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# **A MATLAB/Simulink based GUI for The CERES Simulator**

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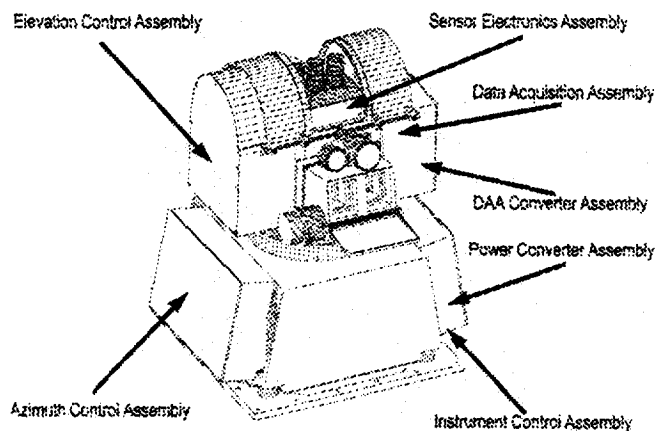
## **Abstract**

The Clouds and The Earth's Radiant Energy System (CERES) simulator will allow flight operational familiarity with the CERES instrument prior to launch. It will provide a CERES instrument simulation facility for NASA Langley Research Center, NASA Goddard Space Flight Center, and TRW. One of the objectives of building this simulator would be for use as a testbed for functionality checking of atypical memory uploads and for anomaly investigation. For instance, instrument malfunction due to memory damage requires troubleshooting on a simulator to determine the nature of the problem and to find a solution.

## Introduction

The purpose of this overview is to provide a brief summary of the Clouds and The Earth's Radiant Energy System (CERES) simulator, objectives, perspective, advantages, and its relationship to other Earth Observing System (EOS) instruments. An important theoretical background concerning the CERES project will be given as a guide for introducing the CERES concepts.

The CERES instrument, as shown in Figure 1, is a key part of NASA's Earth Observing System. It is designed for use in Tropical Rainfall Measurements Mission (TRMM) and EOS satellites that will be measuring radiant energy reflected from Earth's clouds starting in 1997. The CERES data is critical for advancing the understanding of cloud-radiation interactions; in particular, clouds' feedback effects on the Earth's radiation balance. CERES data is fundamental to our ability to understand and detect global climate change. CERES results are also important for studying regional climate changes associated with deforestation, desertification, anthropogenic aerosols, and El Nino events. The CERES simulator is being built at NASA Langley Research Center to be used as a ground testbed for anomaly investigations and to test software uploads, that control the instrument, prior to transmitting them to the satellite.



**Figure 1. CERES Instrument**

## CERES Background

The CERES data is intended to substantially improve our understanding of cloud's energy flows. The CERES investigation concentrates on four primary areas: Earth radiation budget and cloud radiative forcing, cloud properties, surface radiation budget, and radiative components of the

atmosphere's energy budget. Therefore, due to the importance of the CERES instrument for TRMM and EOS, the design and implementation of a CERES simulator was proposed.

## **CERES Simulator Description**

The CERES simulator consists of circuit cards functionally identical to the flight items, though fitted with low cost commercial specification microcircuits and components. Two host personal computers (PC's) will support the electronics ensemble. One PC will contain a 1553 interface card which will function as the telemetry path for commands and memory uploads, while the second PC will provide a representation of the mechanical components such as the azimuth and elevation drive components and covers.

