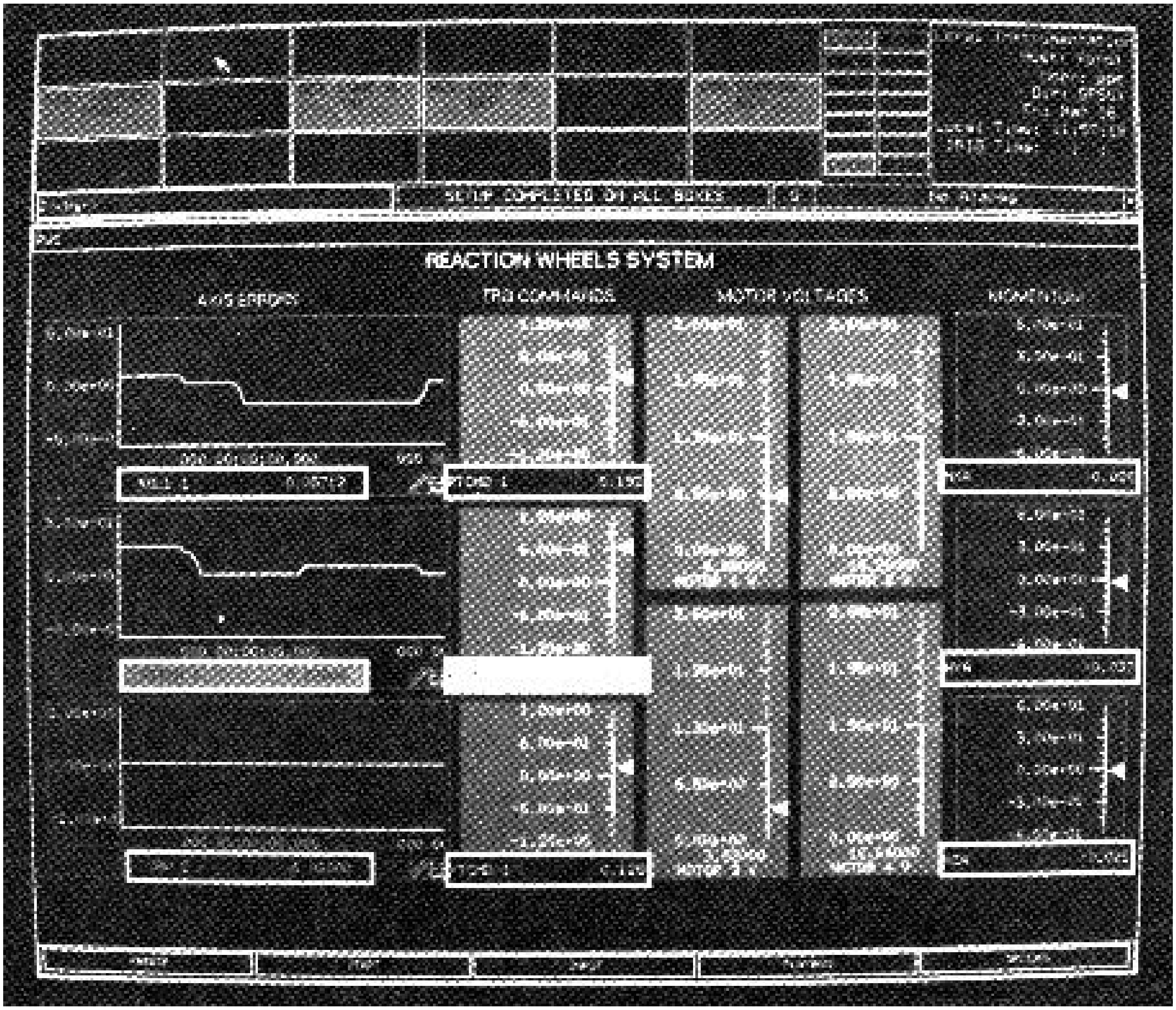

Figure 3. Example display screen showing a snapshot of attitude control system transcient behavior.

