DESIGN AND ANALYSIS OF PRECISE POINTING SYSTEMS
Final Report

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1. Summary

In order to provide a desirable microgravity environment for experimental science payloads using the Microgravity Science Glovebox (MSG), NASA/MSFC is developing a microgravity vibration system named g-LIMIT (Glovebox Integrated Microgravity Isolation Technology) under an Advanced Technology Development (ATD) Project. The g-LIMIT is an experiment level active vibration isolation control system which implements an acceleration control logic and a position control logic that apply the controlled forces to the platform to negate the undesirable motion of the platform. Under this contract, the mathematical models of the g-LIMIT dynamics and control system were developed for MATLAB and TREETOPS simulations. These two models were cross-checked each other for their validation. An acceleration control logic and a proportional-integral-derivative (PID) position control logic were developed and implemented into the g-LIMIT dynamics model for simulation. The details of the g-LMIT dynamics and control models and their performance analysis using MATLAB and TREETOPS simulations are described in section 2.

The Laboratory Support Equipment (LSE) project is to provide generic laboratory thermal sensor, digital thermometer (DT) for payloads onboard ISS (International Space Station) that is manifested to support the 7A.1 launch in August 2000. Under this contract, the functional operation and performance of the chosen DT, Tektronix DTM920 were studied and incorporated in the DT operational procedures. The inputs to the crew procedures and training of digital thermometer were documented in section 3.

2. Control/Dynamics Simulation of g-LIMIT System

2.1 Introduction

The ambient acceleration environment of the International Space Station (ISS) is expected to exceed the desirable micro-gravity environment for some experimental science payloads. Therefore, an active vibration isolation control system may be needed to provide a more quiescent acceleration environment. For microgravity science experiments using the Microgravity Science Glovebox (MSG), a vibration isolation system, g-LIMIT (Glovebox Integrated Microgravity Isolation Technology), is being developed by the NASA/MSFC team.

The g-LIMIT system is an active vibration isolation system with six degrees of freedom acceleration and position controllers. The g-LIMIT system consists of an isolation platform on which experimental science payloads are mounted, three integrated isolator modules (IM), each of which is comprised of a dual axis actuator, two accelerometers and two position sensors, and associated electronics and control boards. The isolation platform is connected to the base through umbilical cords.

In this report, the mathematical model of g-LIMIT Dynamics/Control system, which was developed earlier in reference [1], is modified for the up-to-date g-LIMIT system. This linear model, coded using MATLAB, was mainly used to conveniently design control logic of the g-LIMIT acceleration and position controllers under the MATLAB environment. In order to verify this model and estimate the on-orbit g-LIMIT performance using transient response analysis, a high fidelity, nonlinear, multi-body simulation was developed using TREETOPS [2]. This report describes the details of TREETOPS model of the g-LIMIT dynamics and control system, and presents the results of the performance analysis of the g-LIMIT system using TREETOPS simulation. For detailed information on the analytical formulation and modeling aspects of TREETOPS, the reader is referred to the user's guide [2].

2.2 g-LIMIT Control Algorithms

The g-LIMIT will implement a variety of candidate control methods in both local control and central control architectures as described in reference [3]. In this section, a local single-input/single-output (SISO) control architecture is adopted for implementation in g-LIMIT control/dynamics simulation.

The high performance characteristics of the isolator are the result of active feedback loops involving actuators, sensors, and electronics. The isolated platform will be controlled by means of six independent control channels, one for each actuator force direction. Each g-LIMIT control channel will consist of one fast inner acceleration control loop and one slow outer position control loop. The key to the robust performance of g-LIMIT will be its six independent position and acceleration loops which provide high bandwidth acceleration feedback along with a positioning system that is insensitive to drift. A block diagram of this system is shown in Figure 2.2-1.

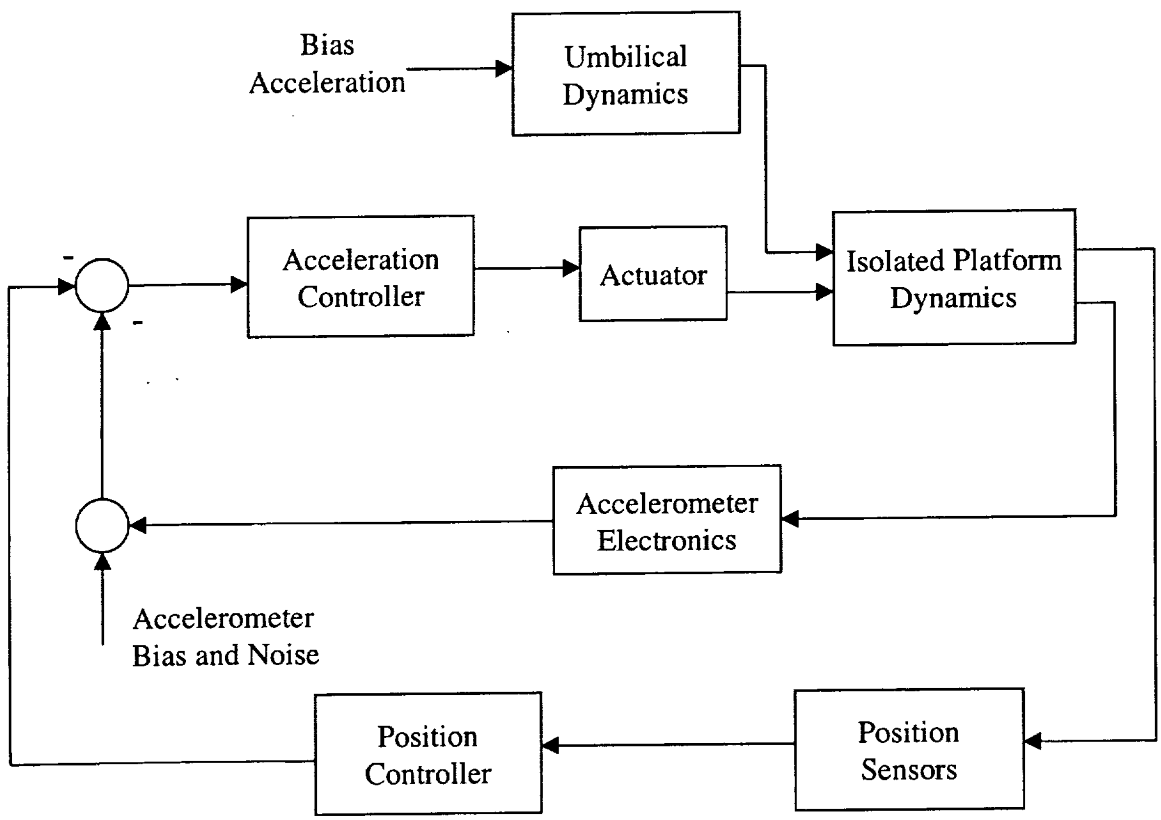

Figure 2.2-1: g-LIMIT General Block Diagram

A vibration isolator must attenuate "high-frequency" vibrations and be able to move with respect to the support structure and thus maintain an inertial position (or velocity) while the surrounding structure is in motion. To accomplish this, space must be provided around the isolated structure for it to "sway" back and forth. The geometry of the sway space determines the lower frequency limit for attenuation of base motion. Below this low-frequency limit, quasi-steady forces must be transmitted to the platform so that the platform will follow the low-frequency motion of the support structure. The position controller serves this purpose.

The baseline g-LIMIT SISO controller will consists of a proportional-integral-derivative (PID) controller with a series of four first order lag-lead filters and two first order low-pass filters. The six filters will be implemented to provide the general capability for loop shaping to enhance stability margin and performance when they are needed. However, these filters are not include in the current g-LIMIT analytical dynamics and control model.

The position loop will be a low bandwidth digital PID controller with 100 *msec.* sampling time. The low bandwidth digital position controller will calculate acceleration commands from the position sensor measurements to keep the floating platform centered in the sway space over a period of minutes. These acceleration commands are summed with the accelerometer signals and form the input to the acceleration loop control law.

The acceleration loop will be a high bandwidth digital PID controller with 1 *msec.* sampling time. The acceleration controller will generate a force command to the corresponding actuator force axis based on the designed analog control law. Performance of the acceleration loop will be limited by controller bandwidth, accelerometer noise, resolution- and temperature-dependent bias variations, and disturbances transmitted through the umbilical connections.

A block diagram of the discrete time PID controller is shown in Figure 2.2-2.

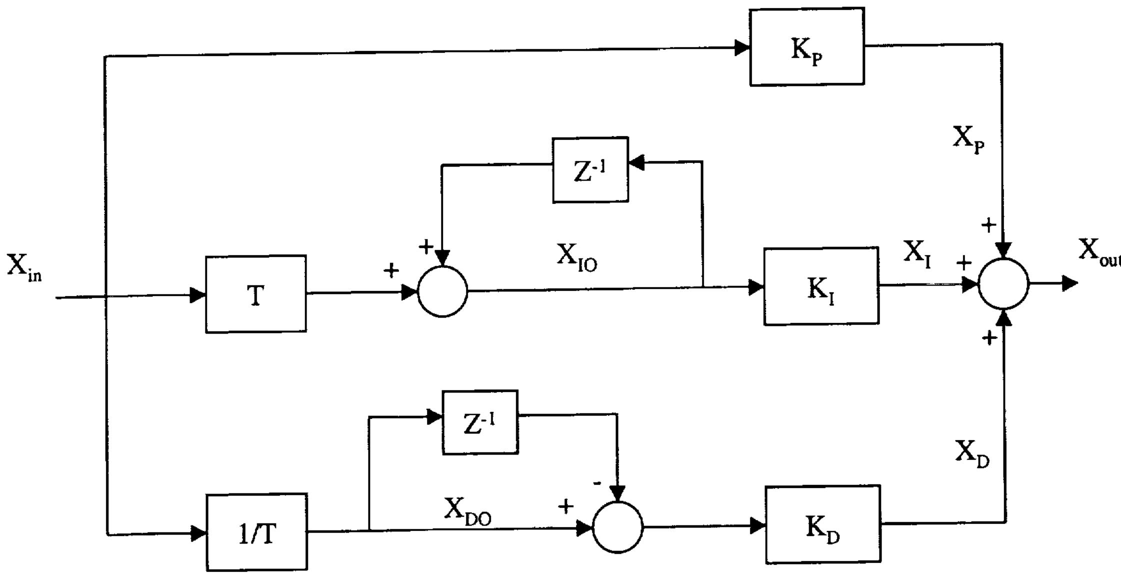

Figure 2.2-2: Discrete PID Controller Block Diagram

The equations that implement the PID controller transfer functions for the g-LIMIT MATLAB simulation are

$$
\begin{aligned}
X_P &= K_P * X_{in} \\
X_{IO} &= T * X_{in} + X_{IO} \\
X_I &= K_I * X_{IO} \\
X_D &= K_D * \left(\frac{1}{T} * X_{in} - X_{DO} \right) \\
X_{DO} &= \frac{1}{T} * X_{in} \\
X_{out} &= X_P + X_I + X_D .
\end{aligned}
\qquad (2.2\text{-}1)
$$

These equations are coded using MATLAB and attached in Appendix A.

The discrete PID controller is implemented in the g-LIMIT TREETOPS model using a discrete block diagram controller (DBDC) with transfer functions as shown in Figure 2.2-3.

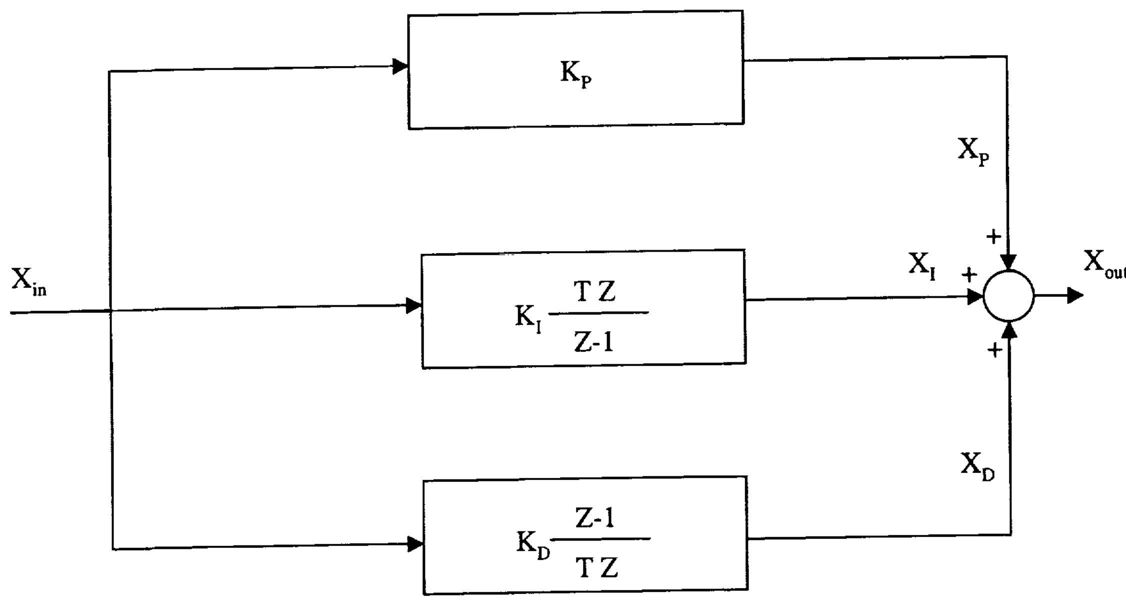

Figure 2.2-3: TREETOPS Discrete PID Controller Block Diagram

2.3 Description of g-LIMIT MATLAB Simulation

In this section the mathematical model of the g-LIMIT dynamics and control system, which was derived for an arbitrary configuration and mass properties in reference [1] was modified for up-to-date g-LIMIT configuration and mass properties. This updated mathematical g-LIMIT model was coded using MATLAB and attached in Appendix A. The MATLAB simulation was used for the validation of the TREETOPS simulation that was described in section 2.4. The equations of motion of the g-LIMIT platform, accelerometer sensor model, and position sensor model are rewritten from reference [1]. For detailed derivation of g-LIMIT mathematical model, the reader is referred to reference [1].

The equation of motion of the g-LIMIT platform can be written as the following second order ordinary differential equation

$$M_X \ddot{X} + C_X \dot{X} + K_X X = F_X, \qquad (2.3\text{-}1)$$

with

$$M_X = \begin{bmatrix} M\, I_{3x3} & -M\, \tilde{r}_c \\ 0_{3x3} & I_m \end{bmatrix}, \qquad (2.3\text{-}2a)$$

$$C_X = \sum_{i=1}^{2} \begin{bmatrix} C_{u_i} \begin{bmatrix} I_{3x3} & -\tilde{r}_{u_i} \end{bmatrix} \\ \tilde{r}_{Fu_i}\, C_{u_i} \begin{bmatrix} I_{3x3} & -\tilde{r}_{u_i} \end{bmatrix} \end{bmatrix}, \qquad (2.3\text{-}2b)$$

$$K_X = \sum_{i=1}^{2} \begin{bmatrix} K_{u_i} \begin{bmatrix} I_{3x3} & -\tilde{r}_{u_i} \end{bmatrix} \\ \tilde{r}_{Fu_i}\, K_{u_i} \begin{bmatrix} I_{3x3} & -\tilde{r}_{u_i} \end{bmatrix} \end{bmatrix}, \qquad (2.3\text{-}2c)$$

$$\begin{aligned} F_X = &-\begin{bmatrix} M\, I_{3x3} \\ 0_{3x3} \end{bmatrix} \ddot{R}_0^{\,T} + \begin{bmatrix} (I_{3x3} + \tilde{\theta}) \\ \tilde{R}_{Fd} \end{bmatrix} f_d^{\,T} \\ &+ \begin{bmatrix} \left(I_{3x3} + \tilde{\theta}\right)[C_1 \quad C_2 \quad C_3] & & \\ \left(\tilde{R}_{Fa_1} C_1\right) & \left(\tilde{R}_{Fa_2} C_2\right) & \left(\tilde{R}_{Fa_3} C_3\right) \end{bmatrix} U_T\, f_a^{\,T}, \end{aligned} \qquad (2.3\text{-}2d)$$

$$\tilde{R}_{Fa_m} \equiv \left[\tilde{r}_{Fa_m} + \tilde{r}_{Fa_m}\tilde{\theta} - (r_{Fa_m}\tilde{\theta})^{\sim}\right] \qquad (2.3\text{-}2e)$$

$$\tilde{R}_{Fd} \equiv \left[\tilde{r}_{Fd} + \tilde{r}_{Fd}\,\tilde{\theta} - (r_{Fd}\;\tilde{\theta})^{\sim}\right]. \qquad (2.3\text{-}2f)$$

The symbols used in the above equations are as follows.

$C_m = \begin{bmatrix} \cos\theta_m & -\sin\theta_m & 0 \\ \sin\theta_m & \cos\theta_m & 0 \\ 0 & 0 & 1 \end{bmatrix}$ is transformation matrix from the platform coordinates to the *m*th IM's coordinates whose origins are located at the counterclockwise (*m=1,2,3*) azimuths of $\theta_1 = 90^\circ, \theta_2 = 210^\circ, \theta_3 = 330^\circ$ about the z-axis from the positive x-axis

C_{u_i} = 3 by 3 matrix whose elements are damping coefficient of the *i*th umbilical cord in the directions of the inertial coordinates

$f_a = \begin{bmatrix} F_{a_{1x}} & F_{a_{1z}} & F_{a_{2x}} & F_{a_{2z}} & F_{a_{3x}} & F_{a_{3z}} \end{bmatrix}$, row matrix whose components are x and z-axis directional forces of three actuators

f_d = row matrix whose three elements are x, y, and z-axis components of the disturbance force in the platform coordinates.

I_m = mass moment of inertia matrix of the g-LIMIT floating platform about the platform coordinate fixed to the CM

I_{3x3} = 3 by 3 unity matrix; 0_{3x3} = 3 by 3 zero matrix

K_{u_i} = 3 by 3 stiffness coefficient matrix whose elements are spring stiffness of the *i*th umbilical cord in the direction of the inertial coordinates.

M = mass of the g-LIMIT floating platform

$\tilde{r}_c$ = skew matrix of $r_c = [x_c \; y_c \; z_c]$ that is a row matrix of position vector from the origin of the platform coordinates to the CM of the platform

$\tilde{r}_{Fa_m}$ = skew matrix of $r_{Fa_m} = [(x_{f_m} - x_c) \quad (y_{f_m} - y_c) \quad (z_{f_m} - z_c)]$, where x_{f_m}, y_{f_m}, and z_{f_m} are three components of position vector from the origin of the platform coordinates to mth actuators, $\vec{r}_{f_m}$ $(m = 1, 2, 3)$.

$\tilde{r}_{Fd}$ = skew matrix of $r_{Fd} = [(x_d - x_c) \quad (y_d - y_c) \quad (z_d - z_c)]$, where $r_d = [x_d \; y_d \; z_d]$ is row matrix of position vector from the origin of the platform coordinates to the external force's acting point on the platform

$\tilde{r}_{Fu_i}$ = skew matrix of $r_{u_i} - r_c = [(x_{u_i} - x_c) \quad (y_{u_i} - y_c) \quad (z_{u_i} - z_c)]$

$\tilde{r}_{u_i}$ = skew matrix of two position vectors from the origin of the platform coordinates to two umbilical cords' attached points on the platform, $\vec{r}_{u_i}$ $(i = 1, 2)$

$\ddot{R}_0$ = row matrix whose three components are base accelerations to the direction of x, y, and z-axis of the inertial coordinates

$$U_T = \begin{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} & 0_{3x2} & 0_{3x2} \\ 0_{3x2} & \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} & 0_{3x2} \\ 0_{3x2} & 0_{3x2} & \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \end{bmatrix}$$

$X =$ a column matrix of state $[X \;\; Y \;\; Z \;\; \theta_x \;\; \theta_y \;\; \theta_z]^T$, where X, Y, Z are three components of relative displacement vector, $\vec{r}$ of the platform at the origin of the platform coordinates, and $\theta_x, \theta_y, \theta_z$ are three rotational DOF about x, y, z-axis of the platform coordinates, respectively

$\tilde{\theta}$ = skew matrix of row matrix $[\theta_x, \theta_y, \theta_z]$

$(\;)^T$ = transpose matrix of the matrix inside the parenthesis.

$(\;)^{\sim}$ = skew matrix of the row matrix inside the parenthesis.

In order to solve the equation (2.3-1) numerically, a new state $Z = [X^T \quad \dot{X}^T]^T$ is introduced and the second order differential equation is converted to the following first order ordinary differential equation

$$\dot{Z} = \begin{bmatrix} 0_{6x6} & I_{6x6} \\ -M_X^{-1} K_X & -M_X^{-1} C_X \end{bmatrix} Z + \begin{Bmatrix} 0_{6x1} \\ M_X^{-1} F_X \end{Bmatrix}. \qquad (2.3\text{-}3)$$

The g-LIMIT system has three isolator modules (IMs) and each g-LIMIT IM has two accelerometers which measure the accelerations at the location of the accelerometer in the x and z-axis directions of the IM coordinates. The output of total accelerometers, $A = \begin{bmatrix} a_{1_x} & a_{1_z} & a_{2_x} & a_{2_z} & a_{3_x} & a_{3_z} \end{bmatrix}$ can be determined by

$$A^T = \begin{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_1^T \begin{bmatrix} I_{3x3} & -\tilde{r}_{a_1} \end{bmatrix} \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_2^T \begin{bmatrix} I_{3x3} & -\tilde{r}_{a_2} \end{bmatrix} \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_3^T \begin{bmatrix} I_{3x3} & -\tilde{r}_{a_3} \end{bmatrix} \end{bmatrix} \ddot{\mathrm{X}} + \begin{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_1^T \begin{bmatrix} 0_{3x3} & \tilde{\ddot{R}}_0 \end{bmatrix} \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_2^T \begin{bmatrix} 0_{3x3} & \tilde{\ddot{R}}_0 \end{bmatrix} \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_3^T \begin{bmatrix} 0_{3x3} & \tilde{\ddot{R}}_0 \end{bmatrix} \end{bmatrix} \mathrm{X} + \begin{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_1^T \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_2^T \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_3^T \end{bmatrix} \ddot{R}_0^T, \tag{2.3-4}$$

where $\tilde{r}_{a_i}$ is a skew matrix of three position vectors from the origin of the platform coordinates to the centers of three accelerometer assembly boxes, $\vec{r}_{a_i}$ $(i = 1, 2, 3)$.