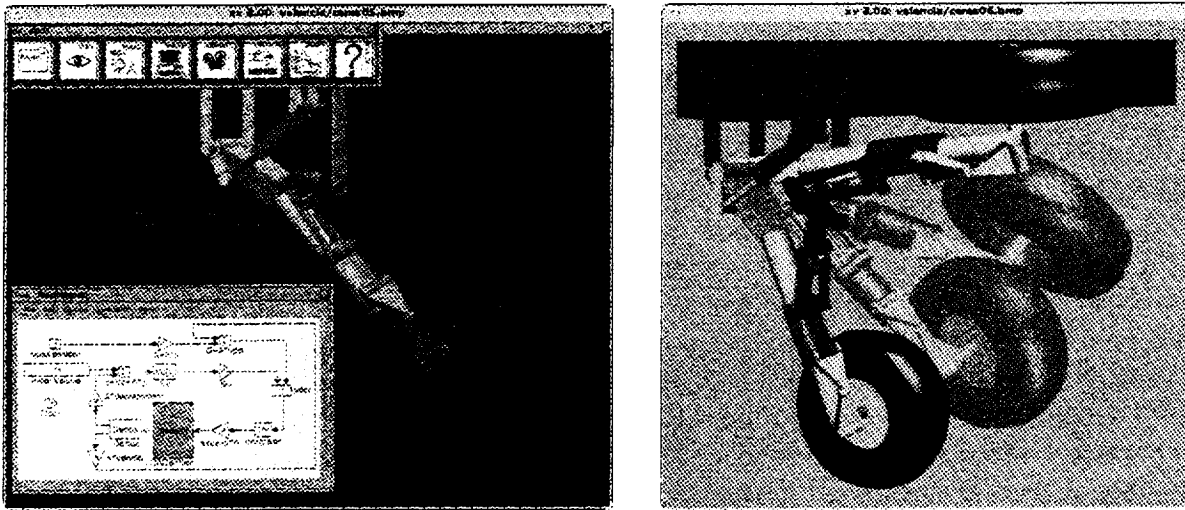
DADS/Plant software incorporating a Graphical User Interface (GUI) which will be driven by I/O interface cards via MATLAB/Simulink is currently being developed. The mechanical control system simulation will be accomplished by using the MATLAB/Simulink software package with real-time executable files to call I/O card drivers. The mechanical components of the instrument must be represented by dedicated I/O ports linked with the host PC software to respond to processor commands simulating the physical hardware they represent in a realistic fashion.

The CADSI DADS/Plant software provides for animation of CAD/CAM drawings in real-time, as shown in Figure 2. The DADS/Plant program when linked with Simulink will display interactive visualization of 3D geometry of the controls software.

The MATLAB package is available for SUN, PC-486/Pentium, and SGI platforms, among others etc. The task is to seamlessly integrate PC I/O cards to read the CERES processor control lines, input this signal to the MATLAB/Simulink software, and then output a virtual position back to the CERES processor in a manner that mimics the actual hardware.

The obvious solution would be to use MATLAB on a 120MHz Pentium-based PC and do the I/O on one inexpensive, dedicated platform, with the GUI on the same PC. Likewise, an interesting alternative would be to use the PC to drive command lines to a SUN (or SGI) GUI. MATLAB can do this when linked to DADS/Plant as a recent demonstration has shown (see Figure 2).

The CERES simulator consists of CERES circuit cards (identical to those designed by TRW), populated with socketed DIP and SMT chips. It will use low cost, although identical commercial grade chips, as well as some mil-spec chips. A PC-486 host computer with a 1553 B interface card will be dedicated for TRW developed GSE code and cots. Similarly, a 120MHz Pentium with MATLAB/Simulink software will be used for elevation and azimuth drive simulation. The system will also incorporate multifunction I/O cards: a 16-bit parallel digital I/O card, a time code generator card, a graphics accelerator card, and a DT2811 A/D converter.



**Figure 2. Demo sample of DADS/Plant. Step by step animation of landing gear mechanism.**

## Method

To accomplish the stated task, Simulink software has been used for simulating the dynamic system. As an extension to MATLAB, which is the controlling platform, Simulink adds many features specific to dynamic systems, while retaining MATLAB's general purpose functionality.

Simulink consists of two phases: model definition and model analysis. A typical session starts by either defining a model or recalling a previously defined model, and then proceeding with an analysis of that model. In practice, these two steps are often performed iteratively as the model designer creates and modifies a model to achieve the desired behavior.

To facilitate model definition, Simulink adds a new class of windows called block diagram windows. In these windows, models are created and edited principally by mouse driven commands. It is imperative that the user becomes familiar with the manipulation of model components within these windows.

After the user defines a model, one can analyze it either by choosing options from the Simulink menus or by entering commands in MATLAB's command window. Built-in analysis tools include various simulation algorithms, such as "linmod", a tool for extracting linear models of systems, and "trim", a tool for finding equilibrium points.

The progress of a simulation can be viewed while the simulation is running, and the final results can be made available in the MATLAB workspace when the simulation is complete.

Simulink uses the metaphor of a block diagram to represent dynamic systems. Defining a system is similar to drawing a block diagram. Instead of drawing the individual blocks, blocks are copied from

libraries of blocks: either the standard block library supplied with Simulink, or block libraries the user creates.