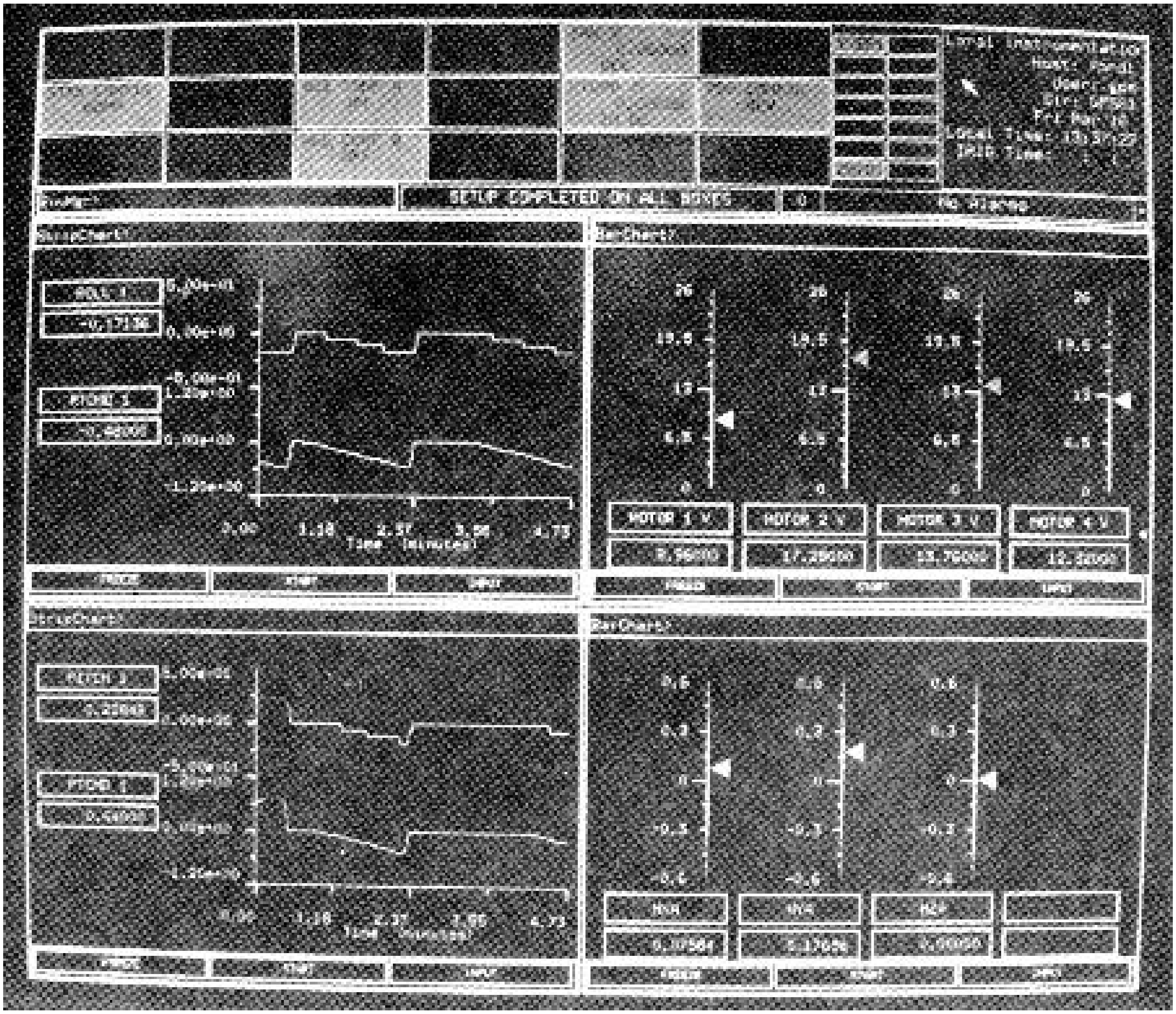

Figure 4. Example display screen showing a snapshot of attitude control system transient behavior.