Each g-LIMIT IM has two position sensors which measure the relative movements at the location of position sensor to the x and z-axis directions of the IM coordinates. The output of total position sensors, $\delta P = \begin{bmatrix} \delta_{P_{1x}} & \delta_{P_{1z}} & \delta_{P_{2x}} & \delta_{P_{2z}} & \delta_{P_{3x}} & \delta_{P_{3z}} \end{bmatrix}$ can be determined by

$$\begin{aligned} \delta P^T &= \begin{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_1^T \begin{bmatrix} I_{3x3} & -\tilde{r}_{P_1} \end{bmatrix} \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_2^T \begin{bmatrix} I_{3x3} & -\tilde{r}_{P_2} \end{bmatrix} \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} C_3^T \begin{bmatrix} I_{3x3} & -\tilde{r}_{P_3} \end{bmatrix} \end{bmatrix} \mathrm{X} \\ &\equiv T_X^P \, \mathrm{X}, \end{aligned} \tag{2.3-5}$$

where $\tilde{r}_{P_i}$ is a skew matrix of three position vectors from the origin of the platform coordinates to the centers of three position sensor assemblies, $\vec{r}_{P_i}$ $(i = 1, 2, 3)$.

2.4 Description of g-LIMIT TREETOPS Simulation

In order to verify the control system and estimate the performance of the g-LIMIT in the orbital environment, a detailed structural and control model of the g-LIMIT was developed for the TREETOPS simulation. Since the isolation platform of the g-LIMIT is floating freely within the MSG locker box that is rigidly attached to the space shuttle, the g-LIMIT system was modeled as two rigid bodies (Body #1 for the space shuttle and MSG locker box including g-LIMIT system components fixed to the MSG base and Body #2 for the floating platform including g-LIMIT system components fixed to the platform). The only physical connections between the platform and bases are the umbilical cables (that transfers data and power between the platform and base) which are modeled six degree of freedom (DOF) hinge connection with spring stiffness specified to match the dynamic properties of the umbilical cables.

The g-LIMIT actuator that yields two orthogonal forces is modeled using two TREETOPS JET actuators and each g-LIMIT accelerometer sensor is modeled using the TREETOPS ACCELEROMETER sensor. Actuator and accelerometer sensor models are idealized and do not include high frequency dynamics. Since there is no built-in TREETOPS position sensor model that exactly corresponds to the g-LIMIT position sensor, a mathematical position sensor model was developed using the built-in TREETOPS POSITION VECTOR sensor. This position sensor model was implemented in a user defined continuous controller subroutine (USCC) and incorporated with main TREETOPS dynamics simulation.

The local coordinates and locations of the actuators and sensors are shown in Figure 2.4-1. Each integrated isolator module (IM) is comprised of a dual axis actuator, two accelerometers and two position sensors. In this figure F_{ij}, A_{ij}, and e_{ij} denote *j*th actuator force component, *j*th acceleration component of, and *j*th position error component of *i*th isolator module, respectively. (1st, 2nd, and 3rd components stand for x, y and z axis components, respectively.)

With supplied mass properties (mass and moments of inertia) of two bodies and the locations of center of mass, actuators, accelerometers, position sensors, and umbilical cords connection, TREETOPS determines the kinematics and dynamics of the g-LIMIT system. The fast continuous acceleration control loop was implemented in the g-LIMIT TREETOPS model using the built-in TREETOPS discrete block diagram controller (DBDC) and the slow digital position control loop was implemented in the g-LIMIT TREETOPS model also using a DBDC. The g-LIMIT local SISO controller has six independent control channels, whose architectures are exactly same, for six actuator forces. The architecture of g-LIMIT TREETOPS dynamics and control model is shown in Figure 2.4-2. In Figure 2.4-2 CO*m*_I*n* denotes *n*th input of controller #*m* and CO*m*_O*n* denotes *n*th output of controller #*m*.

Since the objective of the g-LIMIT TREETOPS simulation is to analyze the attenuation of acceleration disturbance from the locker box to the isolation platform of the g-LIMIT, Body #1 was modeled as one arbitrary rigid body that gives a disturbance to the g-LIMIT platform through umbilical cables. According to the TREETOPS tree topology, Body #1 and linked by Hinge #1 with six degrees of freedom (three rotational and three translational) with respect to the origin of the inertial coordinate system. The platform floating inside the locker box is defined by Body #2 and connected to Body #1 through Hinge #2 with six D.O.F. The umbilical connection between the platform and locker box are modeled as the combination of six linear spring devices with a 10 meter undeformed length.

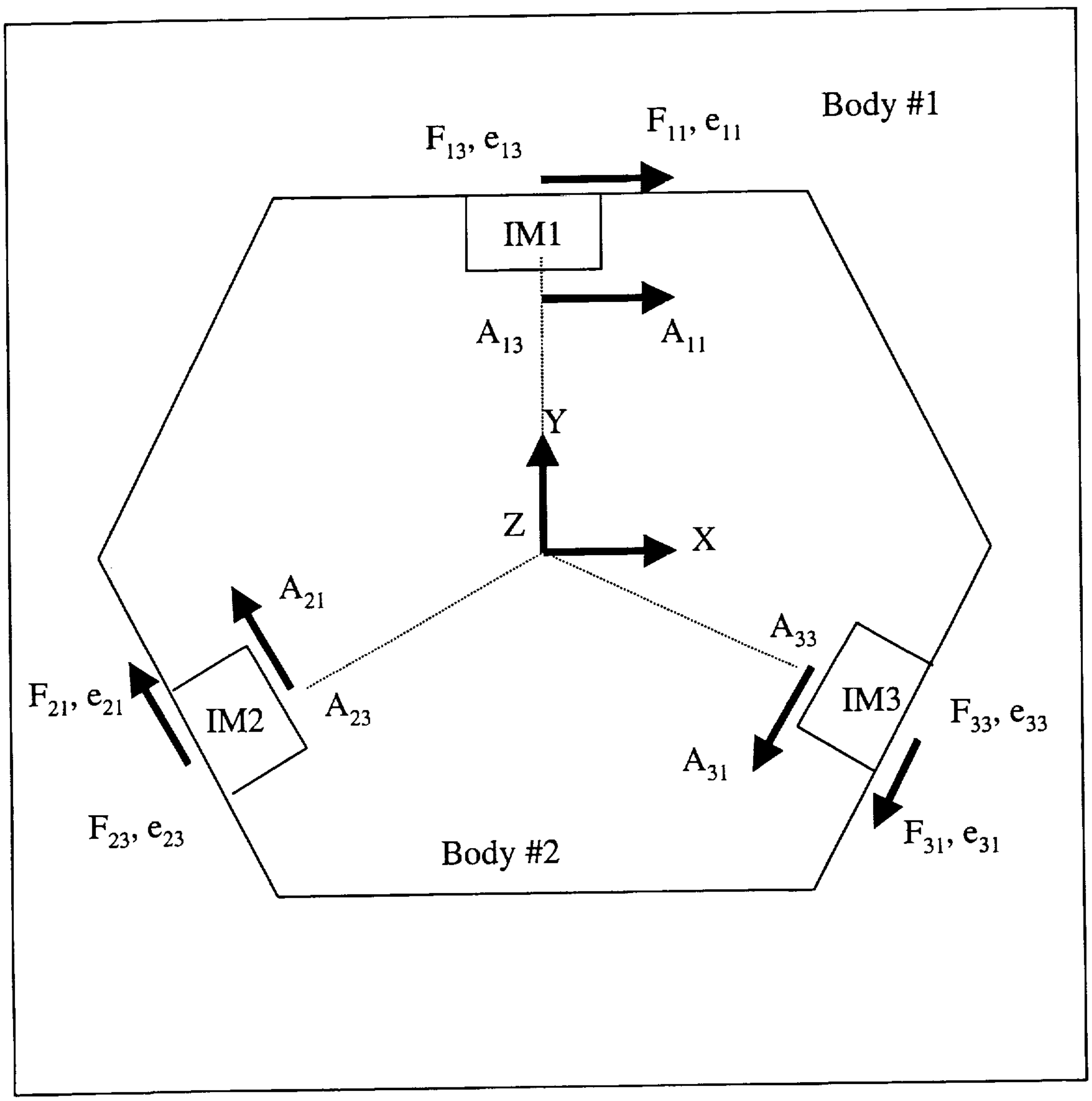

Figure 2.4-1: g-LIMIT TREETOPS Model Coordinate System

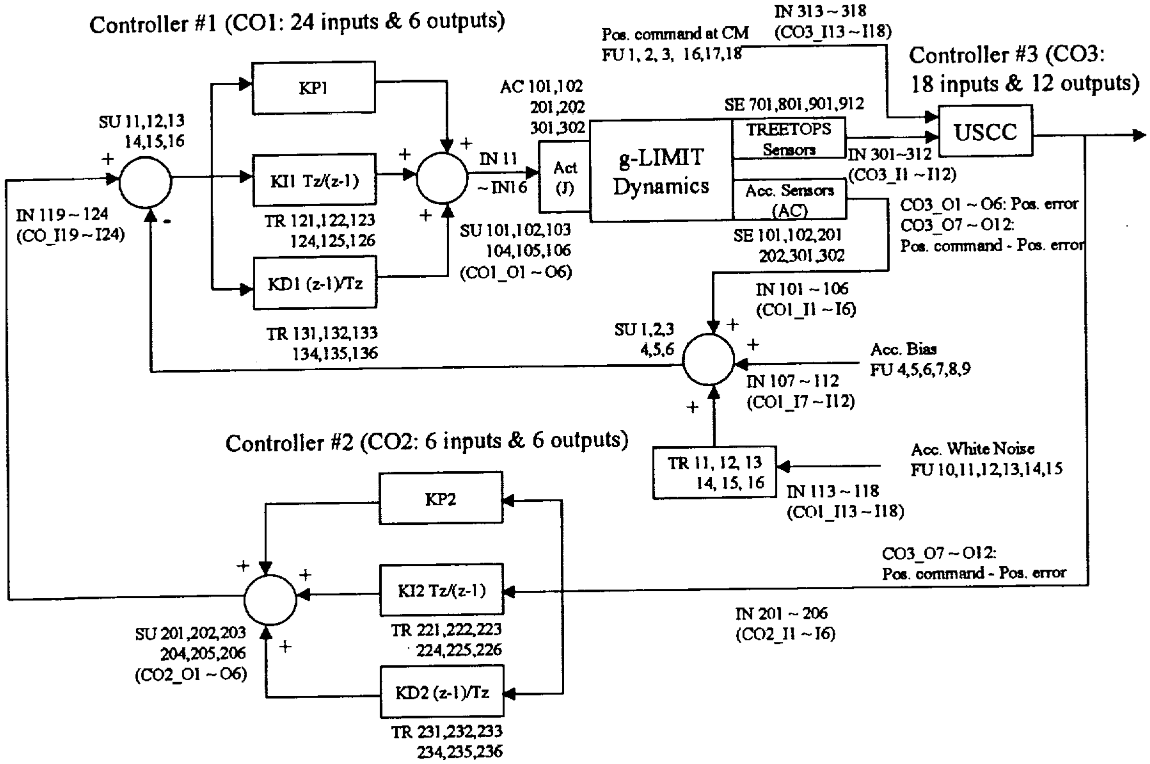

Figure 2.4-2. Architecture of g-LIMIT TREETOPS Model

2.4.1 g-LIMIT Structural TREETOPS Model

For Body #1, twelve nodal points are chosen to represent the center of mass, origin of local coordinate system of Body #1, three corresponding points to the original positions of position sensors, one corresponding point to the center of mass of the Body #2, and six umbilical cords attaching points. For Body #2, thirteen nodal points are chosen to represent the center of mass, origin of local coordinate system of Body #2, three actuator attaching points, three accelerometer attaching points, three position sensor attaching points, and two umbilical attaching points. Table 2.4.1-1 summarized the nodes of Body #1 (for example, B1N2 denotes node #2 of Body #1). And the nodes of Body #2 are summarized in Table 2.4.1-2 (for example, B2N2 denotes node #2 of Body #2). The definitions of all hinges of STABLE TREETOPS model are summarized in Table 2.4.1-3.

Table 2.4.1-1: Nodes Definition of TREETOPS g-LIMIT Body #1

Node	Description	Location in body coordinates (meter)
B1N1	C.M. of Body #1	(0,0,0.02)
B1N2	Origin of Body #1 coordinates	(0,0,0)
B1N3	Position sensor #1, #2	(0,0.1226,0.0848)
B1N4	Position sensor #3, #4	(-0.1062,-0.0613,0.0848)
B1N5	Position sensor #5, #6	(0.1062,-0.0613,0.0848)
B1N6	C.M. of Body #2	(0.004,-0.02,0.067)
B1N7	X umbilical #1	(10.0686,-0.0787,-0.0205)
B1N8	Y umbilical #1	(0.0686,9.9213,-0.0205)
B1N9	Z umbilical #1	(0.0686,-0.0787,9.9795)
B1N10	X umbilical #2	(9.9314,-0.0787,-0.0205)
B1N11	Y umbilical #2	(-0.0686,9.9213,-0.0205
B1N12	Z umbilical #2	(-0.0686,-0.0787,9.9795)

Table 2.4.1-2: Nodes Definition of TREETOPS g-LIMIT Body #2

Node	Description	Location in body coordinates (meter)
B2N1	C.M. of Body #2	(0.004,-0.020,0.067)
B2N2	Origin of Body #2 coordinates	(0,0,0)
B2N3	Accelerometer #1, #2	(0,0.0411,0.0747)
B2N4	Accelerometer #3, #4	(-0.0356,-0.0206,0.0747)
B2N5	Accelerometer #5, #6	(0.0356,-0.0206,0.0747)
B2N6	Position sensor #1, #2	(0,0.1226,0.0848)
B2N7	Position sensor #3, #4	(-0.1062,-0.0613,0.0848)
B2N8	Position sensor #5, #6	(0.1062,-0.0613,0.0848)
B2N9	Actuator #1, #2	(0,0.1226,0.0848)
B2N10	Actuator #3, #4	(-0.1062,-0.0613,0.0848)
B2N11	Actuator #5, #6	(0.1062,-0.0613,0.0848)
B2N12	Umbilical #1	(0.0686,-0.0787,-0.0205)
B2N13	Umbilical #2	(-0.0686,-0.0787,-0.0205)

Table 2.4.1-3: Hinges Definition of g-LIMIT TREETOPS Model

Hinge	Connecting nodes	No. of DOF	L1_in - L1_out	L3_in - L3_out
1	B0N0 - B1N2	3RDOF, 3TDOF	(1,0,0) - (1,0,0)	(0,0,1) - (0,0,1)
2	B1N6 - B2N1	3RDOF, 3TDOF	(1,0,0) - (1,0,0)	(0,0,1) - (0,0,1)

2.4.2 g-LIMIT Sensors TREETOPS Model

g-LIMIT has six QA-3000 accelerometers on the floating platform to measure acceleration at the attached nodes. This accelerometer was modeled as TREETOPS ACCELEROMETER (AC) sensor that measures the acceleration of body at the specified node to the specified direction. Therefore, six AC sensors are attached on the nodes #3,4,5 of Body #2 and defined as SE 101, SE 102, SE 201, SE 202, SE 301, and SE 302. STABLE has three position sensor assemblies to measure the relative position errors between the floating platform and locker base at three position sensor locations. The six components of these three position sensors are determined by transferring the position components, that are obtained using three TREETOPS POSITION VECTOR (P3) sensors, SE 701, SE702, and SE703, to the directions of isolated module coordinates. Therefore, the outputs of mth position sensor are given by

$$\begin{Bmatrix} dx \\ dz \end{Bmatrix}_m = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} [C_m]^T [C]^T \begin{Bmatrix} p_x \\ p_y \\ p_z \end{Bmatrix}_m \qquad (m = 1, 2, 3),$$

where C_m is a transformation matrix from the platform coordinates to the mth IM's coordinates, and C is a transformation matrix from the inertial coordinates to the platform coordinate. The C matrix can be calculated with Euler angles of Body #2 coordinates obtained using TREETOPS IMU sensor, SE 912. All TREETOPS sensors that are implemented in g-LIMIT TREETOPS model are summarized in Table 2.4.2-1.

2.4.3 g-LIMIT Actuator TREETOPS Model

The g-LIMIT has three electro-magnetic dual-axis actuators which generate two orthogonal forces. Each actuator is modeled as two TREETOPS JET (J) actuators. The JET actuator applies a force to the specified direction at the node of the platform where the actuator is attached. The six JET actuators are attached on the nodes #9,10,11 of Body #2. For the purpose of performance analysis, disturbance can be given by applying force on the C.M. of Body # 1 using a separate JET actuator. All TREETOPS actuators that are implemented in g-LIMIT TREETOPS model are summarized in Table 2.4.3-1.

Table 2.4.2-1: Definition of g-LMIT TREETOPS Sensors Model

Sensor ID No. (Type)	Measurement Quantity	Location (Direction)
SE 1 (AC)	$a_{x_{CM}}$ of Body #2	B2N1 (1,0,0)
SE 2 (AC)	$a_{y_{CM}}$ of Body #2	B2N1 (0,1,0)
SE 3 (AC)	$a_{z_{CM}}$ of Body #2	B2N1 (0,0,1)
SE 101 (AC)	Acceleration #1	B2N3 (1,0,0)
SE 102 (AC)	Acceleration #2	B2N3 (0,0,1)
SE 201 (AC)	Acceleration #3	B2N4 (-0.5,0.86603,0)
SE 202 (AC)	Acceleration #4	B2N4 (0,0,1)
SE 301 (AC)	Acceleration #5	B2N5 (-0.5,-0.86603,0)
SE 302 (AC)	Acceleration #6	B2N5 (0,0,1)
SE 701 (P3)	x_{p1}, y_{p1}, z_{p1}	(B1N3)-(B2N6)
SE 801 (P3)	x_{p2}, y_{p2}, z_{p2}	(B1N4)-(B2N7)
SE 901 (P3)	x_{p3}, y_{p3}, z_{p3}	(B1N5)-(B2N8)
SE 911 (P3)	Relative movement of Body #2 C.M. w.r.t Body #1	(B1N6)-(B2N1)
SE 912 (IM)	Euler angles of Body #2 frame	B2N1
SE 921 (P3)	Movement of Body #1 C.M.	(B0N0)-(B1N1)
SE 922 (IM)	Euler angles of Body #1 frame	B1N2

Table 2.4.3-1: Definition of g-LIMIT TREETOPS Actuators Model

Actuator ID No. (Type)	Measurement Quantity	Location (Direction)
AC 1 (J)	base disturbance force (x-axis direction)	B1N2 (1,0,0)
AC 2 (J)	base disturbance force (y-axis direction)	B1N2 (0,1,0)
AC 3 (J)	base disturbance force (z-axis direction)	B1N2 (0,0,1)
AC 101 (J)	Actuator force #1	B2N9 (1,0,0)
AC 102 (J)	Actuator force #2	B2N9 (0,0,1)
AC 201 (J)	Actuator force #3	B2N10 (-0.5,0.86603,0)
AC 202 (J)	Actuator force #4	B2N10 (0,0,1)
AC 301 (J)	Actuator force #5	B2N11 (-0.5,-0.86603,0)
AC 302 (J)	Actuator force #6	B2N11 (0,0,1)

2.4.4 g-LIMIT Control TREETOPS Model

The g-LIMIT TREETOPS control model consists of three TREETOPS controllers (CO1, CO2, and CO3). The controller #1 implements one fast inner PID acceleration control loop using a TREETOPS control module, DBDC (Discrete Block Diagram Control). The controller #1 has twenty four inputs : six accelerometer outputs (SE 101,102,201,202,301,302), six accelerometer bias (Function Generators FU 4~9), six accelerometer noise (FU 10~15), and six acceleration commands calculated from position control loop (CO2_O1~O6). The controller #1 generates six actuator commands (SU 101~106). The controller #1 consists of eighteen transfer functions (TR 11~16, TR 121~126, TR 131~136), eighteen summing junctions (SU 1~6, SU 11~16, SU 101~106), and twenty four interconnects (IN 11~IN 16, IN 101~106, IN 107~112, IN 113~118, IN 119~124).

The controller #2 implements one slow outer PID position control loop using a TREETOPS control module, DBDC.). The controller #1 has six inputs (Subtraction of position sensor outputs from position commands at the position sensor's locations, CO3_O7~O12) and six outputs (six acceleration commands, SU 201~206). The controller #2 consists of twelve transfer functions (TR 221~226, TR 231~236), six summing junctions (SU 201~206), and six interconnects (IN 201~206).

The controller #3 is implemented using a USCC (User Defined Continuous Control) subroutine to calculate the g-LIMIT position sensor outputs and the inputs for the controller #2. This USCC routine is attached in Appendix B. This controller requires eighteen inputs (thee outputs from each TREETOPS sensors SE 701, 801, 901, 912 and six position command at the platform CM, FU 1, 2, 3, 16, 17, 18) and uses eighteen interconnects (IN 301~318) to read inputs. The complete input file of the g-LIMIT TREETOPS model is attached in Appendix C.