The standard block library is organized into several subsystems, grouping blocks according to their behavior. Blocks can be copied from these or any other libraries or models into a current model. By placing the blocks it most commonly uses into one system and setting your preferences for default values, the software can set up a personal block library.

The CERES elevation and azimuth drive simulation is shown in Figure 3. The equations of motion describing the translation and rotation for each articulation of the CERES instrument, and all associated physical parameters were obtained from TRW, see reference 1. The appropriated equations and parameters were extracted and used in designing the MATLAB/Simulink software program input block diagrams to simulate the control system of the azimuth and elevation drives. Each equation of motion defines a particular parameter such as friction, torque, or scanning mode (see Figures 4 through 7) within the azimuth or elevation drive control system. Each module parameter contains a unique simulation which will be governed and connected by the main module shown in Figure 3. The entire simulation requires a CERES voltage command which, for this particular case, is generated by a signal generator.

A TRW scan head mechanical model would be simulated as the diagram depicted in Figure 7 validated for open loop gains. From the diagram, the  $Kdeg$  gain converts any input from radians to degrees. After obtaining the input in degree format, integration will yield the velocity of the motor; while a second integration produces the position and elevation. This approach was used for all of the mechanical parameters within the CERES simulator.

## Results

Figure 8 presents the results for a simple open loop control system configuration. The entire simulation has been successfully executed for non real-time data. However, the results obtained should vary with real-time input data driven by I/O cards. To study the system behavior in the presence of noise, gains and amplitudes were varied. A given input corresponds to a certain output, which yields a variation for each input parameter. As mentioned earlier, a typical periodic sinusoidal signal generator was used as an input generator rather than real-time data. However, the CERES simulator will require real-time input driven by I/O cards in order to obtain accurate results.

The simulator was also tested for the azimuth drives. The results were similar to those of the elevation drives. Although the azimuth simulation appeared to be noisier in some cases, the scanning position was accurated. As previously mentioned, Figure 8 shows the preliminary results from the control system of the CERES simulator. The effects visibly changed through time, as computing time increases from 1 to 5 seconds.

At this point, the control system simulations show the behavior of the TRW's CERES scanner servo model. Applying a computer aided design (CAD) tool such as DADS/Plant software would enable complete visualization of the CERES simulator.