2.5 g-LIMIT Simulation Results

Since all of the hardware elements of the g-LIMIT system, including umbilical cords, are not yet defined, numerical simulation is performed based on currently available configuration and mass properties with estimated stiffness of umbilical cords. Mass properties of the g-LIMIT platform used for numerical simulation are described in Table 2.5-1.

Table 2.5-1: Mass Properties of The g-LIMIT Platform

Mass (*Kg*)	7.8681
$I_{xx}, I_{yy}, I_{zz}, I_{xy}, I_{xz}, I_{yz}$ $(Kg - m^2)$	0.0793, 0.0807, 0.1407, 0, 0, 0

The stiffness of umbilical cords used for g-LIMIT TREETOPS model are 18 *N/m* in the positive X-axis direction, 13.5 *N/m* in the positive Y-axis direction and 20 *N/m* in the positive Z-axis direction. The g-LIMIT control logic implemented in TREETOPS simulation consists of two control modes (active mode and standby mode). The standby control mode has only position controller on. For the implementation of this control mode in the TREETOPS simulation, proportional gain of acceleration PID controller is set to one with zero derivative and integral gains. The active control mode has both acceleration and position controllers on. The control parameters used for the acceleration controller and position controller of the g-LIMIT system were determined through iterative design and performance analysis and summarized in Table 2.5-2.

Table 2.5-2: g-LIMIT Control Parameters

Control Parameters	Active Mode	Standby Mode
$KD1\ (N\sec^3/m)$	0	0
$KP1\ (N\sec^2/m)$	0	1
$KI1\ (N\sec/m)$	3e+3	0
$KD2\ (1/\sec)$	6.2e-2	12.4
$KP2\ (1/\sec^2)$	2.4e-2	19.8
$KI2\ (1/\sec^3)$	2.5e-4	25

Biased acceleration and white noise are added to the accelerometer outputs to represent the hardware characteristics of the g-LIMIT accelerometers. The acceleration biases for the six accelerometers were chosen arbitrarily for this simulation as shown in Table 2.5-3.

Table 2.5-3: Acceleration Biases of Six Accelerometers

Acc. Bias	A11	A13	A21	A23	A31	A33
μg	105	-155	85	-125	25	115

The white noise accelerations were generated by multiplying pseudo random numbers by the following transfer function.

$$T_{wh} = \frac{K\omega_n^2(s+a)}{a(s^2+2\xi\omega_n s+\omega_n^2)}$$

where $K = 2\times 10^{-5}\, m/\sec^2$, $a = 2\pi(20)\, rad/\sec$, $\omega_n = 2\pi(100)\, rad/\sec$ and $\xi = 0.85$.

This transfer function was converted to the discrete form as

$$T_{wh} = \frac{K\omega_n^2 T}{a}\frac{-z+(1+aT)z^2}{1-2(1+\xi\omega_n T)z+(1+2\xi\omega_n T+\omega_n^2T^2)z^2},$$

where T is sampling time of 1 *msec*. and implemented into the TREETOPS transfer functions, TR 11, 12, 13, 14, 15, 16 of g-LIMIT TREETOPS controller #1.

2.5.1 Stability Analysis

In order to verify the g-LIMIT MATLAB and TREETOPS models and investigate the stability of g-LIMIT system with acceleration and position control, two test cases are studied: The first test case is the transient response analysis with initial displacement and second one is the transient response analysis with initial excitation. Both MATLAB and TREETOPS simulations were performed for these cases under active control mode and their numerical results are compared.

For the first test case, the g-LIMIT platform was initially displaced from the nominal resting position by 10 *mm* in each x, y, z axis direction and transient response analysis were performed. The accelerations and displacements at the platform CM obtained from MATLAB and TREETOPS simulation are shown in Figure 2.5.1-1 and Figure 2.5.1.-2. These figures show close match between MATLAB and TREETOPS simulation results and good recovery from initial displacement to nominal rest position.

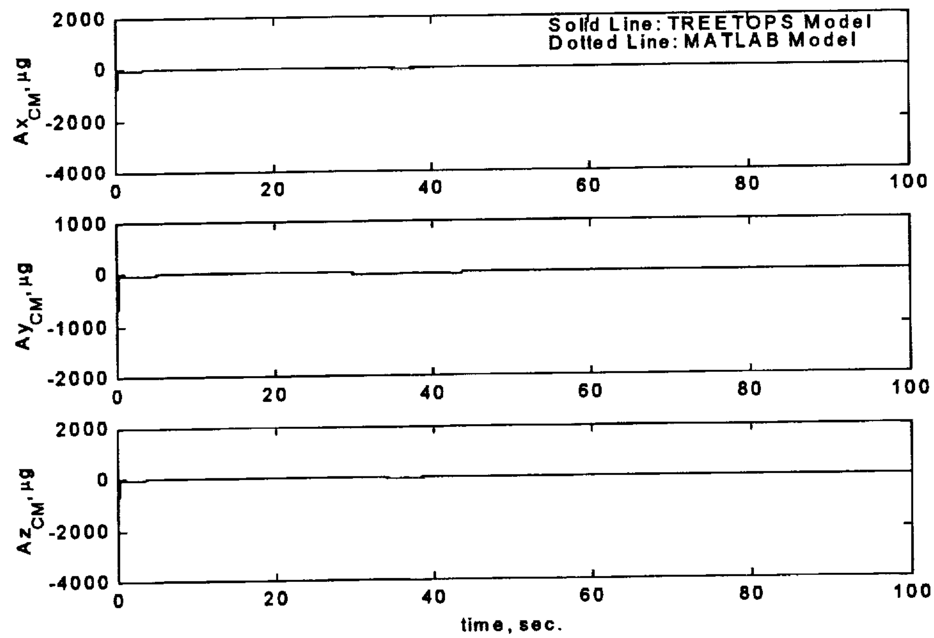

Figure 2.5.1-1: Acceleration at Platform CM with Initial Displacement

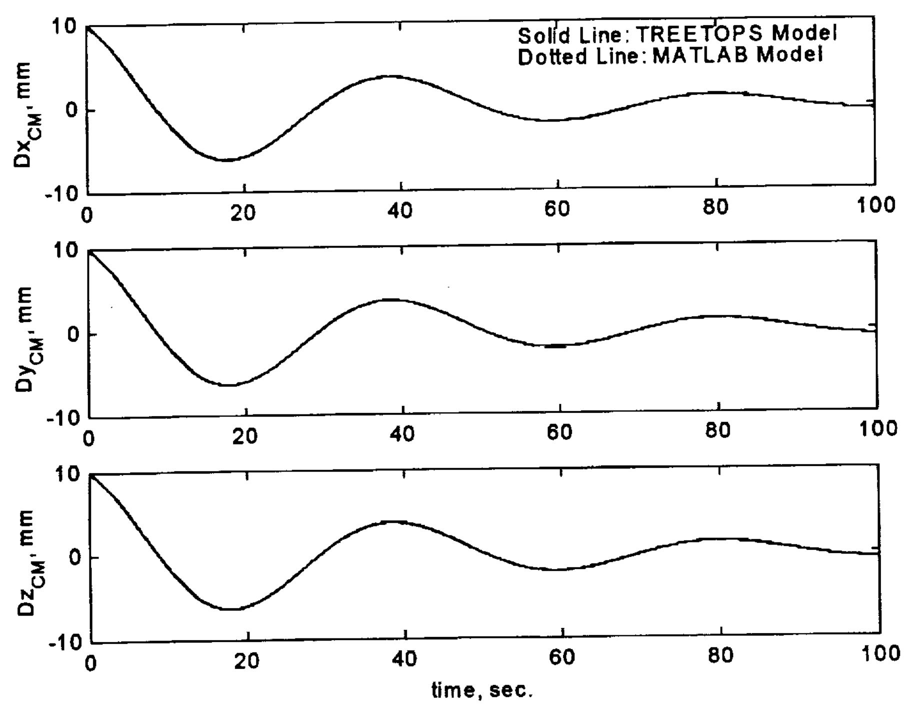

Figure 2.5.1-2: Displacement at Platform CM with Initial Displacement

For the second test case, in order to demonstrate how well the g-LIMIT system can overcome sudden disturbance, 100 μg pulse-type disturbance was given to the base in each x, y, z axis direction for 1 second and then transient response analysis were performed. The numerical results obtained from MATLAB and TREETOPS simulation for this case are shown in Figure 2.5.1-3 and Figure 2.5.1.-4. These figures show accelerations and displacements at the platform CM that converge to the nominal rest values. These also demonstrate that the MATLAB and TREETOPS g-LIMIT models are in good agreement.

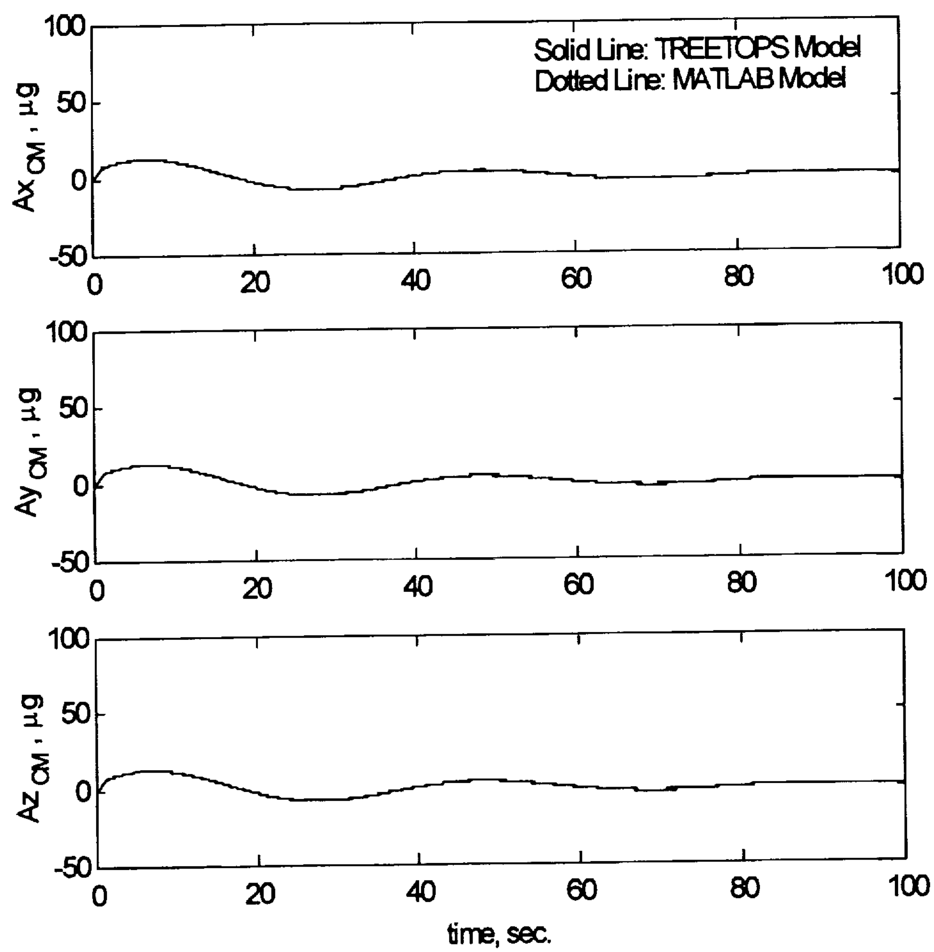

Figure 2.5.1-3: Acceleration at Platform CM with Initial Excitation

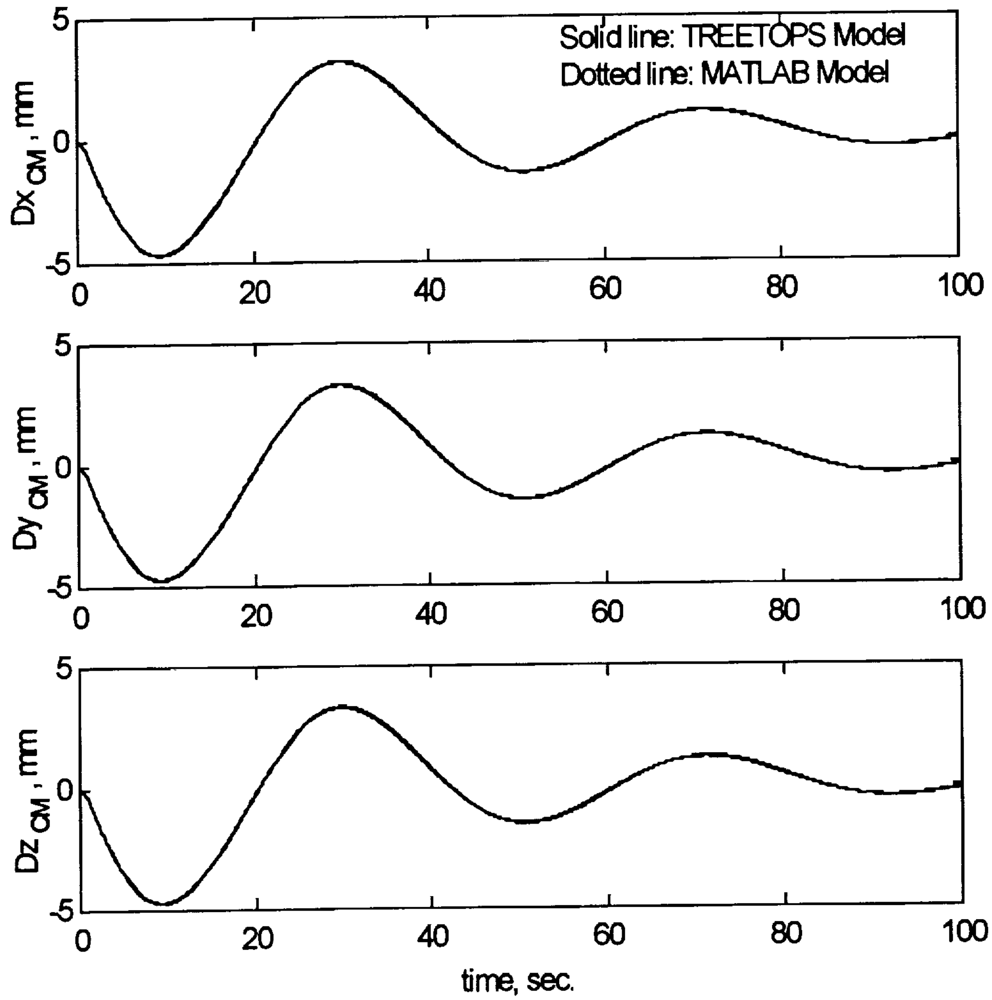

Figure 2.5.1-4: Displacement at platform CM with Initial Excitation

2.5.2 Accelerometer Bias Estimation Analysis

Accelerometer sensor hardware has nonzero bias for zero acceleration condition and this will be a false input that the g-LIMIT acceleration controller must compensate for. This action of acceleration controller causes the movement of the platform, however the position controller compensates for any movement out of the nominal rest position. Since compensations for accelerometer bias make g-LIMIT controllers use unnecessary power when there is no acceleration disturbance, the accelerometer bias needs to be estimated and subtracted from the input of acceleration controller. In order to demonstrate the estimation of accelerometer bias, arbitrary acceleration biases of six accelerometers shown in Table 2.5-3 are implemented in g-LIMIT TREETOPS model. The output of position controller obtained from TREETOPS simulation under active control model are the acceleration commands that equal to the estimated accelerometer biases. Figure 2.5.2-1 shows the actual acceleration biases of six accelerometers given as inputs and the estimated ones obtained from TREETOPS simulation. The estimated biases match closely to the actual ones in 20 seconds.

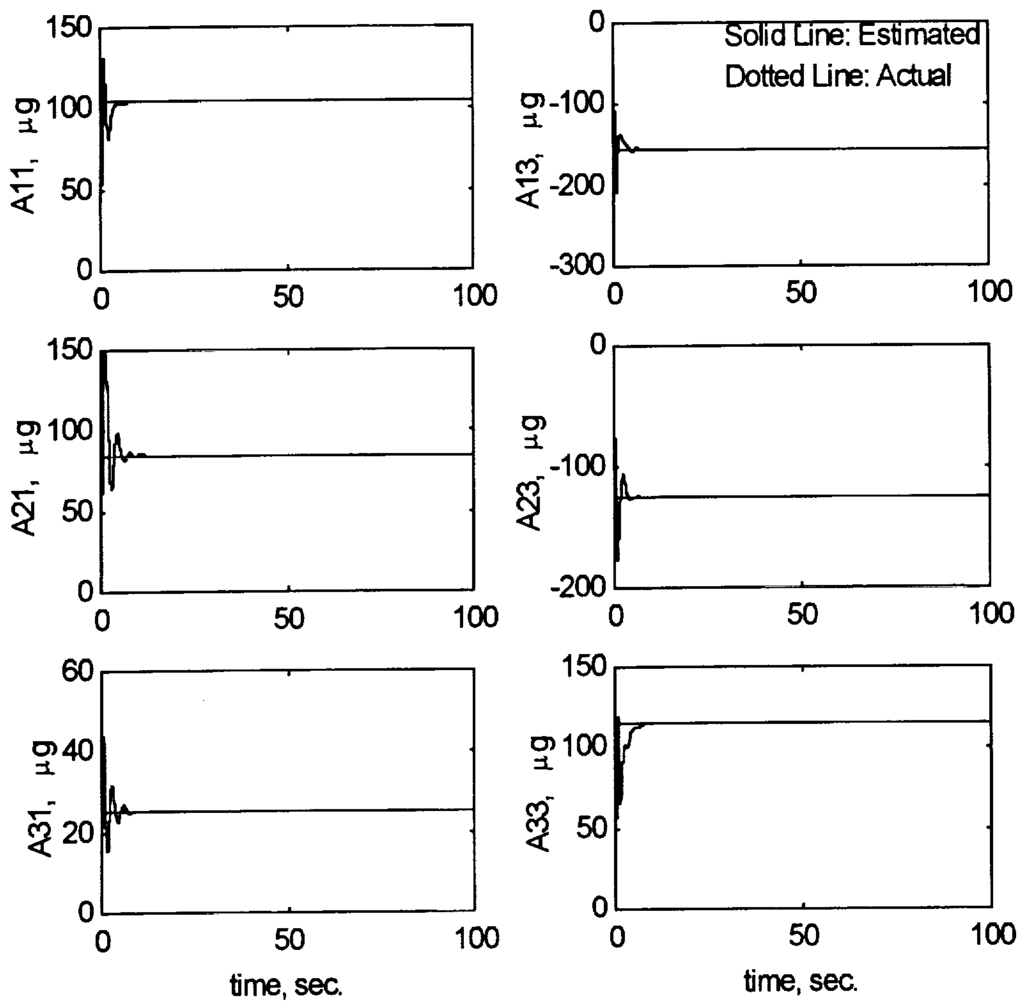

Figure 2.5.2-1: Estimated Accelerometer Bias

2.5.3 Umbilical Stiffness Estimation Analysis

The stiffness of the umbilical cords are important factor for the determination of the control gains and the performance of the g-LIMIT system. The umbilical linear stiffness may be estimated from the simulation results of the standby control mode. When 1 *mm* position command is given in each x, y, z axis direction and the equilibrium state is reached, the required control forces at the platform CM per unit position command are estimated linear umbilical stiffness in each x, y, z axis direction. The actual stiffness of umbilical cords (18 *N/m* in the positive X-axis direction, 13.5 *N/m* in the positive Y-axis direction and 20 *N/m* in the positive Z-axis direction) and estimated ones are shown in Figure 2.5.3-1. They match very closely.

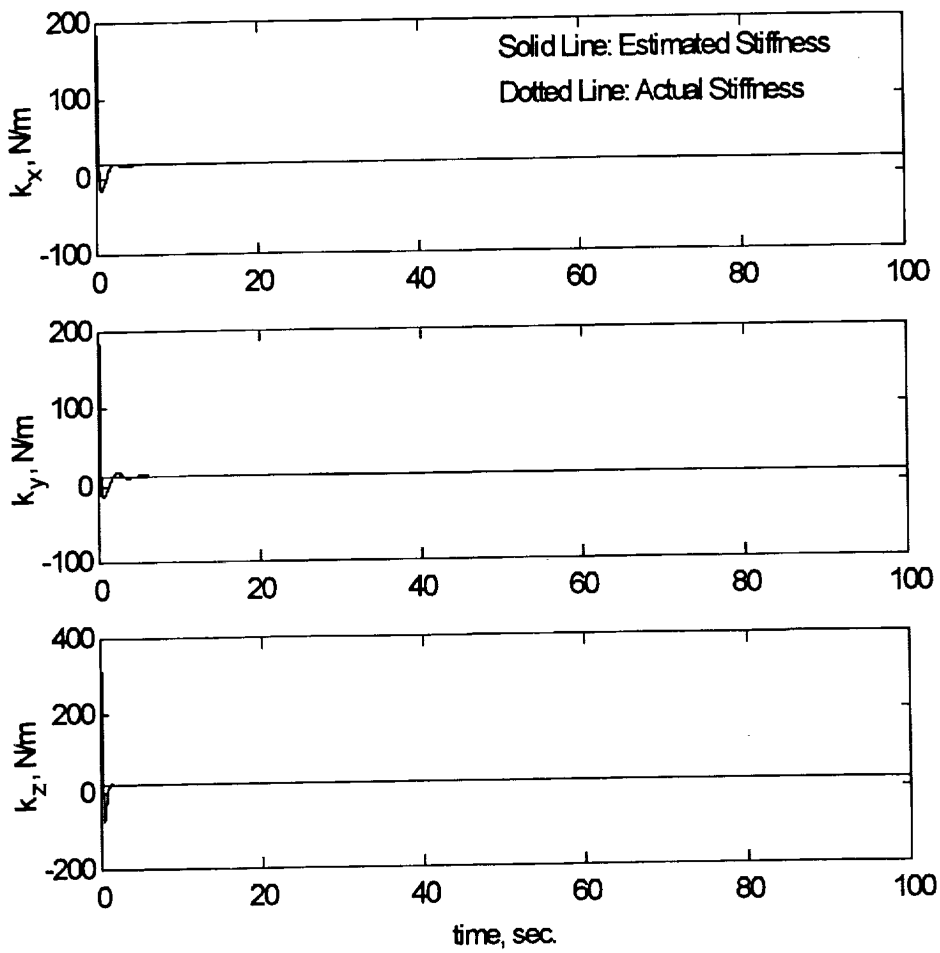

Figure 2.5.3-1: Estimated Stiffness of Umbilical Cords

2.5.4 Platform Acceleration Estimation Analysis

An alternative method to determine the acceleration at the platform CM is necessary if data is not available from the accelerometers. The acceleration at the platform CM may be estimated using actuator forces, position errors, and estimated stiffness obtained from the simulation under the standby control mode. For the numerical simulation, 10 μg of 0.1 Hertz sinusoidal disturbance was given to the base and numerical simulation was performed under the standby control mode. The control forces and position errors at the platform CM are calculated from the TREETOPS simulation results using the transformation matrix from the IM to the platform CM. The estimated accelerations at the platform CM are calculated by dividing the difference between the control forces and the product of estimated stiffness and position errors at the platform CM by platform mass. The actual accelerations at the platform CM are obtained from TREETOPS accelerometer sensors fixed on the platform CM. Both actual and estimated accelerations at the platform CM are shown with good agreement in Figure 2.5.4-1.