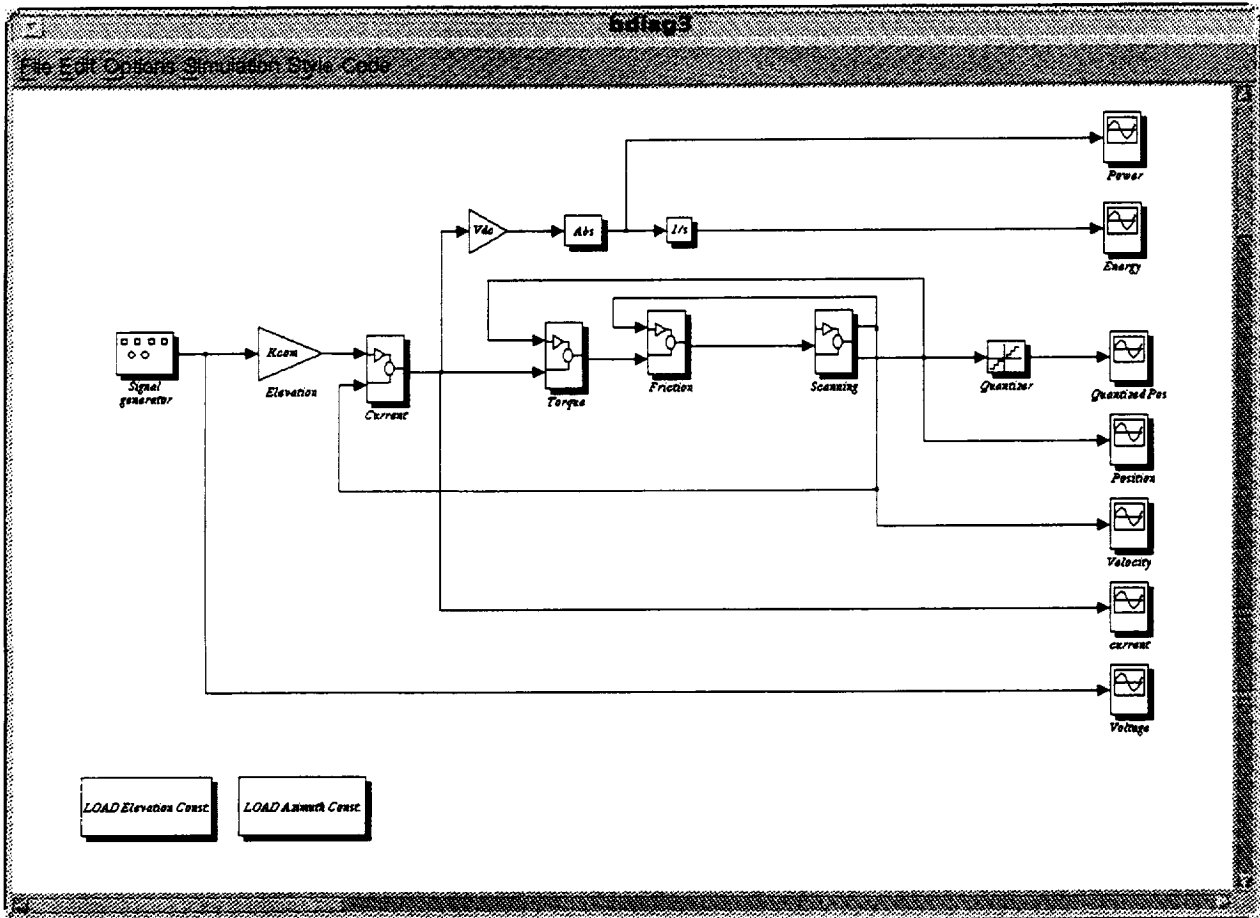


Figure 3. Main Module

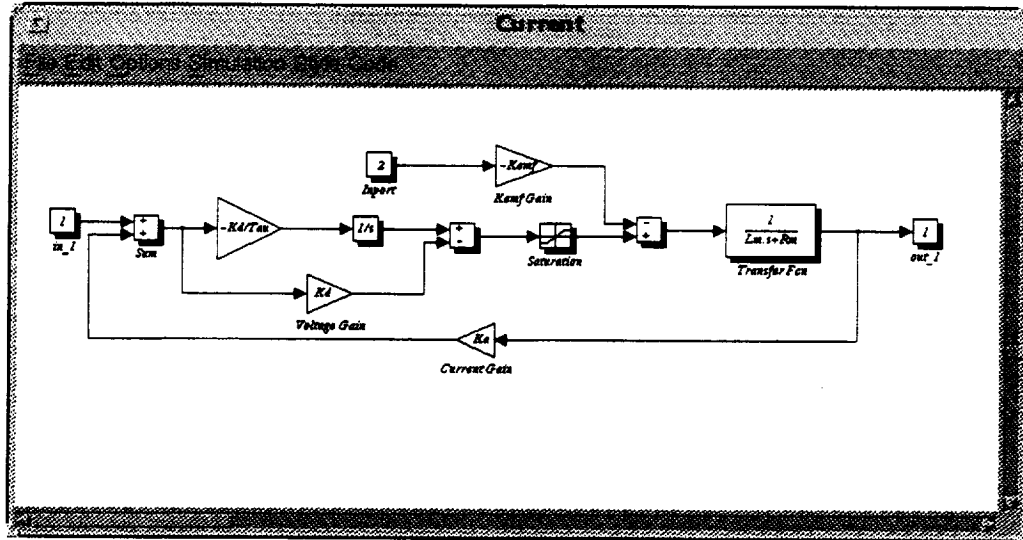


Figure 4. Current Module

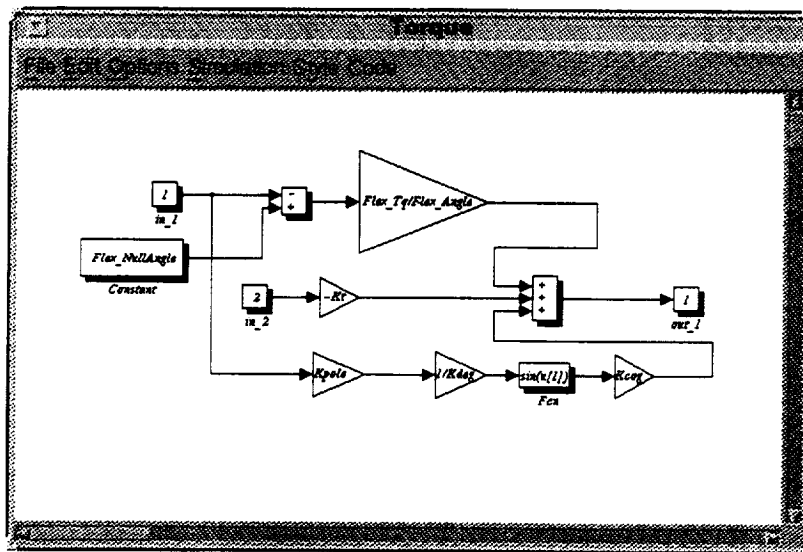


Figure 5. Torque Module



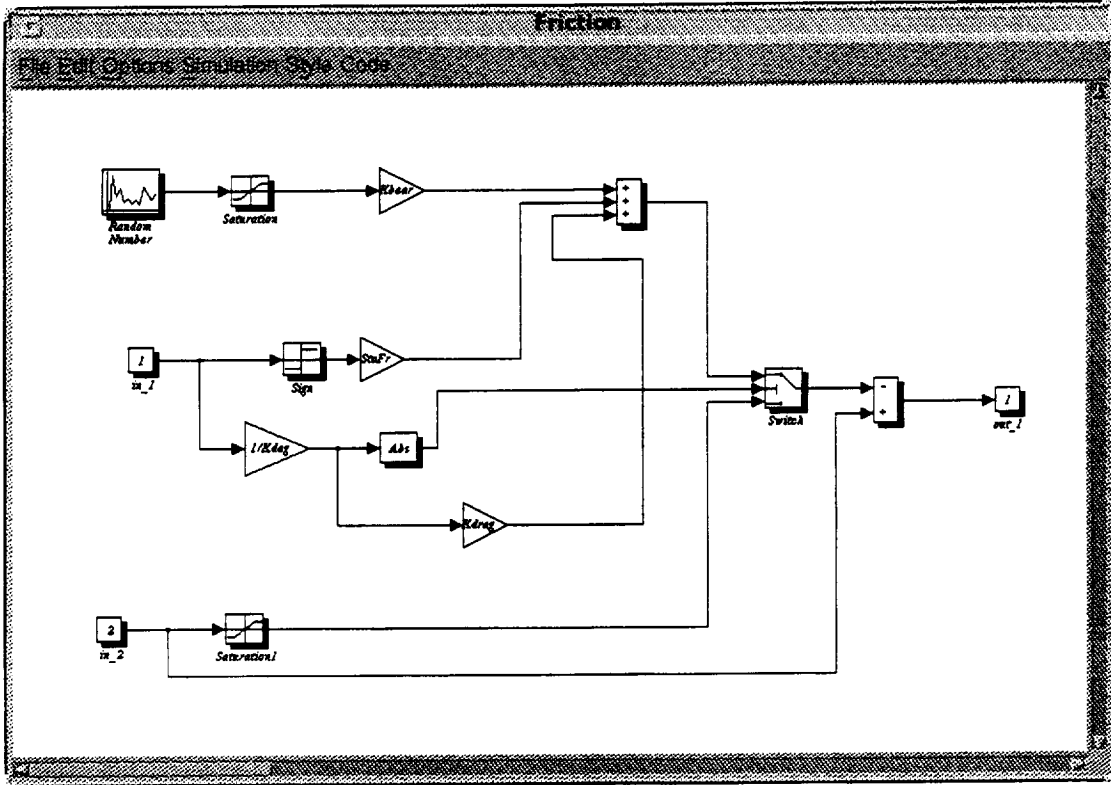


Figure 6. Friction Module

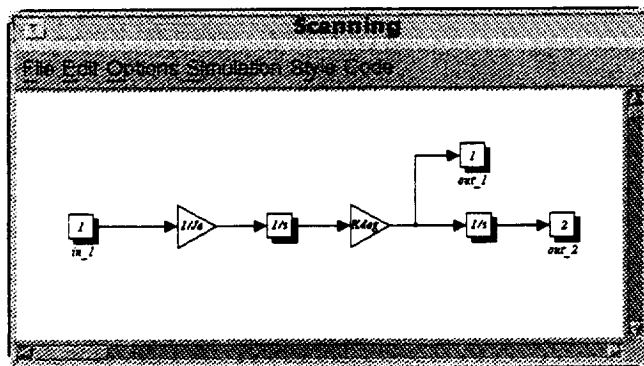


Figure 7. Scanning Module

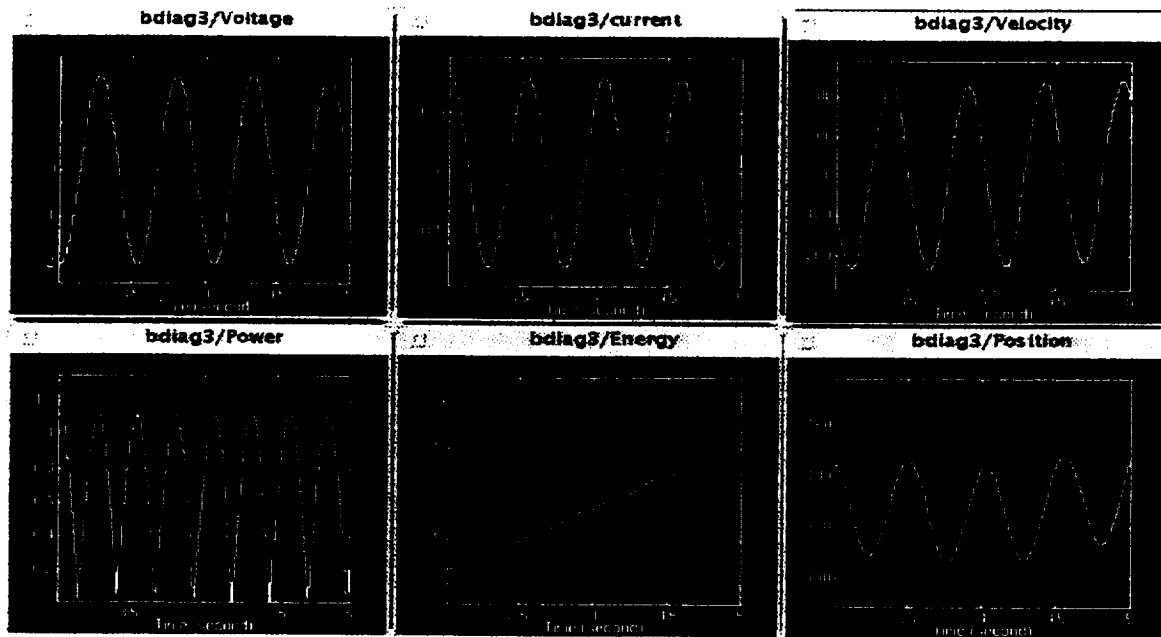


Figure 8. Results

## Conclusion

At this point the CERES simulator is still being assembled, and circuit cards are being populated and wired. It is scheduled to be completed well before the launch of the CERES instrument. Recent work has focused upon the completion of the elevation and azimuth drivers in the MATLAB/Simulink simulation. Most of the I/O cards and some other hardware parts are ready for integration into the system. Work will continue under the direction of John Chapman.