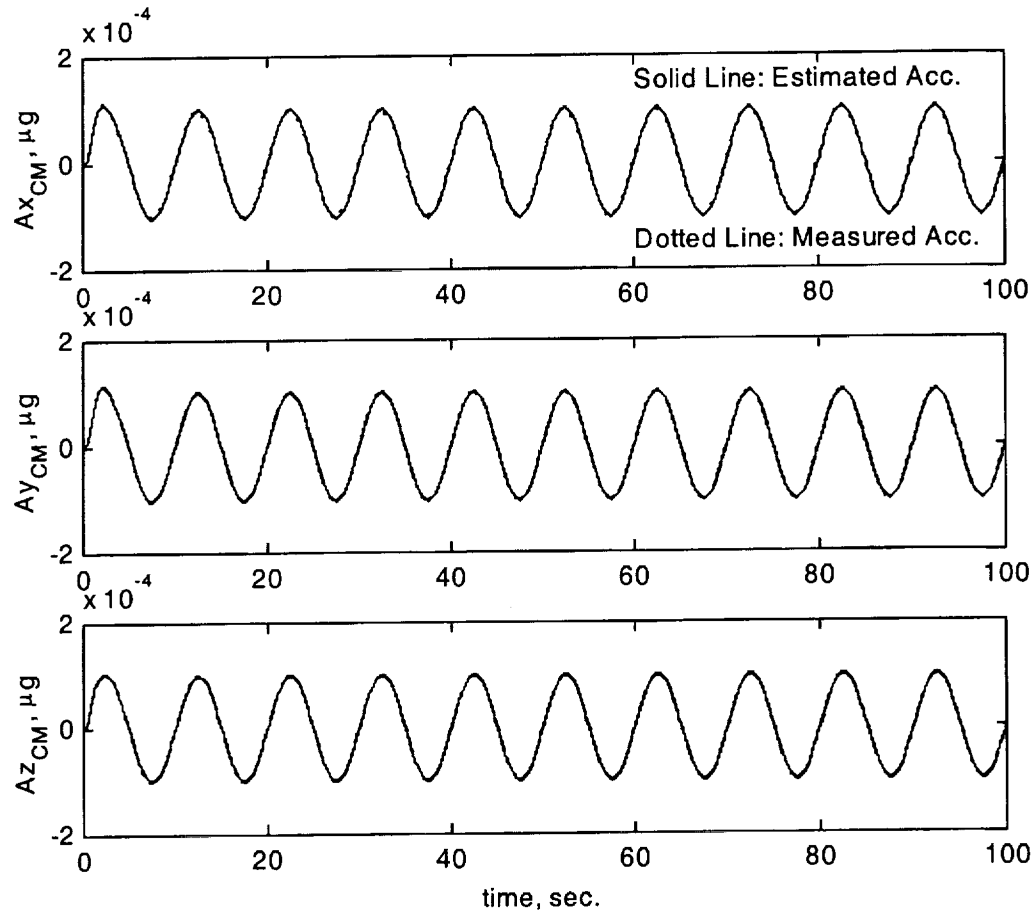

Figure 2.5.4-1: Estimated Acceleration at Platform CM

2.5.5 Acceleration Attenuation Analysis

The main objective of the g-LIMIT system is to provide a low acceleration environment across a broad spectrum of frequencies using an active isolation controller. For the numerical TREETOPS simulation, external acceleration sinusoidal disturbances (combination of $2\mu g$ with 0.01 Hz, $2\mu g$ with 0.05 Hz, $2\mu g$ with 0.1 Hz, $10\mu g$ with 0.5 Hz, $20\mu g$ with 1 Hz, $100\mu g$ with 10 Hz, $200\mu g$ with 10 Hz, $1000\mu g$ with 50 Hz, and $2000\mu g$ with 100 Hz) were given to the base and then the acceleration at platform CM was obtained from TREETOPS simulation under active control mode. In order to determine the ratio of acceleration at platform CM to the base accelerations over defined frequency range, power spectrum density (PSD) plots of both accelerations were generated and then one third octave band RMS (Root Mean Square) of both accelerations were calculated from these PSD plots. The acceleration attenuation curve was determined by taking 20 times the base 10 logarithms of the ratio of acceleration at the platform C.M. to the base accelerations across the frequency range of 0.01 Hz through 100 Hz. This acceleration attenuation curve is shown in Figure 2.5.5-1.

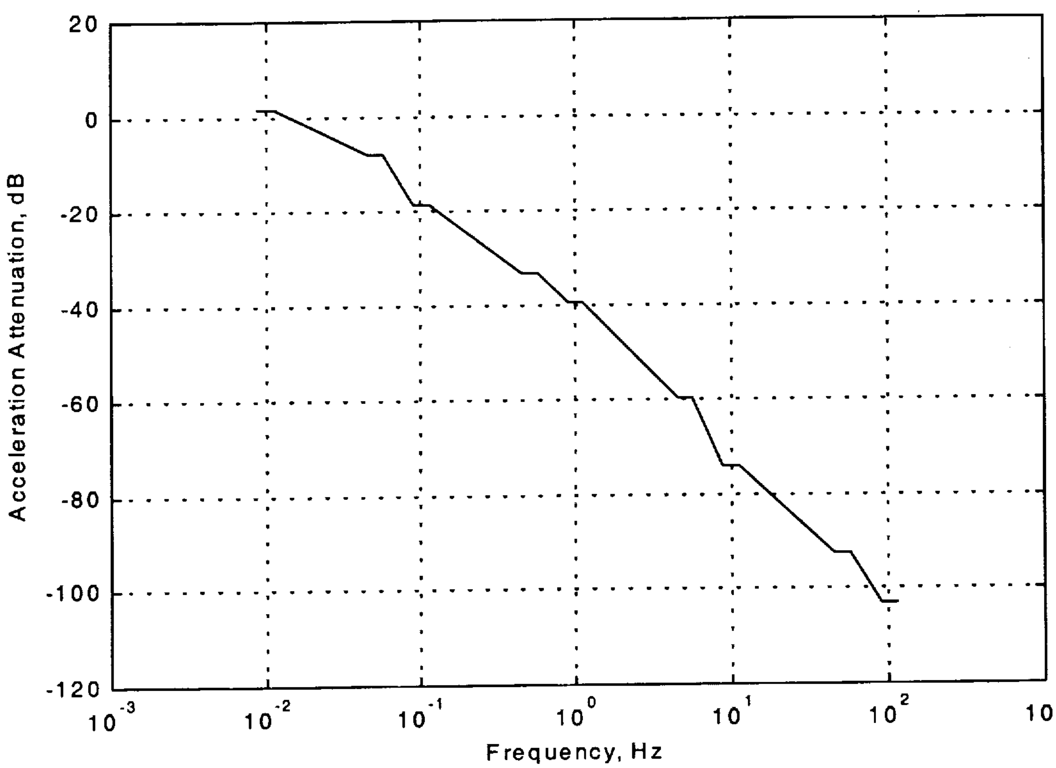

Figure 2.5.5-1: Acceleration Attenuation Curve of g-LIMIT System

2.6 Conclusions

This report documents the updated MATLAB model and the TREETOPS model of the g-LIMIT dynamics/control system for current mass properties and configuration. In order to check the validity of both models, transient response analysis were performed using both models and their numerical results were compared. They matched very closely, so both models were validated. Since the design of final flight control logic has not been completed at this time, preliminary performance analysis were done using simplified control logic that will be baseline for final control logic. The performance of g-LIMIT system was determined by the acceleration attenuation curve obtained from TREETOPS simulation. This document also presents the post-processing analysis that estimate accelerometer bias, umbilical stiffness, and platform acceleration. For the more accurate performance analysis of g-LIMIT system, the current MATAB and TREETOPS models need to be upgraded by implementing the actual flight control code when that is available.

2.7 References

[1] Kim, Y.K.: "Integrated Modeling and Analysis of Flexible Mutibody Systems Including Optical Elements for Pointing Control Systems Performance," NAS-37095/H28511D Final Report, 31 March 1999.

[2] "User's Manual for TREETOPS, A Control System Simulation for Structures With a Tree Topology," NASA Contract NAS-36287, Marshall Space Flight Center, April 1990.

[3] Whorton M.S.: "development of Control Algorithms for g-LIMIT Characterization Test," NASA Draft Report, October 1999.

3. Inputs to Crew Procedures and Training of Digital Thermometer

The Laboratory Support Equipment (LSE) project is to provide generic laboratory thermal sensor, Digital Thermometer (DT) units and thermocouple probes for payloads onboard International Space Station (ISS) that is manifested to support 7A.1 launch in August 2000.

The general and functional requirements to select a digital thermometer unit are described on Table 3-1. Since the digital thermometer must be selected from available commercial off-the-shelve (COTS) hardware, four COTS DT units were tested and compared with the DT functional requirements. The Tektronix DTM920 digital thermometer unit was selected among four candidate DTs in 1998. After the selection of the DT was completed, we found out that Tektronix DTM920 model was discontinued at the end of 1998. However, the required number of Tektronix DTM920 units were ordered to purchase to support the LSE project.

Table 3-1: Digital Thermometer (DT) General/Functional Requirements

General/Functional Requirements	Tektronix DTM920 Capability
Portable hand held temperature measuring system	Yes
Provide capability to measure temperature at any position in a rack accessible to crew members from the aisle	Yes
Temperature spot checking and fault diagnosis in experiment systems	Yes
The planned life for the DTs is one mission cycle or the equivalent of one year on ISS operations.	Expected to satisfy
Provide a real-time digital display of temperature in Celsius and Fahrenheit	Yes
Provide for simultaneous connection of two probes and the ability to readily read-out between the two probes	Yes
Temperature spot checking and fault diagnosis in experiment systems	Yes

Table 3-1: Digital Thermometer (DT) General/Functional Requirements (continued)

General/Functional Requirements	Tektronix DTM920 Capability
The planned life for the DTs is one mission cycle or the equivalent of one year on ISS operations.	Expected to satisfy
Provide a real-time digital display of temperature in Celsius and Fahrenheit	Yes
Provide for simultaneous connection of two probes and the ability to readily read-out between the two probes	Yes
Provide accommodation for plug-in temperature probes for surface contact, immersion, and air sensing, with Type K thermocouples	Yes
Provide the capability to measure facility and support equipment surface temperature accessible to the crew, with a range of -40 degree C to 200 degree C	Yes
Provide the capability to take measurements with a portable probe and/or user-provided thermocouples, in a range of -200 degree C to 1250 degree C	Yes
Accuracy in the range of -200 degree C to -40 degree C: $\pm$4.5 degree C	Yes
Accuracy in the range of -40 degree C to 4 degree C: $\pm$1.5 degree C	Yes
Accuracy in the range of 200 degree C to 1250 degree C: $\pm$4.5 degree C	Yes
Accuracy in the range of 4 degree C to 100 degree C: $\pm$0.5 degree C	Yes
Provide a velcro surface attachment for holding the DT instrument	capable
Provide a velcro surface attachment for holding the temperature probes	capable
Provide a storage case	capable
Provide temperature probe extension leads	capable
Utilize LSE Battery Charger and rechargeable batteries	capable
The DT shall be capable of being stored in a middeck locker	yes

In order to measure temperature of air environment, surface, and interior of payloads, three different kinds of thermocouple probes (air sensing, surface contact, and immersion) are provided with the DT unit. The requirements of temperature measurement for thermocouple probes are listed in Table 3-2.

A thermocouple probe with cable should be able to reach from the DT unit to the subject in the range from 1 ft to 6 ft. The Tektronix DTM920 unit has one miniature connector for thermocouple probe. However, it is desirable to provide a connection to the DT unit for payload user provided thermocouple probes which may require a standard connector. For this purpose, OMEGA's Probe Handle with Retractable Cable (model no. SDX-UST-K-SMP-M) and OMEGA's 12 inch K-type thermocouple probes (Air probe, Penetration Probe, and Surface Probe) are recommended. This OMEGA's Probe Handle is supplied with 1 ft of retractable cable that can be expanded to 5 ft and accepts probes with both standard and miniature connectors. The temperature measurement range requirements of thermocouple probes are described in Table 3-2.

Table 3-2: Thermocouple Probe Temperature Measurement Range Requirement

K Type Thermocouple Probe	Temperature Range (Degree, Celsius)
Air Probe	-200 to 800
Immersion Probe	-200 to 1250
Surface Probe	-28 to 200

The required hardware items for the LSE project to support the temperature measurement for payloads, system, and crew activity are listed in Table 3-3. Currently one Tektronix DTM920 and three Omega's Integral Handle Thermocouple Probes are available to test functionality and crew operational procedures.

Table 3-3: Required Hardware Items for Temperature Measurement

Required Items	Numbers in possession	Numbers to be ordered
Training Tektronix DTM920 Thermometer	1	0
Ground Support Equipment (GSE) Tektronix DTM920 Thermometer	None	2
Flight Tektronix DTM920 Thermometer	None	4
K-type Thermocouple Probes (Surface Contact, Immersion, Air Sensing)	1 Set (Integral Handle Probes)	8 Sets (without Handle)
Probe Handle with Retractable Cable (model no. SDX-UST-K-SMP-M)	None	TBD
Temperature Extension Lead	None	TBD
Rechargeable Battery	None	TBD
Storage Case	None	TBD

Table 3-4 describes weights and dimension of the Tektronix DTM920 unit and Integral Handle Probes. The weights and dimension of OMEGA's Probe Handle with Retractable Cable (model no. SDX-UST-K-SMP-M) and OMEGA's 12 inch K-type thermocouple probes (Air probe, Penetration Probe, and Surface Probe) are not known at this time. Once these items are in possession, weights and dimension will be measured.

Table 3-4: Weight and Dimension of Tektronix DTM920 unit and Integral Handle Probes

Items	Weight (oz)	Dimension (Width x Length x Height, inch)
Tektronix DTM920 unit	7.45	2.5 x 6.25 x 1
Soft Cover	4.81	3 x 6.75 x 1.5
Integral Handle Probe (Air Sensing, Immersion)	4.73	length = 18 (without cord); handle = 6; width = 1; retractable cord = 20 inch long
Integral Handle Probe (Surface Contact)	3.15	length = 7 (without cord) retractable cord = 20 inch long

Since the Tektronix DTM920 thermometer is quite simple to use, dedicated crew training for the operational procedures is not recommended. However, if Tektronix DTM920 thermometer is to be used by payloads, crew training for this hardware will be part of that payload's crew training. For the purpose of on-board crew training and reference, a CD-ROM will be provided which describes functionality, thermal capability, and operation procedures of the Tektronix DTM920 thermometer and thermocouple probes. The operational procedures of Tektronix DTM920 thermometer include activation procedure, deactivation procedure, thermocouple probe change procedure, and battery change procedure. These procedures are described as follows.

Digital Thermometer (Tektronix DTM920) Activation Procedure

1. Take digital thermometer, probe handle(s), and thermocouple probe(s) out of storage box according to payload procedure.

2. Plug the selected probe(s) into connector(s) in handle of probe handle(s).

3. Plug connector(s) on cable of the probe handle(s) into **T1** and/or **T2** connector(s) of digital thermometer according to payload procedure.

4. Turn on digital thermometer.
   Press **Power ON/OFF** button (small circle with vertical line inside).

5. Select temperature unit Celsius (degree C) or Fahrenheit (degree F) according to payload procedure.
   Press **degree C/degree F** button.

   The 'degree C' or 'degree F' will be shown at top right corner of thermometer display.

6. Select probe to be read for temperature measurement (T1 or T2: Reading from T1 or T2 probe; T1-T2: Reading difference between T1 and T2 probe.)
   Press **T1**, **T2**, or **T1-T2** button

   The 'T1', 'T2', or 'T1-T2' will be shown at bottom center of thermometer display.

7. Hold or Attach the probe(s) to the location(s) to be measured according to payload procedure. (Allow time for the reading to stabilize.)

8. Read the displayed temperature.
   To freeze the display: Press **HOLD** button.

   The 'HOLD' will be shown at bottom left corner of thermometer display.

   To take new measurement: Press **HOLD** button again.

9. To display maximum/minimum temperature, Press **MAX/MIN** button and complete measurement.
   To display the maximum temperature:
   Press **MAX/MIN** button.

   To toggle between maximum and minimum temperatures:
   Press **MAX/MIN** button again.

   The 'MAX' or 'MIN' will be shown at top left corner of thermometer display.

   To cancel measurement of maximum and minimum temperature:
   press and hold **MAX/MIN** button for 2 seconds.

Digital Thermometer (Tektronix DTM920) Deactivation Procedure

1. Turn off digital thermometer by pressing **Power ON/OFF** button.

2. Disconnect connector(s) on cable of the probe handle(s) from digital thermometer.

3. Disconnect the thermocouple probe(s) from probe handle(s).

4. Take cleaning cloth out of storage box and clean the thermometer, probe handle(s), and thermocouple probe(s).

5. Stow the thermometer, probe handle(s), thermocouple probe(s), and cleaning cloth in storage box.

Digital Thermometer (Tektronix DTM920) Probe Change Procedure

The thermometer normally operates with K-type thermocouple probes.
(The letter 'K' is shown at bottom right corner of thermometer display.)

To change to J-type thermocouple probes

1. Turn off the thermometer by pressing **Power ON/OFF** button.
2. Pressing **Power ON/OFF** and **HOLD** buttons at the same time.
3. Release **Power ON/OFF** button but continue to press **HOLD** button for 2 seconds.

The letter 'J' will be appeared at bottom right corner of thermometer display when J-type thermocouple probe is selected.

To change back to K-type thermocouple probes

1. Turn off the thermometer by pressing **Power ON/OFF** button.
2. Turn on the thermometer by pressing **Power ON/OFF** button.

Digital Thermometer (Tektronix DTM920) Battery Change Procedure

A 9V battery needs to be replaced when the battery symbol (square with - and + sign) is shown at bottom left corner of thermometer display.

1. Turn off the thermometer by pressing **Power ON/OFF** button.
2. Disconnect connector(s) on cable of the probe handle(s) from digital thermometer.
3. Remove digital thermometer from soft carry case
4. Take out #TBD Phillips screwdriver from ISS toolbox.
5. Take out a new 9V battery and a ziplock bag.
6. Remove back cover of thermometer battery compound using the screwdriver and store the cover and screw in ziplock bag temporarily.

7. Remove old battery from thermometer and store it with "USED" marked in ziplock bag.

8. Install a new 9V battery and put back the cover and screw.

9. Put back thermometer in the soft carry case.

10. Stow the used battery in ziplock bag and screwdriver.

References

[1] "Digital Thermometers for Space Station Laboratory Support Equipment Component End Item Specification," MSFC-RQMT-TBD, October 1998.

[2] "Development Testing for Digital Thermometers," NASA Contract NAS8-98098, October 16, 1998.

[3] "User's Manual for Tektronix Digital Thermometer DTM920," Tektronix, Inc.

[4] "The Temperature Handbook," Omega Engineering, Inc.

Appendix A.

g-LIMIT MATLAB Simulation Model

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Input data for g-LIMIT (glconfig1_data.m)
% written by Young Kim.   updated on 11-19-99
% based on mass properties and configuration as of 11/02/99.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clear
global ABASE0 ABASESKEW0 C1 C2 C3 C4 C5 C6
global fd0 fdskew0 frq1 frq2 IM CU1 CU2 KU1 KU2 M
global ra1skew ra2skew ra3skew ra4skew ra5skew ra6skew
global rcskew rFa1 rFa2 rFa3 rFa1skew rFa2skew rFa3skew rFd rFdskew
global rFu1skew rFu2skew rp1skew rp2skew rp3skew ru1skew ru2skew
global TM_P2F TM_CM2P TM_FA2FCM
global invMX KX0 CX0
%
%Input data (1 lbm = 0.45359 kg; 1 inch = 0.0254 meter)
LBM2KG=0.45359; INCH2METER=0.0254;
%
IM=[2.7087e2  1.4857  -8.3617e-2; 1.4857  2.7589e2  -5.7899e-1;
    -8.3617e-2  -5.7899e-1  4.8068e2]      %lbm-inch^2
M=17.3462                                  %lbm
IM=IM*LBM2KG*INCH2METER^2
M=M*LBM2KG
KU1=[18 0 0; 0 13.5 0; 0 0 20];
KU2=[18 0 0; 0 13.5 0; 0 0 20]*0;
CU1=KU1/M * 2 * (0.01) * sqrt(M*KU1)*0;
CU2=KU2/M * 2 * (0.01) * sqrt(M*KU2)*0;
%
PSI_a1=0*pi/180; PSI_a2=120*pi/180; PSI_a3=240*pi/180;  % IM positions
PSI_p1=PSI_a1; PSI_p2=PSI_a2; PSI_p3=PSI_a3;
%
R_AC = 1.62*2.54/100  % Distance from the center of platform to the center of
Accelerometer (meter)
ra1 = [R_AC*[cos(PSI_a1+90*pi/180) sin(PSI_a1+90*pi/180)]  2.94*INCH2METER]
% Accelerometer #1 (a_1x)
ra2 = ra1;                                      % Accelerometer #2 (a_1z)
ra3 = [R_AC*[cos(PSI_a2+90*pi/180) sin(PSI_a2+90*pi/180)]  2.94*INCH2METER]
% Accelerometer #3 (a_2x)
ra4 = ra3;                                      % Accelerometer #4 (a_2z)
ra5 = [R_AC*[cos(PSI_a3+90*pi/180) sin(PSI_a3+90*pi/180)]  2.94*INCH2METER]
% Accelerometer #5 (3_3x)
ra6 = ra5;                                      % Accelerometer #6 (a_3z)
%
R_IM = 4.826*2.54/100  % Distance from the center of platform to the center of IM
(meter)
```

```
rf1 = [R_IM*[cos(PSI_a1+90*pi/180) sin(PSI_a1+90*pi/180)]  3.34*INCH2METER]
% Actuator #1
rf2 = [R_IM*[cos(PSI_a2+90*pi/180) sin(PSI_a2+90*pi/180)]  3.34*INCH2METER]
% Actuator #2
rf3 = [R_IM*[cos(PSI_a3+90*pi/180) sin(PSI_a3+90*pi/180)]  3.34*INCH2METER]
% Actuator #3
rp1 = rf1;                             % Position Sensor #1
rp2 = rf2;                             % Position Sensor #2
rp3 = rf3;                             % Position Sensor #3
%
rc  = [0.004  -0.020  0.067];           % Platform C.M.
rd  = [0.004  -0.020  0.067];           % External force position
%
ru1 = [0.0686  -0.0787  -0.0205];  % Umbilical #1
ru2 = [-0.0686  -0.0787  -0.0205];  % Umbilical #2
%
C1 = [cos(PSI_a1) -sin(PSI_a1) 0; sin(PSI_a1) cos(PSI_a1) 0; 0 0 1];
C2 = [cos(PSI_a2) -sin(PSI_a2) 0; sin(PSI_a2) cos(PSI_a2) 0; 0 0 1];
C3 = [cos(PSI_a3) -sin(PSI_a3) 0; sin(PSI_a3) cos(PSI_a3) 0; 0 0 1];
C4 = [cos(PSI_p1) -sin(PSI_p1) 0; sin(PSI_p1) cos(PSI_p1) 0; 0 0 1];
C5 = [cos(PSI_p2) -sin(PSI_p2) 0; sin(PSI_p2) cos(PSI_p2) 0; 0 0 1];
C6 = [cos(PSI_p3) -sin(PSI_p3) 0; sin(PSI_p3) cos(PSI_p3) 0; 0 0 1];
%
ra1skew = skewm (ra1);
ra2skew = skewm (ra2);
ra3skew = skewm (ra3);
ra4skew = skewm (ra4);
ra5skew = skewm (ra5);
ra6skew = skewm (ra6);
%
rcskew = skewm (rc);
%
rf1skew = skewm (rf1);
rf2skew = skewm (rf2);
rf3skew = skewm (rf3);
%
rFa1 = [rf1 - rc]; rFa2 = [rf2 - rc]; rFa3 = [rf3 - rc];
rFa1skew = skewm (rFa1);
rFa2skew = skewm (rFa2);
rFa3skew = skewm (rFa3);
rFd = [rd - rc];
rFdskew = skewm (rFd);
rFu1 = [ru1 - rc]; rFu2 = [ru2 - rc];
rFu1skew = skewm (rFu1);
rFu2skew = skewm (rFu2);
```

```
rp1skew = skewm (rp1);
rp2skew = skewm (rp2);
rp3skew = skewm (rp3);
ru1skew = skewm (ru1);
ru2skew = skewm (ru2);
%
% System Matrices
%
MX = [M * eye(3) (-M * rcskew); zeros(3) IM];
invMX = inv(MX);
KX0 = [(KU1 + KU2) (-KU1 * ru1skew - KU2 * ru2skew);
    (rFu1skew * KU1 + rFu2skew * KU2) ...
    -(rFu1skew * KU1 * ru1skew + rFu2skew * KU2 * ru2skew)];
CX0 = [(CU1 + CU2) (-CU1 * ru1skew - CU2 * ru2skew);
    (rFu1skew * CU1 + rFu2skew * CU2) ...
    -(rFu1skew * CU1 * ru1skew + rFu2skew * CU2 * ru2skew)];
%
% Controller
%
TM_X2F =[ [1 0 0; 0 0 1] * C1' * [eye(3,3) (-rf1skew) ] ;
        [1 0 0; 0 0 1] * C2' * [eye(3,3) (-rf2skew) ] ;
        [1 0 0; 0 0 1] * C3' * [eye(3,3) (-rf3skew) ] ];
TM_X2P =[ [1 0 0; 0 0 1] * C4' * [eye(3,3) (-rp1skew) ] ;
        [1 0 0; 0 0 1] * C5' * [eye(3,3) (-rp2skew) ] ;
        [1 0 0; 0 0 1] * C6' * [eye(3,3) (-rp3skew) ] ];
TM_P2F = TM_X2F * inv(TM_X2P);
%
TM_X2CM =[ eye(3,3)   (-rcskew) ;
           zeros(3,3) eye(3,3) ];
TM_CM2P = TM_X2P * inv(TM_X2CM)
%
TM_FA2FCM = [      C1           C2            C3;
          (rFa1skew * C1) (rFa2skew * C2) (rFa3skew * C3) ];
%TM_CM2F = TM_X2F * inv(TM_X2CM)
%TM_P2CM = TM_X2CM * inv(TM_X2P)
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% main routine for g-LIMIT (glconfig1.m)
% written by Young Kim
% updated on 11-19-99
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Zrow      = Six states and six state derivatives at the origin of
%             platform coordinates and six actuator forces.
% YACMrow   = Accelerations at the C.M. of platform
% YPCMrow   = Displacements at the C.M. of platform
% YArow     = Six accerometers output
% YProw     = Six position sensors output
% Drow      = Movement at the center of the six actuators gap
% FACTrow   = Six actuator forces
% FCMrow    = Three control forces and three control torque at the C.M.
%             of the platform
%----------------------------------------------------------------------
% for disturbance
global Abias ABASE0 ABASESKEW0 fd0 fdskew0 frq1 frq2
global td1start td1end td2start td2end
global Fact
global X_LL0 Y_LL0 Y_LP0 Yacc_I0 Yacc_D0 Ypos_I0 Ypos_D0
% for Acceleration Controller
global KP1 KI1 KD1
% for PID controller
global TM_CM2P TM_FA2FCM TM_P2F
global KDLOW KDHIGH KILOW KIHIGH KPLOW KPHIGH
%
jobstart = fix(clock); Job_Start = jobstart(4:6)
ON = 1; OFF = 0; MICRO_G=9.8e-6;
% Simulation Time
tol=1e-4; epsilon=1e-6;
%t0=0; tf=2; TS=1e-1; tp=1e-2; dt=1e-3; TS_acc=1e-3;   %nominal
t0=0; tf=30; TS=1e-1; tp=1e-2; dt=1e-2; TS_acc=1e-2; %position control only
%t0=0; tf=2; TS=1e-1; tp=1e-2; dt=1e-2; TS_acc=1e-2;   %nominal
nint=ceil( (tf - t0)/dt);
%Disturbances
% If frq1=0 and frq2=0, disturbance will be pulse function and
% start and end times must be given.
%
ABASE0=[1e2; 1e2; 1e2]*MICRO_G*OFF; frq1=10; td1start=0; td1end=100;
fd0=[1e2; 1e2; 1e2]*M*MICRO_G*OFF;  frq2=1; td2start=0; td2end=100;
ABASESKEW0 = skewm (ABASE0);
fdskew0 = skewm (fd0);
Abias = [105; -155; 85; -125; 25; 115]*MICRO_G*OFF;
```

```
%Position Command
DCOM =[0.01; 0.01; 0.01; 0; 0; 0]*ON;
YPCOM = TM_CM2P * DCOM;
%PID Controller Input
Aconflag =OFF;   % 1/0; Accelerometer controller on/off
Dconflag =ON;    % 1/0; Position controller on/off
%Nominal Active Mode
%KD1 = 0.;  KI1 = 3e3.;  KP1=0.;
%KD2=6.2e-2; KI2=2.5e-4; KP2=2.4e-2;
%Standby Mode: Position controller is only on (to measure stiffness k)
KD1 = 0.;  KI1 = 0.;  KP1=1.;
KD2=25; KI2=19.8; KP2=12.4;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Initialization for Simulation
%
t=t0;
Fact = [0;0;0;0;0;0;];  % Initial control forces
X_LL0 = [0;0;0;0;0;0;]; Y_LL0 = [0;0;0;0;0;0;];
Y_LP0 = [0;0;0;0;0;0;];
Yacc_I0 = [0;0;0;0;0;0;]; Yacc_D0 = [0;0;0;0;0;0;];
Ypos_I0 = [0;0;0;0;0;0;]; Ypos_D0 = [0;0;0;0;0;0;];
Z0=zeros(12,1);         %Initial States
Z0(1)=0.0;     Z0(2)=0.0;     Z0(3)=0.0;
        Zrow=Z0';
%       ZDrow = ( feval('gleqn',t0,Z0) )';
        ZDrow=zeros(1,12);
X0 = Z0(1:6); XDD0 = ZDrow(7:12)';
%
[YACM0, YPCM0] = cmmove(t0,X0,XDD0);
        YACMrow = YACM0';
        YPCMrow = YPCM0';
%
YA0 = glacc(t0,X0,XDD0);
YP0 = glpos(t0,X0);
        YArow = YA0';
        YProw = YP0';
%
% Initialization for PID position and accleration controller's output
%
Acom = pospid(t0,YPCOM-YP0,KP2,KI2,KD2,TS);
Aerr = Acom*Dconflag - YA0*Aconflag;
Fact = accpid(t0,Aerr,KP1,KI1,KD1,TS_acc);
        Factrow = Fact';
```

```
%
% Beginning of Simulation
%
for i=1:nint
[t1, Z1row] = ode45mod('gleqn',t0,dt,Z0,tol);
ZD1 = feval('gleqn', t1, Z1row');
        if abs((t1/tp) - round(t1/tp)) <= epsilon
                Zrow = [Zrow; Z1row];
                ZDrow = [ZDrow; ZD1'];
        end
%
t0 = t1;
Z0 = Z1row';
%%%%%%
X1 = Z1row(1:6)'; XDD1 = ZD1(7:12);
%
[YACM1, YPCM1] = cmmove(t1,X1,XDD1);
YA1 = glacc (t1, X1,XDD1);
YP1 = glpos (t1, X1);
        if abs((t1/tp) - round(t1/tp)) <= epsilon
                YACMrow = [YACMrow; YACM1'];
                YPCMrow = [YPCMrow; YPCM1'];
                YArow = [YArow; YA1'];
                YProw = [YProw; YP1'];
                t = [t; t1];
        end
%%%%%%%% Acceleration Controller %%%%%%%%%%%
if abs(t1/TS_acc - round(t1/TS_acc)) <= epsilon
        if abs(t1/TS - round(t1/TS)) <= epsilon
                Acom = pospid(t1,YPCOM-YP1,KP2,KI2,KD2,TS);
        end
Aerr = Acom*Dconflag - YA1*Aconflag;
Fact = accpid(t1,Aerr,KP1,KI1,KD1,TS_acc);
end
        if abs((t1/tp) - round(t1/tp)) <= epsilon
                Factrow = [Factrow; Fact'];
        end
end
%End of Simulation
```

```
PACT = [1 0 0 0 0 0;
     0 0 0 0 0 0;
     0 1 0 0 0 0;
     0 0 1 0 0 0;
     0 0 0 0 0 0;
     0 0 0 1 0 0;
     0 0 0 0 1 0;
     0 0 0 0 0 0;
     0 0 0 0 0 1];
FCM = (TM_FA2FCM * PACT) * Factrow';
        FCMrow =FCM';
%Kest = FCMrow / DCOM;
jobend = fix(clock); Job_End = jobend(4:6)
%
save
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% 6 DOF equation of motion for g-LIMIT (gleqn.m)
% written by Young Kim
% updated on 9-9-99
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function ZD = gleqn (t,Z)
global C1 C2 C3
global invMX CX0 KX0 M
global rFa1 rFa2 rFa3 rFa1skew rFa2skew rFa3skew rFd rFdskew
global Fact
%
%%% Twelve states
ZSTATE = Z(1:12);  thet = Z(4:6);
thetskew = skewm(thet);
RFdskew = rFdskew + rFdskew * thetskew + skewm(rFd * thetskew);
RFa1skew = rFa1skew + rFa1skew * thetskew - skewm(rFa1 * thetskew);
RFa2skew = rFa2skew + rFa2skew * thetskew - skewm(rFa2 * thetskew);
RFa3skew = rFa3skew + rFa3skew * thetskew - skewm(rFa3 * thetskew);
%
PMACT = [[1 0; 0 0; 0 1] zeros(3,2) zeros(3,2);
      zeros(3,2) [1 0; 0 0; 0 1] zeros(3,2);
      zeros(3,2) zeros(3,2) [1 0; 0 0; 0 1]];
%
%%% Base disturbance acceleration and Floator disturbance force
  [ABASE, ABASESKEW] = basedist(t);
        [fd, fdskew] = fdist(t);
%
```

```
Fbase = - [M*eye(3); zeros(3)] * ABASE;
Fdist = [eye(3) + thetskew; ...
      RFdskew ] * fd;
Fcont = [(eye(3) + thetskew) * [C1 C2 C3]; ...
      (RFa1skew * C1) (RFa2skew * C2) (RFa3skew * C3)] ...
     * PMACT * Fact;
%
FX = Fbase + Fdist + Fcont ;
%
ZD(1:12,1) = [zeros(6) eye(6); (-invMX*KX0) (-invMX*CX0)]*ZSTATE ...
  +[zeros(6,1); invMX*FX];
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Accelerometer models for STABLE (glacc.m)
% written by Young Kim
% updated on 6-24-98
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function YA = glacc (t,X,XDD)
global C1 C2 C3
global ra1skew ra2skew ra3skew ra4skew ra5skew ra6skew
global Abias
%
%%% Base disturbance acceleration
%
      [ABASE,       ABASESKEW] = basedist(t);
%%%%%%%%%%%%%%%
pivotxm = [1 0 0]; pivotzm = [0 0 1];
YA(1,:) = pivotxm * [C1' (-C1' * ra1skew)] * XDD ...
      +pivotxm * [zeros(3)  C1'* ABASESKEW] * X ...
      +pivotxm * C1' * ABASE ;
YA(2,:) = pivotzm * [C1' (-C1' * ra2skew)] * XDD ...
      +pivotzm * [zeros(3)  C1'* ABASESKEW] * X  ...
      +pivotzm * C1' * ABASE ;
YA(3,:) = pivotxm * [C2' (-C2' * ra3skew)] * XDD ...
      +pivotxm * [zeros(3)  C2'* ABASESKEW] * X ...
      +pivotxm * C2' * ABASE ;
YA(4,:) = pivotzm * [C2' (-C2' * ra4skew)] * XDD ...
      +pivotzm * [zeros(3)  C2'* ABASESKEW] * X ...
      +pivotzm * C2' * ABASE ;
YA(5,:) = pivotxm * [C3' (-C3' * ra5skew)] * XDD ...
      +pivotxm * [zeros(3)  C3'* ABASESKEW] * X ...
      +pivotxm * C3' * ABASE ;
YA(6,:) = pivotzm * [C3' (-C3' * ra6skew)] * XDD ...
      +pivotzm * [zeros(3)  C3'* ABASESKEW] * X ...
      +pivotzm * C3' * ABASE ;
```

```
%
%%% Adding Acceleration bias
%
YA = YA + Abias;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Position sensor models for g-LIMIT (glpos.m)
% written by Young Kim
% updated on 6-24-98
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function YP = glpos (t,X)
global C4 C5 C6 rp1skew rp2skew rp3skew
%
pivotm = [1 0 0; 0 0 1];
YP(1:2,:) = pivotm * C4'* [eye(3) [-rp1skew]] * X;
YP(3:4,:) = pivotm * C5'* [eye(3) [-rp2skew]] * X;
YP(5:6,:) = pivotm * C6'* [eye(3) [-rp3skew]] * X;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Base disturbance function (basedist.m)
% updated on 6-24-98
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [ABASE, ABASESKEW] = basedist(t)
global ABASE0 ABASESKEW0 frq1 td1start td1end
%
if frq1 == 0
    if t >= td1start & t <= td1end
        ABASE = ABASE0; ABASESKEW = ABASESKEW0;
    else
        ABASE = ABASE0*0; ABASESKEW = ABASESKEW0*0;
    end
else
    ABASE = ABASE0 * sin(frq1 * 2*pi * t);
    ABASESKEW = ABASESKEW0 * sin(frq1 * 2*pi * t );
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Accelerations and Displacements at the platform C.M. (cmmove.m)
% updated on 6-24-98
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [YACM, YPCM] = cmmove (t,X,XDD)
global rcskew
%%% Base disturbance acceleration
    [ABASE, ABASESKEW] = basedist(t);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
YACM = [eye(3) (-rcskew)] * XDD + ABASE;
YPCM = [eye(3) (-rcskew)] * X;
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Force disturbance given at floator. (fdist.m)
% updated on 6-24-98
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [fd, fdskew] = fdist(t)
global fd0 fdskew0 frq2 td2start td2end
%
if frq2 == 0
    if t >= td2start & t <= td2end
        fd = fd0; fdskew = fdskew0;
    else
        fd = fd0*0; fdskew = fdskew0*0;
    end
else
        fd = fd0 * sin(frq2 * 2*pi * t );
        fdskew = fdskew0 * sin(frq2 * 2*pi * t );
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Skew matrix (skewm.m)
% updated on 6-24-98
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function vskew = skewm(v)
vskew = [0 -v(3) v(2); v(3) 0 -v(1); -v(2) v(1) 0];
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function Yacc_PID = accpid(t,xin,KP,KI,KD,TS)
%PID controller
        Yacc_P = accprop(t,xin,KP,TS);
        Yacc_I = accinteg(t,xin,KI,TS);
  Yacc_D = accrate(t,xin,KD,TS);
  Yacc_PID = Yacc_P + Yacc_I + Yacc_D;
function Yacc_P = pidprop(t,xin,KP,TS)
%Proportional control loop
        Yacc_P = KP*xin;
function Yacc_I = accinteg(t,xin,KI,TS)
%Integral control loop
global Yacc_I0
        Yacc_I1 = TS*xin + Yacc_I0;
  Yacc_I0 = Yacc_I1;
  Yacc_I = KI*Yacc_I1;
function Yacc_D = accrate(t,xin,KD,TS)
%Derivative control loop
global Yacc_D0
        Yacc_D1 = KD*(1/TS*xin - Yacc_D0);
  Yacc_D0 = 1/TS*xin;
  Yacc_D = Yacc_D1;
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function Ypos_PID = pospid(t,xin,KP,KI,KD,TS)
%PID controller
        Ypos_P = posprop(t,xin,KP,TS);
        Ypos_I = posinteg(t,xin,KI,TS);
  Ypos_D = posrate(t,xin,KD,TS);
  Ypos_PID = Ypos_P + Ypos_I + Ypos_D;
function Ypos_P = pidprop(t,xin,KP,TS)
%Proportional control loop
        Ypos_P = KP*xin;
function Ypos_I = posinteg(t,xin,KI,TS)
%Integral control loop
global Ypos_I0
        Ypos_I1 = TS*xin + Ypos_I0;
  Ypos_I0 = Ypos_I1;
  Ypos_I = KI*Ypos_I1;
function Ypos_D = posrate(t,xin,KD,TS)
%Derivative control loop
global Ypos_D0
  Ypos_D1 = KD*(1/TS*xin - Ypos_D0);
  Ypos_D0 = 1/TS*xin;
  Ypos_D = Ypos_D1;
```

Appendix B

g-LIMIT User Defined Controller Subroutine

```
C
    SUBROUTINE USDC(T,U,R)
    IMPLICIT DOUBLE PRECISION (A-H,O-Z)
    DIMENSION U(1),R(1)
C
     RETURN
     END
c
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
c   For glconfig1.int
c   written by Young Kim on 9/30/99
c   modified on 11/1/99
c--------------------------------------------------
    SUBROUTINE USCC(T,U,X,R,XDOT)
    IMPLICIT DOUBLE PRECISION(A-H,O-Z)
    INCLUDE 'DBP.F'
    INCLUDE 'DBC.F'
    DIMENSION U(18),R(12),X(1),XDOT(1)
    DIMENSION Ctr1(3,3),Ctr2(3,3),Ctr3(3,3),Ctrans(3,3)
    DIMENSION TM(6,6),temp(3),rvec(3),rcom(6)
C
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
c Controller #3 Input:
c
c   u(1):  SE701 (Position vector sensor #1 at B2N3), dx (x component)
c   u(2):  SE701 (Position vector sensor #1 at B2N3), dy (y component)
c   u(3):  SE701 (Position vector sensor #1 at B2N3), dz (z component)
c   u(4):  SE801 (Position vector sensor #2 at B2N5), dx (x component)
c   u(5):  SE801 (Position vector sensor #2 at B2N5), dy (y component)
c   u(6):  SE801 (Position vector sensor #2 at B2N5), dz (z component)
c   u(7):  SE901 (Position vector sensor #3 at B2N7), dx (x component)
c   u(8):  SE901 (Position vector sensor #3 at B2N7), dy (y component)
c   u(9):  SE901 (Position vector sensor #3 at B2N7), dz (z component)
c   u(10): SE912 (IMU sensor #1 at B2N1), Theta_x
c   u(11): SE912 (IMU sensor #1 at B2N1), Theta_y
c   u(12): SE912 (IMU sensor #1 at B2N1), Theta_z
c   u(13): FU1   (Function generator #1), x_cm command
c   u(14): FU2   (Function generator #2), y_cm command
c   u(15): FU3   (Function generator #3), z_cm command
c   u(16): FU16  (Function generator #16), THx_cm command
c   u(17): FU17  (Function generator #17), THy_cm command
c   u(18): FU18  (Function generator #18), THz_cm command
c
```