The MATLAB input files, describing the coefficients and equations of motion, the block diagrams depicting the mechanical components, and parameters for the elevation and azimuth scanner have been produced for MATLAB on a SUN workstation. MATLAB claims file portability between IBM PC, SUN, and SGI platforms. A functional demonstration of MATLAB/Simulink linked with CADSI DADS/Plant has been performed to verify this claim.

The DADS/Plant software eliminates the time-consuming, error-prone process of deriving and manipulating equations of motion for the plant model in simulation programs. It provides interactive, graphical and visualization construction of the plant mechanism model as well. The system simulation is performed under the control of the simulation program. Data transfer between DADS/Plant and the simulation program is completely automatic and transparent. The goal is to simulate the behavior of the CERES mechanical system in order to validate and improve designs from concepts of testing. Both the MATLAB/Simulink and DADS/Plant software are available for either Unix or SGI platforms.

## Langley Research Center Equipment and Facilities Employed

The project involved the use of several different computer platforms at Langley. Code development and control system simulations were performed on a SUN workstation. Simulations were performed using MATLAB/Simulink software. The DADS/Plant software is intended to be use as a visualization tool, which combines its features of mechanism modeling with the systems and control modeling features available in MATLAB/Simulink. This integrated solution provides an accurate, easily manipulated simulation of simple mechanisms and highly complex controlled mechanical systems.

## Acknowledgments

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