```
c Controller #3 Output:
c The followings are calculated from analytic equation.
c    r(1):  #1 position sensor error y component
c    r(2):  #1 position sensor error z component
c    r(3):  #2 position sensor error y component
c    r(4):  #2 position sensor error z component
c    r(5):  #3 position sensor error y component
c    r(6):  #3 position sensor error z component
c    r(7):  position command - position error (y component at IM #1)
c    r(8):  position command - position error (z component at IM #1)
c    r(9):  position command - position error (y component at IM #2)
c    r(10): position command - position error (z component at IM #2)
c    r(11): position command - position error (y component at IM #3)
c    r(12): position command - position error (z component at IM #3)
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
c Initialization
      if (t .eq. 0.D0) then
         pi=4.d0*datan(1.d0)
C
C     DEFINE TRANSFORMATION MATRIX BETWEEN DISPLACEMENTS AT
C     C.M AND POSTION SENSOR OUTPUTS.
C
      DO 10 I=1,6
      DO 10 J=1,6
         TM(I,J)=0.D0
   10 CONTINUE
      TM(1,1)=1.D0
      TM(1,5)=0.0178D0
      TM(1,6)=-0.1426D0
      TM(2,3)=1.D0
      TM(2,4)=0.1426D0
      TM(2,5)=0.0040D0
      TM(3,1)=-0.5D0
      TM(3,2)=0.8660D0
      TM(3,4)=-0.0154D0
      TM(3,5)=-0.0089D0
      TM(3,6)=-0.1160D0
      TM(4,3)=1.D0
      TM(4,4)=-0.0413D0
      TM(4,5)=0.1102D0
      TM(5,1)=-0.5D0
      TM(5,2)=-0.8660D0
      TM(5,4)=0.0154D0
      TM(5,5)=-0.0089D0
      TM(5,6)=-0.1091D0
```

```
      TM(6,3)=1.D0
      TM(6,4)=-0.0413D0
      TM(6,5)=-0.1022D0
c
c Transpose of C matrix from body #2 frame to IM #1 frame
c
        psi1 = 0.d0*pi/180.d0
        s1 = DSIN(psi1)
        c1 = DCOS(psi1)

        Ctr1(1,1)=c1
        Ctr1(2,1)=-s1
        Ctr1(3,1)=0.d0
        Ctr1(1,2)=s1
        Ctr1(2,2)=c1
        Ctr1(3,2)=0.d0
        Ctr1(1,3)=0.d0
        Ctr1(2,3)=0.d0
        Ctr1(3,3)=1.d0
c
c Transpose of C matrix from body #2 frame to IM #2 frame
c
        psi2 = 120.d0*pi/180.d0
        s2 = DSIN(psi2)
        c2 = DCOS(psi2)

        Ctr2(1,1)=c2
        Ctr2(2,1)=-s2
        Ctr2(3,1)=0.d0
        Ctr2(1,2)=s2
        Ctr2(2,2)=c2
        Ctr2(3,2)=0.d0
        Ctr2(1,3)=0.d0
        Ctr2(2,3)=0.d0
        Ctr2(3,3)=1.d0
c
c Transpose of C matrix from body #3 frame to IM #1 frame
c
        psi3 = 240.d0*pi/180.d0
        s3 = DSIN(psi3)
        c3 = DCOS(psi3)

        Ctr3(1,1)=c3
        Ctr3(2,1)=-s3
        Ctr3(3,1)=0.d0
```

```
        Ctr3(1,2)=s3
        Ctr3(2,2)=c3
        Ctr3(3,2)=0.d0
        Ctr3(1,3)=0.d0
        Ctr3(2,3)=0.d0
        Ctr3(3,3)=1.d0
      endif
c
c Determine a transpose of transformation matrix Ctrans from inertial
c frame to body 2 frame using three Euler angles (theta_x, theta_y, theta_z) obtained
c from IMU sensor fixed on C.M. of body 2.
c
        s1 = DSIN(u(10))
        c1 = DCOS(u(10))
        s2 = DSIN(u(11))
        c2 = DCOS(u(11))
        s3 = DSIN(u(12))
        c3 = DCOS(u(12))
c
c Transpose of C matrix from inertial frame to body 1 frame
c
      Ctrans(1,1)=c2*c3
      Ctrans(2,1)=-c2*s3
      Ctrans(3,1)=s2
      Ctrans(1,2)=s1*s2*c3+s3*c1
      Ctrans(2,2)=-s1*s2*s3+c3*c1
      Ctrans(3,2)=-s1*c2
      Ctrans(1,3)=-c1*s2*c3+s3*s1
      Ctrans(2,3)=c1*s2*s3+c3*s1
      Ctrans(3,3)=c1*c2
c
c Determine position sensor errors.
c
c
c Transform relative position vector from inertial frame IM #1 frame
c
      CALL MDM(Ctrans,u(1),temp(1),3,3,3,1)
      CALL MDM(Ctr1,temp(1),rvec(1),3,3,3,1)
      r(1)= rvec(1)
      r(2)= rvec(3)
c
c Transform relative position vector from inertial frame IM #2 frame
c
      CALL MDM(Ctrans,u(4),temp(1),3,3,3,1)
      CALL MDM(Ctr2,temp(1),rvec(1),3,3,3,1)
```

```
      r(3)= rvec(1)
      r(4)= rvec(3)
c
c Transform relative position vector from inertial frame IM #3 frame
c
      CALL MDM(Ctrans,u(7),temp(1),3,3,3,1)
      CALL MDM(Ctr3,temp(1),rvec(1),3,3,3,1)
      r(5)= rvec(1)
      r(6)= rvec(3)
C
C TRAANSFORM POSITION COMMAND AT THE C.M. OF PLATFORM FROM
BODY #2 FRAME
C TO IM #1,2,3 FRAME.
C
      CALL MDM(TM,u(13),rcom(1),6,6,6,1)
c
c Determine position PID controller input by subtracting position sensor output
c from postion command at the C.M. of each IM.
c
      do 20 i=1,6
        r(6+i)=rcom(i)-r(i)
   20 continue
c
      RETURN
      END
```

Appendix C

g-LIIMIT TREETOPS Simulation Model

TREETOPS REV 10 06/05/95

SIM CONTROL

```
 1 SI    0 Title                                                 GLCONFIG1
 2 SI    0 Simulation stop time                                  200
 3 SI    0 Plot data interval                                    1E-2
 4 SI    0 Integration type (R,S or U)                           R
 5 SI    0 Step size (sec)                                       5E-4
 6 SI    0 Sandia integration absolute and relative error
 7 SI    0 Linearization option  (L,Z or N)                      L
 8 SI    0 Restart option        (Y/N)                           N
 9 SI    0 Contact force computation option     (Y/N)            N
10 SI    0 Constraint force computation option  (Y/N)            N
11 SI    0 Small angle speedup option (All,Bypass,First,Nth)     A
12 SI    0 Mass matrix speedup option (All,Bypass,First,Nth)     A
13 SI    0 Non-Linear  speedup option (All,Bypass,First,Nth)     A
14 SI    0 Constraint  speedup option (All,Bypass,First,Nth)     A
15 SI    0 Constraint stabilization option  (Y/N)                N
16 SI    0 Stabilization epsilon
```

BODY

```
17 BO    1 Body ID number                                        1
18 BO    1 Type (Rigid,Flexible,NASTRAN)                         R
19 BO    1 Number of modes
20 BO    1 Modal calculation option (0, 1 or 2)
21 BO    1 Foreshortening option (Y/N)
22 BO    1 Model reduction method (NO,MS,MC,CC,QM,CV)
23 BO    1 NASTRAN data file FORTRAN unit number (40 - 60)
24 BO    1 Number of augmented nodes (0 if none)
25 BO    1 Damping matrix option (NS,CD,HL,SD)
26 BO    1 Constant damping ratio
27 BO    1 Low frequency, High frequency ratios
28 BO    1 Mode ID number, damping ratio
29 BO    1 Conversion factors: Length,Mass,Force
30 BO    1 Inertia reference node (0=Bdy Ref Frm; 1=mass cen) 1
31 BO    1 Moments of inertia (kg-m2) Ixx,Iyy,Izz                1.E7,1.E7,1.E7
32 BO    1 Products of inertia (kg-m2) Ixy,Ixz,Iyz               0,0,0
33 BO    1 Mass (kg)                                             1.E5
34 BO    1 Number of Nodes                                       12
35 BO    1 Node ID, Node coord. (meters) x,y,z                   1,0,0,0.02
36 BO    1 Node ID, Node coord. (meters) x,y,z                   2,0,0,0
37 BO    1 Node ID, Node coord. (meters) x,y,z                   3,0,0.1226,0.0848
38 BO    1 Node ID, Node coord. (meters) x,y,z                   4,-0.1062,-0.0613,0.0848
39 BO    1 Node ID, Node coord. (meters) x,y,z                   5,0.1062,-0.0613,0.0848
40 BO    1 Node ID, Node coord. (meters) x,y,z                   6,0.004,-0.02,0.067
41 BO    1 Node ID, Node coord. (meters) x,y,z                   7,10.0686,-0.0787,-0.0205
42 BO    1 Node ID, Node coord. (meters) x,y,z                   8,0.0686,9.9213,-0.0205
43 BO    1 Node ID, Node coord. (meters) x,y,z                   9,0.0686,-0.0787,9.9795
44 BO    1 Node ID, Node coord. (meters) x,y,z                   10,9.9314,-0.0787,-0.0205
45 BO    1 Node ID, Node coord. (meters) x,y,z                   11,-0.0686,9.9213,-0.0205
46 BO    1 Node ID, Node coord. (meters) x,y,z                   12,-0.0686,-0.0787,9.9795
47 BO    1 Node ID, Node structual joint ID

48 BO    2 Body ID number                                        2
49 BO    2 Type (Rigid,Flexible,NASTRAN)                         R
50 BO    2 Number of modes
51 BO    2 Modal calculation option (0, 1 or 2)
52 BO    2 Foreshortening option (Y/N)
53 BO    2 Model reduction method (NO,MS,MC,CC,QM,CV)
54 BO    2 NASTRAN data file FORTRAN unit number (40 - 60)
55 BO    2 Number of augmented nodes (0 if none)
56 BO    2 Damping matrix option (NS,CD,HL,SD)
57 BO    2 Constant damping ratio
58 BO    2 Low frequency, High frequency ratios
59 BO    2 Mode ID number, damping ratio
60 BO    2 Conversion factors: Length,Mass,Force
61 BO    2 Inertia reference node (0=Bdy Ref Frm; 1=mass cen) 1
62 BO    2 Moments of inertia (kg-m2) Ixx,Iyy,Izz                0.0793,0.0807,0.1407
63 BO    2 Products of inertia (kg-m2) Ixy,Ixz,Iyz               -0.0004,0,-0.0002
```

64	BO	2	Mass (kg)	7.8681
65	BO	2	Number of Nodes	13
66	BO	2	Node ID, Node coord. (meters) x,y,z	1,0.004,-0.020,0.067
67	BO	2	Node ID, Node coord. (meters) x,y,z	2,0,0,0
68	BO	2	Node ID, Node coord. (meters) x,y,z	3,0,0.0411,0.0747
69	BO	2	Node ID, Node coord. (meters) x,y,z	4,-0.0356,-0.0206,0.0747
70	BO	2	Node ID, Node coord. (meters) x,y,z	5,0.0356,-0.0206,0.0747
71	BO	2	Node ID, Node coord. (meters) x,y,z	6,0,0.1226,0.0848
72	BO	2	Node ID, Node coord. (meters) x,y,z	7,-0.1062,-0.0613,0.0848
73	BO	2	Node ID, Node coord. (meters) x,y,z	8,0.1062,-0.0613,0.0848
74	BO	2	Node ID, Node coord. (meters) x,y,z	9,0,0.1226,0.0848
75	BO	2	Node ID, Node coord. (meters) x,y,z	10,-0.1062,-0.0613,0.0848
76	BO	2	Node ID, Node coord. (meters) x,y,z	11,0.1062,-0.0613,0.0848
77	BO	2	Node ID, Node coord. (meters) x,y,z	12,0.0686,-0.0787,-0.0205
78	BO	2	Node ID, Node coord. (meters) x,y,z	13,-0.0686,-0.0787,-0.0205
79	BO	2	Node ID, Node structual joint ID	

HINGE

80	HI	1	Hinge ID number	1
81	HI	1	Inboard body ID, Outboard body ID	0,1
82	HI	1	"p" node ID, "q" node ID	0,2
83	HI	1	Number of rotation DOFs, Rotation option (F or G)	3,F
84	HI	1	L1 unit vector in inboard body coord. x,y,z	1,0,0
85	HI	1	L1 unit vector in outboard body coord. x,y,z	1,0,0
86	HI	1	L2 unit vector in inboard body coord. x,y,z	
87	HI	1	L2 unit vector in outboard body coord. x,y,z	
88	HI	1	L3 unit vector in inboard body coord. x,y,z	0,0,1
89	HI	1	L3 unit vector in outboard body coord. x,y,z	0,0,1
90	HI	1	Initial rotation angles (deg)	0 0 0
91	HI	1	Initial rotation rates (deg/sec)	0 0 0
92	HI	1	Rotation stiffness (newton-meters/rad)	0 0 0
93	HI	1	Rotation damping (newton-meters/rad/sec)	0 0 0
94	HI	1	Null torque angles (deg)	0 0 0
95	HI	1	Number of translation DOFs	3
96	HI	1	First translation unit vector g1	1 0 0
97	HI	1	Second translation unit vector g2	0 1 0
98	HI	1	Third translation unit vector g3	0 0 1
99	HI	1	Initial translation (meters)	0,0,0
100	HI	1	Initial translation velocity (meters/sec)	0 0 0
101	HI	1	Translation stiffness (newtons/meters)	0 0 0
102	HI	1	Translation damping (newtons/meter/sec)	0 0 0
103	HI	1	Null force translations	0 0 0
104	HI	2	Hinge ID number	2
105	HI	2	Inboard body ID, Outboard body ID	1,2
106	HI	2	"p" node ID, "q" node ID	6,1
107	HI	2	Number of rotation DOFs, Rotation option (F or G)	3
108	HI	2	L1 unit vector in inboard body coord. x,y,z	1,0,0
109	HI	2	L1 unit vector in outboard body coord. x,y,z	1,0,0
110	HI	2	L2 unit vector in inboard body coord. x,y,z	
111	HI	2	L2 unit vector in outboard body coord. x,y,z	
112	HI	2	L3 unit vector in inboard body coord. x,y,z	0,0,1
113	HI	2	L3 unit vector in outboard body coord. x,y,z	0,0,1
114	HI	2	Initial rotation angles (deg)	0 0 0
115	HI	2	Initial rotation rates (deg/sec)	0 0 0
116	HI	2	Rotation stiffness (newton-meters/rad)	0 0 0
117	HI	2	Rotation damping (newton-meters/rad/sec)	0 0 0
118	HI	2	Null torque angles (deg)	0 0 0
119	HI	2	Number of translation DOFs	3
120	HI	2	First translation unit vector g1	1 0 0
121	HI	2	Second translation unit vector g2	0 1 0
122	HI	2	Third translation unit vector g3	0 0 1
123	HI	2	Initial translation (meters)	0.0,0.0,0.0
124	HI	2	Initial translation velocity (meters/sec)	0 0 0
125	HI	2	Translation stiffness (newtons/meters)	0 0 0
126	HI	2	Translation damping (newtons/meter/sec)	0 0 0
127	HI	2	Null force translations	0 0 0

SENSOR

128	SE	1	Sensor ID number	1
129	SE	1	Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)	AC
130	SE	1	Mounting point body ID, Mounting point node ID	2,1

```
131 SE   1 Second mounting point body ID, Second node ID
132 SE   1 Input axis unit vector (IA) x,y,z                 1,0,0
133 SE   1 Mounting point Hinge index, Axis index
134 SE   1 First focal plane unit vector  (Fp1) x,y,z
135 SE   1 Second focal plane unit vector (Fp2) x,y,z
136 SE   1 Sun/Star unit vector (Us) x,y,z
137 SE   1 Euler Angle Sequence (1-6)
138 SE   1 CMG ID number and Gimbal number

139 SE   2 Sensor ID number                                  2
140 SE   2 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)     AC
141 SE   2 Mounting point body ID, Mounting point node ID    2,1
142 SE   2 Second mounting point body ID, Second node ID
143 SE   2 Input axis unit vector (IA) x,y,z                 0,1,0
144 SE   2 Mounting point Hinge index, Axis index
145 SE   2 First focal plane unit vector  (Fp1) x,y,z
146 SE   2 Second focal plane unit vector (Fp2) x,y,z
147 SE   2 Sun/Star unit vector (Us) x,y,z
148 SE   2 Euler Angle Sequence (1-6)
149 SE   2 CMG ID number and Gimbal number

150 SE   3 Sensor ID number                                  3
151 SE   3 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)     AC
152 SE   3 Mounting point body ID, Mounting point node ID    2,1
153 SE   3 Second mounting point body ID, Second node ID
154 SE   3 Input axis unit vector (IA) x,y,z                 0,0,1
155 SE   3 Mounting point Hinge index, Axis index
156 SE   3 First focal plane unit vector  (Fp1) x,y,z
157 SE   3 Second focal plane unit vector (Fp2) x,y,z
158 SE   3 Sun/Star unit vector (Us) x,y,z
159 SE   3 Euler Angle Sequence (1-6)
160 SE   3 CMG ID number and Gimbal number

161 SE 101 Sensor ID number                                  101
162 SE 101 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)     AC
163 SE 101 Mounting point body ID, Mounting point node ID    2,3
164 SE 101 Second mounting point body ID, Second node ID
165 SE 101 Input axis unit vector (IA) x,y,z                 1,0,0
166 SE 101 Mounting point Hinge index, Axis index
167 SE 101 First focal plane unit vector  (Fp1) x,y,z
168 SE 101 Second focal plane unit vector (Fp2) x,y,z
169 SE 101 Sun/Star unit vector (Us) x,y,z
170 SE 101 Euler Angle Sequence (1-6)
171 SE 101 CMG ID number and Gimbal number

172 SE 102 Sensor ID number                                  102
173 SE 102 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)     AC
174 SE 102 Mounting point body ID, Mounting point node ID    2,3
175 SE 102 Second mounting point body ID, Second node ID
176 SE 102 Input axis unit vector (IA) x,y,z                 0,0,1
177 SE 102 Mounting point Hinge index, Axis index
178 SE 102 First focal plane unit vector  (Fp1) x,y,z
179 SE 102 Second focal plane unit vector (Fp2) x,y,z
180 SE 102 Sun/Star unit vector (Us) x,y,z
181 SE 102 Euler Angle Sequence (1-6)
182 SE 102 CMG ID number and Gimbal number

183 SE 201 Sensor ID number                                  201
184 SE 201 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)     AC
185 SE 201 Mounting point body ID, Mounting point node ID    2,4
186 SE 201 Second mounting point body ID, Second node ID
187 SE 201 Input axis unit vector (IA) x,y,z                 -0.5,0.86603,0
188 SE 201 Mounting point Hinge index, Axis index
189 SE 201 First focal plane unit vector  (Fp1) x,y,z
190 SE 201 Second focal plane unit vector (Fp2) x,y,z
191 SE 201 Sun/Star unit vector (Us) x,y,z
192 SE 201 Euler Angle Sequence (1-6)
193 SE 201 CMG ID number and Gimbal number

194 SE 202 Sensor ID number                                  202
195 SE 202 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)     AC
196 SE 202 Mounting point body ID, Mounting point node ID    2,4
197 SE 202 Second mounting point body ID, Second node ID
198 SE 202 Input axis unit vector (IA) x,y,z                 0,0,1
199 SE 202 Mounting point Hinge index, Axis index
200 SE 202 First focal plane unit vector  (Fp1) x,y,z
```

```
201 SE 202 Second focal plane unit vector (Fp2) x,y,z
202 SE 202 Sun/Star unit vector (Us) x,y,z
203 SE 202 Euler Angle Sequence (1-6)
204 SE 202 CMG ID number and Gimbal number

205 SE 301 Sensor ID number                                    301
206 SE 301 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)       AC
207 SE 301 Mounting point body ID, Mounting point node ID      2,5
208 SE 301 Second mounting point body ID, Second node ID
209 SE 301 Input axis unit vector (IA) x,y,z                   -0.5,-0.86603,0
210 SE 301 Mounting point Hinge index, Axis index
211 SE 301 First focal plane unit vector  (Fp1) x,y,z
212 SE 301 Second focal plane unit vector (Fp2) x,y,z
213 SE 301 Sun/Star unit vector (Us) x,y,z
214 SE 301 Euler Angle Sequence (1-6)
215 SE 301 CMG ID number and Gimbal number

216 SE 302 Sensor ID number                                    302
217 SE 302 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)       AC
218 SE 302 Mounting point body ID, Mounting point node ID      2,5
219 SE 302 Second mounting point body ID, Second node ID
220 SE 302 Input axis unit vector (IA) x,y,z                   0,0,1
221 SE 302 Mounting point Hinge index, Axis index
222 SE 302 First focal plane unit vector  (Fp1) x,y,z
223 SE 302 Second focal plane unit vector (Fp2) x,y,z
224 SE 302 Sun/Star unit vector (Us) x,y,z
225 SE 302 Euler Angle Sequence (1-6)
226 SE 302 CMG ID number and Gimbal number

227 SE 701 Sensor ID number                                    701
228 SE 701 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)       P3
229 SE 701 Mounting point body ID, Mounting point node ID      1,3
230 SE 701 Second mounting point body ID, Second node ID       2,6
231 SE 701 Input axis unit vector (IA) x,y,z
232 SE 701 Mounting point Hinge index, Axis index
233 SE 701 First focal plane unit vector  (Fp1) x,y,z
234 SE 701 Second focal plane unit vector (Fp2) x,y,z
235 SE 701 Sun/Star unit vector (Us) x,y,z
236 SE 701 Euler Angle Sequence (1-6)
237 SE 701 CMG ID number and Gimbal number

238 SE 801 Sensor ID number                                    801
239 SE 801 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)       P3
240 SE 801 Mounting point body ID, Mounting point node ID      1,4
241 SE 801 Second mounting point body ID, Second node ID       2,7
242 SE 801 Input axis unit vector (IA) x,y,z
243 SE 801 Mounting point Hinge index, Axis index
244 SE 801 First focal plane unit vector  (Fp1) x,y,z
245 SE 801 Second focal plane unit vector (Fp2) x,y,z
246 SE 801 Sun/Star unit vector (Us) x,y,z
247 SE 801 Euler Angle Sequence (1-6)
248 SE 801 CMG ID number and Gimbal number

249 SE 901 Sensor ID number                                    901
250 SE 901 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)       P3
251 SE 901 Mounting point body ID, Mounting point node ID      1,5
252 SE 901 Second mounting point body ID, Second node ID       2,8
253 SE 901 Input axis unit vector (IA) x,y,z
254 SE 901 Mounting point Hinge index, Axis index
255 SE 901 First focal plane unit vector  (Fp1) x,y,z
256 SE 901 Second focal plane unit vector (Fp2) x,y,z
257 SE 901 Sun/Star unit vector (Us) x,y,z
258 SE 901 Euler Angle Sequence (1-6)
259 SE 901 CMG ID number and Gimbal number

260 SE 911 Sensor ID number                                    911
261 SE 911 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)       P3
262 SE 911 Mounting point body ID, Mounting point node ID      1,6
263 SE 911 Second mounting point body ID, Second node ID       2,1
264 SE 911 Input axis unit vector (IA) x,y,z
265 SE 911 Mounting point Hinge index, Axis index
266 SE 911 First focal plane unit vector  (Fp1) x,y,z
267 SE 911 Second focal plane unit vector (Fp2) x,y,z
268 SE 911 Sun/Star unit vector (Us) x,y,z
269 SE 911 Euler Angle Sequence (1-6)
270 SE 911 CMG ID number and Gimbal number
```

```
271 SE 912 Sensor ID number                                     912
272 SE 912 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)        IM
273 SE 912 Mounting point body ID, Mounting point node ID       2,1
274 SE 912 Second mounting point body ID, Second node ID
275 SE 912 Input axis unit vector (IA) x,y,z
276 SE 912 Mounting point Hinge index, Axis index
277 SE 912 First focal plane unit vector  (Fp1) x,y,z
278 SE 912 Second focal plane unit vector (Fp2) x,y,z
279 SE 912 Sun/Star unit vector (Us) x,y,z
280 SE 912 Euler Angle Sequence (1-6)                           1
281 SE 912 CMG ID number and Gimbal number

282 SE 921 Sensor ID number                                     921
283 SE 921 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)        P3
284 SE 921 Mounting point body ID, Mounting point node ID       0,0
285 SE 921 Second mounting point body ID, Second node ID        1,1
286 SE 921 Input axis unit vector (IA) x,y,z
287 SE 921 Mounting point Hinge index, Axis index
288 SE 921 First focal plane unit vector  (Fp1) x,y,z
289 SE 921 Second focal plane unit vector (Fp2) x,y,z
290 SE 921 Sun/Star unit vector (Us) x,y,z
291 SE 921 Euler Angle Sequence (1-6)
292 SE 921 CMG ID number and Gimbal number

293 SE 922 Sensor ID number                                     922
294 SE 922 Type (G,R,AN,V,P,AC,T,I,SU,ST,IM,P3,V3,CR,CT)        IM
295 SE 922 Mounting point body ID, Mounting point node ID       1,2
296 SE 922 Second mounting point body ID, Second node ID
297 SE 922 Input axis unit vector (IA) x,y,z
298 SE 922 Mounting point Hinge index, Axis index
299 SE 922 First focal plane unit vector  (Fp1) x,y,z
300 SE 922 Second focal plane unit vector (Fp2) x,y,z
301 SE 922 Sun/Star unit vector (Us) x,y,z
302 SE 922 Euler Angle Sequence (1-6)                           1
303 SE 922 CMG ID number and Gimbal number

           ACTR

304 AC    1 Actuator ID number                                  1
305 AC    1 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                 J
306 AC    1 Actuator location; Node or Hinge (N or H)
307 AC    1 Mounting point body ID number, node ID number       1,2
308 AC    1 Second mounting point body ID, second node ID
309 AC    1 Output axis unit vector x,y,z                       1,0,0
310 AC    1 Mounting point Hinge index, Axis index
311 AC    1 Rotor spin axis unit vector x,y,z
312 AC    1 Initial rotor momentum, H
313 AC    1 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
314 AC    1 Outer gimbal axis unit vector x,y,z
315 AC    1 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
316 AC    1 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
317 AC    1 Inner gimbal axis unit vector x,y,z
318 AC    1 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
319 AC    1 Initial length and rate, y(to) and ydot(to)
320 AC    1 Constants; K1 or wo, n or zeta, Kg, Jm
321 AC    1 Non-linearities; TLim, Tco, Dz

322 AC    2 Actuator ID number                                  2
323 AC    2 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                 J
324 AC    2 Actuator location; Node or Hinge (N or H)
325 AC    2 Mounting point body ID number, node ID number       1,2
326 AC    2 Second mounting point body ID, second node ID
327 AC    2 Output axis unit vector x,y,z                       0,1,0
328 AC    2 Mounting point Hinge index, Axis index
329 AC    2 Rotor spin axis unit vector x,y,z
330 AC    2 Initial rotor momentum, H
331 AC    2 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
332 AC    2 Outer gimbal axis unit vector x,y,z
333 AC    2 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
334 AC    2 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
335 AC    2 Inner gimbal axis unit vector x,y,z
336 AC    2 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
337 AC    2 Initial length and rate, y(to) and ydot(to)
338 AC    2 Constants; K1 or wo, n or zeta, Kg, Jm
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339 AC   2 Non-linearities; TLim, Tco, Dz

340 AC   3 Actuator ID number                                    3
341 AC   3 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
342 AC   3 Actuator location; Node or Hinge (N or H)
343 AC   3 Mounting point body ID number, node ID number         1,2
344 AC   3 Second mounting point body ID, second node ID
345 AC   3 Output axis unit vector x,y,z                         0,0,1
346 AC   3 Mounting point Hinge index, Axis index
347 AC   3 Rotor spin axis unit vector x,y,z
348 AC   3 Initial rotor momentum, H
349 AC   3 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
350 AC   3 Outer gimbal axis unit vector x,y,z
351 AC   3 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
352 AC   3 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
353 AC   3 Inner gimbal axis unit vector x,y,z
354 AC   3 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
355 AC   3 Initial length and rate, y(to) and ydot(to)
356 AC   3 Constants; K1 or wo, n or zeta, Kg, Jm
357 AC   3 Non-linearities; TLim, Tco, Dz

358 AC 101 Actuator ID number                                    101
359 AC 101 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
360 AC 101 Actuator location; Node or Hinge (N or H)
361 AC 101 Mounting point body ID number, node ID number         2,9
362 AC 101 Second mounting point body ID, second node ID
363 AC 101 Output axis unit vector x,y,z                         1,0,0
364 AC 101 Mounting point Hinge index, Axis index
365 AC 101 Rotor spin axis unit vector x,y,z
366 AC 101 Initial rotor momentum, H
367 AC 101 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
368 AC 101 Outer gimbal axis unit vector x,y,z
369 AC 101 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
370 AC 101 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
371 AC 101 Inner gimbal axis unit vector x,y,z
372 AC 101 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
373 AC 101 Initial length and rate, y(to) and ydot(to)
374 AC 101 Constants; K1 or wo, n or zeta, Kg, Jm
375 AC 101 Non-linearities; TLim, Tco, Dz

376 AC 102 Actuator ID number                                    102
377 AC 102 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
378 AC 102 Actuator location; Node or Hinge (N or H)
379 AC 102 Mounting point body ID number, node ID number         2,9
380 AC 102 Second mounting point body ID, second node ID
381 AC 102 Output axis unit vector x,y,z                         0,0,1
382 AC 102 Mounting point Hinge index, Axis index
383 AC 102 Rotor spin axis unit vector x,y,z
384 AC 102 Initial rotor momentum, H
385 AC 102 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
386 AC 102 Outer gimbal axis unit vector x,y,z
387 AC 102 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
388 AC 102 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
389 AC 102 Inner gimbal axis unit vector x,y,z
390 AC 102 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
391 AC 102 Initial length and rate, y(to) and ydot(to)
392 AC 102 Constants; K1 or wo, n or zeta, Kg, Jm
393 AC 102 Non-linearities; TLim, Tco, Dz

394 AC 201 Actuator ID number                                    201
395 AC 201 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
396 AC 201 Actuator location; Node or Hinge (N or H)
397 AC 201 Mounting point body ID number, node ID number         2,10
398 AC 201 Second mounting point body ID, second node ID
399 AC 201 Output axis unit vector x,y,z                         -0.5,0.86603,0
400 AC 201 Mounting point Hinge index, Axis index
401 AC 201 Rotor spin axis unit vector x,y,z
402 AC 201 Initial rotor momentum, H
403 AC 201 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
404 AC 201 Outer gimbal axis unit vector x,y,z
405 AC 201 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
406 AC 201 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
407 AC 201 Inner gimbal axis unit vector x,y,z
408 AC 201 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
409 AC 201 Initial length and rate, y(to) and ydot(to)
410 AC 201 Constants; K1 or wo, n or zeta, Kg, Jm
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411 AC 201 Non-linearities; TLim, Tco, Dz

412 AC 202 Actuator ID number                                   202
413 AC 202 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                 J
414 AC 202 Actuator location; Node or Hinge (N or H)
415 AC 202 Mounting point body ID number, node ID number       2,10
416 AC 202 Second mounting point body ID, second node ID
417 AC 202 Output axis unit vector x,y,z                       0,0,1
418 AC 202 Mounting point Hinge index, Axis index
419 AC 202 Rotor spin axis unit vector x,y,z
420 AC 202 Initial rotor momentum, H
421 AC 202 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
422 AC 202 Outer gimbal axis unit vector x,y,z
423 AC 202 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
424 AC 202 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
425 AC 202 Inner gimbal axis unit vector x,y,z
426 AC 202 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
427 AC 202 Initial length and rate, y(to) and ydot(to)
428 AC 202 Constants; K1 or wo, n or zeta, Kg, Jm
429 AC 202 Non-linearities; TLim, Tco, Dz

430 AC 301 Actuator ID number                                   301
431 AC 301 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                 J
432 AC 301 Actuator location; Node or Hinge (N or H)
433 AC 301 Mounting point body ID number, node ID number       2,11
434 AC 301 Second mounting point body ID, second node ID
435 AC 301 Output axis unit vector x,y,z                       -0.5,-0.86603,0
436 AC 301 Mounting point Hinge index, Axis index
437 AC 301 Rotor spin axis unit vector x,y,z
438 AC 301 Initial rotor momentum, H
439 AC 301 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
440 AC 301 Outer gimbal axis unit vector x,y,z
441 AC 301 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
442 AC 301 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
443 AC 301 Inner gimbal axis unit vector x,y,z
444 AC 301 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
445 AC 301 Initial length and rate, y(to) and ydot(to)
446 AC 301 Constants; K1 or wo, n or zeta, Kg, Jm
447 AC 301 Non-linearities; TLim, Tco, Dz

448 AC 302 Actuator ID number                                   302
449 AC 302 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                 J
450 AC 302 Actuator location; Node or Hinge (N or H)
451 AC 302 Mounting point body ID number, node ID number       2,11
452 AC 302 Second mounting point body ID, second node ID
453 AC 302 Output axis unit vector x,y,z                       0,0,1
454 AC 302 Mounting point Hinge index, Axis index
455 AC 302 Rotor spin axis unit vector x,y,z
456 AC 302 Initial rotor momentum, H
457 AC 302 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
458 AC 302 Outer gimbal axis unit vector x,y,z
459 AC 302 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
460 AC 302 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
461 AC 302 Inner gimbal axis unit vector x,y,z
462 AC 302 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
463 AC 302 Initial length and rate, y(to) and ydot(to)
464 AC 302 Constants; K1 or wo, n or zeta, Kg, Jm
465 AC 302 Non-linearities; TLim, Tco, Dz

           CONTROLLER

466 CO   1 Controller ID number                                 1
467 CO   1 Controller type (CB,CM,DB,DM,UC,UD)                  DB
468 CO   1 Sample time (sec)                                    1E-3
469 CO   1 Number of inputs, Number of outputs                  24,6
470 CO   1 Number of states
471 CO   1 Output No., Input type (I,S,T), Input ID, Gain       1,S,101,1
472 CO   1 Output No., Input type (I,S,T), Input ID, Gain       2,S,102,1
473 CO   1 Output No., Input type (I,S,T), Input ID, Gain       3,S,103,1
474 CO   1 Output No., Input type (I,S,T), Input ID, Gain       4,S,104,1
475 CO   1 Output No., Input type (I,S,T), Input ID, Gain       5,S,105,1
476 CO   1 Output No., Input type (I,S,T), Input ID, Gain       6,S,106,1

477 CO   2 Controller ID number                                 2
478 CO   2 Controller type (CB,CM,DB,DM,UC,UD)                  DB
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479	CO	2	Sample time (sec)	1E-1
480	CO	2	Number of inputs, Number of outputs	6,6
481	CO	2	Number of states	
482	CO	2	Output No., Input type (I,S,T), Input ID, Gain	1,S,201,3
483	CO	2	Output No., Input type (I,S,T), Input ID, Gain	2,S,202,3
484	CO	2	Output No., Input type (I,S,T), Input ID, Gain	3,S,203,3
485	CO	2	Output No., Input type (I,S,T), Input ID, Gain	4,S,204,3
486	CO	2	Output No., Input type (I,S,T), Input ID, Gain	5,S,205,3
487	CO	2	Output No., Input type (I,S,T), Input ID, Gain	6,S,206,3
488	CO	3	Controller ID number	3
489	CO	3	Controller type (CB,CM,DB,DM,UC,UD)	UC
490	CO	3	Sample time (sec)	
491	CO	3	Number of inputs, Number of outputs	18,12
492	CO	3	Number of states	0
493	CO	3	Output No., Input type (I,S,T), Input ID, Gain	
			SUMM JUNC	
494	SU	1	Summing junction ID number	1
495	SU	1	Controller ID number	1
496	SU	1	Number of inputs to summing junction	3
497	SU	1	Input number,Input type(I,S,T),Input ID no,Gain	1,I,1,1
498	SU	1	Input number,Input type(I,S,T),Input ID no,Gain	2,I,7,0
499	SU	1	Input number,Input type(I,S,T),Input ID no,Gain	3,T,11,0
500	SU	2	Summing junction ID number	2
501	SU	2	Controller ID number	1
502	SU	2	Number of inputs to summing junction	3
503	SU	2	Input number,Input type(I,S,T),Input ID no,Gain	1,I,2,1
504	SU	2	Input number,Input type(I,S,T),Input ID no,Gain	2,I,8,0
505	SU	2	Input number,Input type(I,S,T),Input ID no,Gain	3,T,12,0
506	SU	3	Summing junction ID number	3
507	SU	3	Controller ID number	1
508	SU	3	Number of inputs to summing junction	3
509	SU	3	Input number,Input type(I,S,T),Input ID no,Gain	1,I,3,1
510	SU	3	Input number,Input type(I,S,T),Input ID no,Gain	2,I,9,0
511	SU	3	Input number,Input type(I,S,T),Input ID no,Gain	3,T,13,0
512	SU	4	Summing junction ID number	4
513	SU	4	Controller ID number	1
514	SU	4	Number of inputs to summing junction	3
515	SU	4	Input number,Input type(I,S,T),Input ID no,Gain	1,I,4,1
516	SU	4	Input number,Input type(I,S,T),Input ID no,Gain	2,I,10,0
517	SU	4	Input number,Input type(I,S,T),Input ID no,Gain	3,T,14,0
518	SU	5	Summing junction ID number	5
519	SU	5	Controller ID number	1
520	SU	5	Number of inputs to summing junction	3
521	SU	5	Input number,Input type(I,S,T),Input ID no,Gain	1,I,5,1
522	SU	5	Input number,Input type(I,S,T),Input ID no,Gain	2,I,11,0
523	SU	5	Input number,Input type(I,S,T),Input ID no,Gain	3,T,15,0
524	SU	6	Summing junction ID number	6
525	SU	6	Controller ID number	1
526	SU	6	Number of inputs to summing junction	3
527	SU	6	Input number,Input type(I,S,T),Input ID no,Gain	1,I,6,1
528	SU	6	Input number,Input type(I,S,T),Input ID no,Gain	2,I,12,0
529	SU	6	Input number,Input type(I,S,T),Input ID no,Gain	3,T,16,0
530	SU	11	Summing junction ID number	11
531	SU	11	Controller ID number	1
532	SU	11	Number of inputs to summing junction	2
533	SU	11	Input number,Input type(I,S,T),Input ID no,Gain	1,I,19,1
534	SU	11	Input number,Input type(I,S,T),Input ID no,Gain	2,S,1,-1
535	SU	12	Summing junction ID number	12
536	SU	12	Controller ID number	1
537	SU	12	Number of inputs to summing junction	2
538	SU	12	Input number,Input type(I,S,T),Input ID no,Gain	1,I,20,1
539	SU	12	Input number,Input type(I,S,T),Input ID no,Gain	2,S,2,-1
540	SU	13	Summing junction ID number	13
541	SU	13	Controller ID number	1

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542 SU  13 Number of inputs to summing junction                2
543 SU  13 Input number,Input type(I,S,T),Input ID no,Gain     1,I,21,1
544 SU  13 Input number,Input type(I,S,T),Input ID no,Gain     2,S,3,-1

545 SU  14 Summing junction ID number                          14
546 SU  14 Controller ID number                                1
547 SU  14 Number of inputs to summing junction                2
548 SU  14 Input number,Input type(I,S,T),Input ID no,Gain     1,I,22,1
549 SU  14 Input number,Input type(I,S,T),Input ID no,Gain     2,S,4,-1

550 SU  15 Summing junction ID number                          15
551 SU  15 Controller ID number                                1
552 SU  15 Number of inputs to summing junction                2
553 SU  15 Input number,Input type(I,S,T),Input ID no,Gain     1,I,23,1
554 SU  15 Input number,Input type(I,S,T),Input ID no,Gain     2,S,5,-1

555 SU  16 Summing junction ID number                          16
556 SU  16 Controller ID number                                1
557 SU  16 Number of inputs to summing junction                2
558 SU  16 Input number,Input type(I,S,T),Input ID no,Gain     1,I,24,1
559 SU  16 Input number,Input type(I,S,T),Input ID no,Gain     2,S,6,-1

560 SU 101 Summing junction ID number                          101
561 SU 101 Controller ID number                                1
562 SU 101 Number of inputs to summing junction                3
563 SU 101 Input number,Input type(I,S,T),Input ID no,Gain     1,S,11 , 0.
564 SU 101 Input number,Input type(I,S,T),Input ID no,Gain     2,T,121, 3000
565 SU 101 Input number,Input type(I,S,T),Input ID no,Gain     3,T,131, 0.0

566 SU 102 Summing junction ID number                          102
567 SU 102 Controller ID number                                1
568 SU 102 Number of inputs to summing junction                3
569 SU 102 Input number,Input type(I,S,T),Input ID no,Gain     1,S,12 , 0.
570 SU 102 Input number,Input type(I,S,T),Input ID no,Gain     2,T,122, 3000
571 SU 102 Input number,Input type(I,S,T),Input ID no,Gain     3,T,132, 0.0

572 SU 103 Summing junction ID number                          103
573 SU 103 Controller ID number                                1
574 SU 103 Number of inputs to summing junction                3
575 SU 103 Input number,Input type(I,S,T),Input ID no,Gain     1,S,13 , 0.
576 SU 103 Input number,Input type(I,S,T),Input ID no,Gain     2,T,123, 3000
577 SU 103 Input number,Input type(I,S,T),Input ID no,Gain     3,T,133, 0.0

578 SU 104 Summing junction ID number                          104
579 SU 104 Controller ID number                                1
580 SU 104 Number of inputs to summing junction                3
581 SU 104 Input number,Input type(I,S,T),Input ID no,Gain     1,S,14 , 0.
582 SU 104 Input number,Input type(I,S,T),Input ID no,Gain     2,T,124, 3000
583 SU 104 Input number,Input type(I,S,T),Input ID no,Gain     3,T,134, 0.0

584 SU 105 Summing junction ID number                          105
585 SU 105 Controller ID number                                1
586 SU 105 Number of inputs to summing junction                3
587 SU 105 Input number,Input type(I,S,T),Input ID no,Gain     1,S,15 , 0.
588 SU 105 Input number,Input type(I,S,T),Input ID no,Gain     2,T,125, 3000
589 SU 105 Input number,Input type(I,S,T),Input ID no,Gain     3,T,135, 0.0

590 SU 106 Summing junction ID number                          106
591 SU 106 Controller ID number                                1
592 SU 106 Number of inputs to summing junction                3
593 SU 106 Input number,Input type(I,S,T),Input ID no,Gain     1,S,16 , 0.
594 SU 106 Input number,Input type(I,S,T),Input ID no,Gain     2,T,126, 3000
595 SU 106 Input number,Input type(I,S,T),Input ID no,Gain     3,T,136, 0.0

596 SU 201 Summing junction ID number                          201
597 SU 201 Controller ID number                                2
598 SU 201 Number of inputs to summing junction                3
599 SU 201 Input number,Input type(I,S,T),Input ID no,Gain     1,I,1   , 1.2E-3
600 SU 201 Input number,Input type(I,S,T),Input ID no,Gain     2,T,221, 1.25E-5
601 SU 201 Input number,Input type(I,S,T),Input ID no,Gain     3,T,231, 3.1E-3

602 SU 202 Summing junction ID number                          202
603 SU 202 Controller ID number                                2
604 SU 202 Number of inputs to summing junction                3
605 SU 202 Input number,Input type(I,S,T),Input ID no,Gain     1,I,2   , 1.2E-3
606 SU 202 Input number,Input type(I,S,T),Input ID no,Gain     2,T,222, 1.25E-5
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607	SU	202	Input number,Input type(I,S,T),Input ID no,Gain	3,T,232, 3.1E-3
608	SU	203	Summing junction ID number	203
609	SU	203	Controller ID number	2
610	SU	203	Number of inputs to summing junction	3
611	SU	203	Input number,Input type(I,S,T),Input ID no,Gain	1,I,3 , 1.2E-3
612	SU	203	Input number,Input type(I,S,T),Input ID no,Gain	2,T,223, 1.25E-5
613	SU	203	Input number,Input type(I,S,T),Input ID no,Gain	3,T,233, 3.1E-3
614	SU	204	Summing junction ID number	204
615	SU	204	Controller ID number	2
616	SU	204	Number of inputs to summing junction	3
617	SU	204	Input number,Input type(I,S,T),Input ID no,Gain	1,I,4 , 1.2E-3
618	SU	204	Input number,Input type(I,S,T),Input ID no,Gain	2,T,224, 1.25E-5
619	SU	204	Input number,Input type(I,S,T),Input ID no,Gain	3,T,234, 3.1E-3
620	SU	205	Summing junction ID number	205
621	SU	205	Controller ID number	2
622	SU	205	Number of inputs to summing junction	3
623	SU	205	Input number,Input type(I,S,T),Input ID no,Gain	1,I,5 , 1.2E-3
624	SU	205	Input number,Input type(I,S,T),Input ID no,Gain	2,T,225, 1.25E-5
625	SU	205	Input number,Input type(I,S,T),Input ID no,Gain	3,T,235, 3.1E-3
626	SU	206	Summing junction ID number	206
627	SU	206	Controller ID number	2
628	SU	206	Number of inputs to summing junction	3
629	SU	206	Input number,Input type(I,S,T),Input ID no,Gain	1,I,6 , 1.2E-3
630	SU	206	Input number,Input type(I,S,T),Input ID no,Gain	2,T,226, 1.25E-5
631	SU	206	Input number,Input type(I,S,T),Input ID no,Gain	3,T,236, 3.1E-3

TRANSFER FUN

632	TR	11	Transfer function ID number	11
633	TR	11	Controller ID number	1
634	TR	11	Input type (I,S or T), Input ID number	I,13
635	TR	11	Order of numerator	2
636	TR	11	Numerator coefficients (4 per line max)	0, -1, 1.1257
637	TR	11	Order of denominator	2
638	TR	11	Denominator coefficients (4 per line max)	1, -3.0681, 2.0688
639	TR	11	Transfer function gain	6.2832E-5
640	TR	12	Transfer function ID number	12
641	TR	12	Controller ID number	1
642	TR	12	Input type (I,S or T), Input ID number	I,14
643	TR	12	Order of numerator	2
644	TR	12	Numerator coefficients (4 per line max)	0, -1, 1.1257
645	TR	12	Order of denominator	2
646	TR	12	Denominator coefficients (4 per line max)	1, -3.0681, 2.0688
647	TR	12	Transfer function gain	6.2832E-5
648	TR	13	Transfer function ID number	13
649	TR	13	Controller ID number	1
650	TR	13	Input type (I,S or T), Input ID number	I,15
651	TR	13	Order of numerator	2
652	TR	13	Numerator coefficients (4 per line max)	0, -1, 1.1257
653	TR	13	Order of denominator	2
654	TR	13	Denominator coefficients (4 per line max)	1, -3.0681, 2.0688
655	TR	13	Transfer function gain	6.2832E-5
656	TR	14	Transfer function ID number	14
657	TR	14	Controller ID number	1
658	TR	14	Input type (I,S or T), Input ID number	I,16
659	TR	14	Order of numerator	2
660	TR	14	Numerator coefficients (4 per line max)	0, -1, 1.1257
661	TR	14	Order of denominator	2
662	TR	14	Denominator coefficients (4 per line max)	1, -3.0681, 2.0688
663	TR	14	Transfer function gain	6.2832E-5
664	TR	15	Transfer function ID number	15
665	TR	15	Controller ID number	1
666	TR	15	Input type (I,S or T), Input ID number	I,17
667	TR	15	Order of numerator	2
668	TR	15	Numerator coefficients (4 per line max)	0, -1, 1.1257
669	TR	15	Order of denominator	2
670	TR	15	Denominator coefficients (4 per line max)	1, -3.0681, 2.0688

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671 TR  15 Transfer function gain                                  6.2832E-5

672 TR  16 Transfer function ID number                             16
673 TR  16 Controller ID number                                    1
674 TR  16 Input type (I,S or T), Input ID number                  I,18
675 TR  16 Order of numerator                                      2
676 TR  16 Numerator coefficients (4 per line max)                 0, -1, 1.1257
677 TR  16 Order of denominator                                    2
678 TR  16 Denominator coefficients (4 per line max)               1, -3.0681, 2.0688
679 TR  16 Transfer function gain                                  6.2832E-5

680 TR 121 Transfer function ID number                             121
681 TR 121 Controller ID number                                    1
682 TR 121 Input type (I,S or T), Input ID number                  S,11
683 TR 121 Order of numerator                                      1
684 TR 121 Numerator coefficients (4 per line max)                 0, 1E-3
685 TR 121 Order of denominator                                    1
686 TR 121 Denominator coefficients (4 per line max)               -1, 1
687 TR 121 Transfer function gain                                  1

688 TR 122 Transfer function ID number                             122
689 TR 122 Controller ID number                                    1
690 TR 122 Input type (I,S or T), Input ID number                  S,12
691 TR 122 Order of numerator                                      1
692 TR 122 Numerator coefficients (4 per line max)                 0, 1E-3
693 TR 122 Order of denominator                                    1
694 TR 122 Denominator coefficients (4 per line max)               -1, 1
695 TR 122 Transfer function gain                                  1

696 TR 123 Transfer function ID number                             123
697 TR 123 Controller ID number                                    1
698 TR 123 Input type (I,S or T), Input ID number                  S,13
699 TR 123 Order of numerator                                      1
700 TR 123 Numerator coefficients (4 per line max)                 0, 1E-3
701 TR 123 Order of denominator                                    1
702 TR 123 Denominator coefficients (4 per line max)               -1, 1
703 TR 123 Transfer function gain                                  1

704 TR 124 Transfer function ID number                             124
705 TR 124 Controller ID number                                    1
706 TR 124 Input type (I,S or T), Input ID number                  S,14
707 TR 124 Order of numerator                                      1
708 TR 124 Numerator coefficients (4 per line max)                 0, 1E-3
709 TR 124 Order of denominator                                    1
710 TR 124 Denominator coefficients (4 per line max)               -1, 1
711 TR 124 Transfer function gain                                  1

712 TR 125 Transfer function ID number                             125
713 TR 125 Controller ID number                                    1
714 TR 125 Input type (I,S or T), Input ID number                  S,15
715 TR 125 Order of numerator                                      1
716 TR 125 Numerator coefficients (4 per line max)                 0, 1E-3
717 TR 125 Order of denominator                                    1
718 TR 125 Denominator coefficients (4 per line max)               -1, 1
719 TR 125 Transfer function gain                                  1

720 TR 126 Transfer function ID number                             126
721 TR 126 Controller ID number                                    1
722 TR 126 Input type (I,S or T), Input ID number                  S,16
723 TR 126 Order of numerator                                      1
724 TR 126 Numerator coefficients (4 per line max)                 0, 1E-3
725 TR 126 Order of denominator                                    1
726 TR 126 Denominator coefficients (4 per line max)               -1, 1
727 TR 126 Transfer function gain                                  1

728 TR 131 Transfer function ID number                             131
729 TR 131 Controller ID number                                    1
730 TR 131 Input type (I,S or T), Input ID number                  S,11
731 TR 131 Order of numerator                                      1
732 TR 131 Numerator coefficients (4 per line max)                 -1, 1
733 TR 131 Order of denominator                                    1
734 TR 131 Denominator coefficients (4 per line max)               0, 1E-3
735 TR 131 Transfer function gain                                  1

736 TR 132 Transfer function ID number                             132
737 TR 132 Controller ID number                                    1
```

738	TR 132 Input type (I,S or T), Input ID number	S,12
739	TR 132 Order of numerator	1
740	TR 132 Numerator coefficients (4 per line max)	-1, 1
741	TR 132 Order of denominator	1
742	TR 132 Denominator coefficients (4 per line max)	0, 1E-3
743	TR 132 Transfer function gain	1
744	TR 133 Transfer function ID number	133
745	TR 133 Controller ID number	1
746	TR 133 Input type (I,S or T), Input ID number	S,13
747	TR 133 Order of numerator	1
748	TR 133 Numerator coefficients (4 per line max)	-1, 1
749	TR 133 Order of denominator	1
750	TR 133 Denominator coefficients (4 per line max)	0, 1E-3
751	TR 133 Transfer function gain	1
752	TR 134 Transfer function ID number	134
753	TR 134 Controller ID number	1
754	TR 134 Input type (I,S or T), Input ID number	S,14
755	TR 134 Order of numerator	1
756	TR 134 Numerator coefficients (4 per line max)	-1, 1
757	TR 134 Order of denominator	1
758	TR 134 Denominator coefficients (4 per line max)	0, 1E-3
759	TR 134 Transfer function gain	1
760	TR 135 Transfer function ID number	135
761	TR 135 Controller ID number	1
762	TR 135 Input type (I,S or T), Input ID number	S,15
763	TR 135 Order of numerator	1
764	TR 135 Numerator coefficients (4 per line max)	-1, 1
765	TR 135 Order of denominator	1
766	TR 135 Denominator coefficients (4 per line max)	0, 1E-3
767	TR 135 Transfer function gain	1
768	TR 136 Transfer function ID number	136
769	TR 136 Controller ID number	1
770	TR 136 Input type (I,S or T), Input ID number	S,16
771	TR 136 Order of numerator	1
772	TR 136 Numerator coefficients (4 per line max)	-1, 1
773	TR 136 Order of denominator	1
774	TR 136 Denominator coefficients (4 per line max)	0, 1E-3
775	TR 136 Transfer function gain	1
776	TR 221 Transfer function ID number	221
777	TR 221 Controller ID number	2
778	TR 221 Input type (I,S or T), Input ID number	I,1
779	TR 221 Order of numerator	1
780	TR 221 Numerator coefficients (4 per line max)	0, 1E-1
781	TR 221 Order of denominator	1
782	TR 221 Denominator coefficients (4 per line max)	-1, 1
783	TR 221 Transfer function gain	1
784	TR 222 Transfer function ID number	222
785	TR 222 Controller ID number	2
786	TR 222 Input type (I,S or T), Input ID number	I,2
787	TR 222 Order of numerator	1
788	TR 222 Numerator coefficients (4 per line max)	0, 1E-1
789	TR 222 Order of denominator	1
790	TR 222 Denominator coefficients (4 per line max)	-1, 1
791	TR 222 Transfer function gain	1
792	TR 223 Transfer function ID number	223
793	TR 223 Controller ID number	2
794	TR 223 Input type (I,S or T), Input ID number	I,3
795	TR 223 Order of numerator	1
796	TR 223 Numerator coefficients (4 per line max)	0, 1E-1
797	TR 223 Order of denominator	1
798	TR 223 Denominator coefficients (4 per line max)	-1, 1
799	TR 223 Transfer function gain	1
800	TR 224 Transfer function ID number	224
801	TR 224 Controller ID number	2
802	TR 224 Input type (I,S or T), Input ID number	I,4
803	TR 224 Order of numerator	1
804	TR 224 Numerator coefficients (4 per line max)	0, 1E-1
805	TR 224 Order of denominator	1

806	TR 224 Denominator coefficients (4 per line max)	-1, 1
807	TR 224 Transfer function gain	1
808	TR 225 Transfer function ID number	225
809	TR 225 Controller ID number	2
810	TR 225 Input type (I,S or T), Input ID number	I,5
811	TR 225 Order of numerator	1
812	TR 225 Numerator coefficients (4 per line max)	0, 1E-1
813	TR 225 Order of denominator	1
814	TR 225 Denominator coefficients (4 per line max)	-1, 1
815	TR 225 Transfer function gain	1
816	TR 226 Transfer function ID number	226
817	TR 226 Controller ID number	2
818	TR 226 Input type (I,S or T), Input ID number	I,6
819	TR 226 Order of numerator	1
820	TR 226 Numerator coefficients (4 per line max)	0, 1E-1
821	TR 226 Order of denominator	1
822	TR 226 Denominator coefficients (4 per line max)	-1, 1
823	TR 226 Transfer function gain	1
824	TR 231 Transfer function ID number	231
825	TR 231 Controller ID number	2
826	TR 231 Input type (I,S or T), Input ID number	I,1
827	TR 231 Order of numerator	1
828	TR 231 Numerator coefficients (4 per line max)	-1, 1
829	TR 231 Order of denominator	1
830	TR 231 Denominator coefficients (4 per line max)	0, 1E-1
831	TR 231 Transfer function gain	1
832	TR 232 Transfer function ID number	232
833	TR 232 Controller ID number	2
834	TR 232 Input type (I,S or T), Input ID number	I,2
835	TR 232 Order of numerator	1
836	TR 232 Numerator coefficients (4 per line max)	-1, 1
837	TR 232 Order of denominator	1
838	TR 232 Denominator coefficients (4 per line max)	0, 1E-1
839	TR 232 Transfer function gain	1
840	TR 233 Transfer function ID number	233
841	TR 233 Controller ID number	2
842	TR 233 Input type (I,S or T), Input ID number	I,3
843	TR 233 Order of numerator	1
844	TR 233 Numerator coefficients (4 per line max)	-1, 1
845	TR 233 Order of denominator	1
846	TR 233 Denominator coefficients (4 per line max)	0, 1E-1
847	TR 233 Transfer function gain	1
848	TR 234 Transfer function ID number	234
849	TR 234 Controller ID number	2
850	TR 234 Input type (I,S or T), Input ID number	I,4
851	TR 234 Order of numerator	1
852	TR 234 Numerator coefficients (4 per line max)	-1, 1
853	TR 234 Order of denominator	1
854	TR 234 Denominator coefficients (4 per line max)	0, 1E-1
855	TR 234 Transfer function gain	1
856	TR 235 Transfer function ID number	235
857	TR 235 Controller ID number	2
858	TR 235 Input type (I,S or T), Input ID number	I,5
859	TR 235 Order of numerator	1
860	TR 235 Numerator coefficients (4 per line max)	-1, 1
861	TR 235 Order of denominator	1
862	TR 235 Denominator coefficients (4 per line max)	0, 1E-1
863	TR 235 Transfer function gain	1
864	TR 236 Transfer function ID number	236
865	TR 236 Controller ID number	2
866	TR 236 Input type (I,S or T), Input ID number	I,6
867	TR 236 Order of numerator	1
868	TR 236 Numerator coefficients (4 per line max)	-1, 1
869	TR 236 Order of denominator	1
870	TR 236 Denominator coefficients (4 per line max)	0, 1E-1
871	TR 236 Transfer function gain	1

FUNCTION GEN

872	FU	1	Function generator ID number	1
873	FU	1	Type (ST,RA,PU,SA,SI,US,NO,DO)	ST
874	FU	1	Amplitude	0.000
875	FU	1	Slope	
876	FU	1	Start time (sec)	0
877	FU	1	Stop time (sec)	
878	FU	1	Frequency (rad/sec)	
879	FU	1	Phase shift (deg)	
880	FU	1	Array location	
881	FU	1	Mean,Seed	
882	FU	1	Variance	
883	FU	1	Pulse width (sec)	
884	FU	1	Second pulse start time (sec)	
885	FU	2	Function generator ID number	2
886	FU	2	Type (ST,RA,PU,SA,SI,US,NO,DO)	ST
887	FU	2	Amplitude	0.000
888	FU	2	Slope	
889	FU	2	Start time (sec)	0
890	FU	2	Stop time (sec)	
891	FU	2	Frequency (rad/sec)	
892	FU	2	Phase shift (deg)	
893	FU	2	Array location	
894	FU	2	Mean,Seed	
895	FU	2	Variance	
896	FU	2	Pulse width (sec)	
897	FU	2	Second pulse start time (sec)	
898	FU	3	Function generator ID number	3
899	FU	3	Type (ST,RA,PU,SA,SI,US,NO,DO)	ST
900	FU	3	Amplitude	0.000
901	FU	3	Slope	
902	FU	3	Start time (sec)	0
903	FU	3	Stop time (sec)	
904	FU	3	Frequency (rad/sec)	
905	FU	3	Phase shift (deg)	
906	FU	3	Array location	
907	FU	3	Mean,Seed	
908	FU	3	Variance	
909	FU	3	Pulse width (sec)	
910	FU	3	Second pulse start time (sec)	
911	FU	4	Function generator ID number	4
912	FU	4	Type (ST,RA,PU,SA,SI,US,NO,DO)	ST
913	FU	4	Amplitude	1.023E-3
914	FU	4	Slope	
915	FU	4	Start time (sec)	0
916	FU	4	Stop time (sec)	
917	FU	4	Frequency (rad/sec)	
918	FU	4	Phase shift (deg)	
919	FU	4	Array location	
920	FU	4	Mean,Seed	
921	FU	4	Variance	
922	FU	4	Pulse width (sec)	
923	FU	4	Second pulse start time (sec)	
924	FU	5	Function generator ID number	5
925	FU	5	Type (ST,RA,PU,SA,SI,US,NO,DO)	ST
926	FU	5	Amplitude	-1.519E-3
927	FU	5	Slope	
928	FU	5	Start time (sec)	0
929	FU	5	Stop time (sec)	
930	FU	5	Frequency (rad/sec)	
931	FU	5	Phase shift (deg)	
932	FU	5	Array location	
933	FU	5	Mean,Seed	
934	FU	5	Variance	
935	FU	5	Pulse width (sec)	
936	FU	5	Second pulse start time (sec)	
937	FU	6	Function generator ID number	6
938	FU	6	Type (ST,RA,PU,SA,SI,US,NO,DO)	ST
939	FU	6	Amplitude	8.33E-4
940	FU	6	Slope	

941	FU	6	Start time (sec)	0
942	FU	6	Stop time (sec)	
943	FU	6	Frequency (rad/sec)	
944	FU	6	Phase shift (deg)	
945	FU	6	Array location	
946	FU	6	Mean,Seed	
947	FU	6	Variance	
948	FU	6	Pulse width (sec)	
949	FU	6	Second pulse start time (sec)	
950	FU	7	Function generator ID number	7
951	FU	7	Type (ST,RA,PU,SA,SI,US,NO,DO)	ST
952	FU	7	Amplitude	-1.225E-3
953	FU	7	Slope	
954	FU	7	Start time (sec)	0
955	FU	7	Stop time (sec)	
956	FU	7	Frequency (rad/sec)	
957	FU	7	Phase shift (deg)	
958	FU	7	Array location	
959	FU	7	Mean,Seed	
960	FU	7	Variance	
961	FU	7	Pulse width (sec)	
962	FU	7	Second pulse start time (sec)	
963	FU	8	Function generator ID number	8
964	FU	8	Type (ST,RA,PU,SA,SI,US,NO,DO)	ST
965	FU	8	Amplitude	2.45E-4
966	FU	8	Slope	
967	FU	8	Start time (sec)	0
968	FU	8	Stop time (sec)	
969	FU	8	Frequency (rad/sec)	
970	FU	8	Phase shift (deg)	
971	FU	8	Array location	
972	FU	8	Mean,Seed	
973	FU	8	Variance	
974	FU	8	Pulse width (sec)	
975	FU	8	Second pulse start time (sec)	
976	FU	9	Function generator ID number	9
977	FU	9	Type (ST,RA,PU,SA,SI,US,NO,DO)	ST
978	FU	9	Amplitude	1.127E-3
979	FU	9	Slope	
980	FU	9	Start time (sec)	0
981	FU	9	Stop time (sec)	
982	FU	9	Frequency (rad/sec)	
983	FU	9	Phase shift (deg)	
984	FU	9	Array location	
985	FU	9	Mean,Seed	
986	FU	9	Variance	
987	FU	9	Pulse width (sec)	
988	FU	9	Second pulse start time (sec)	
989	FU	10	Function generator ID number	10
990	FU	10	Type (ST,RA,PU,SA,SI,US,NO,DO)	NO
991	FU	10	Amplitude	
992	FU	10	Slope	
993	FU	10	Start time (sec)	
994	FU	10	Stop time (sec)	
995	FU	10	Frequency (rad/sec)	
996	FU	10	Phase shift (deg)	
997	FU	10	Array location	
998	FU	10	Mean,Seed	1,1
999	FU	10	Variance	1
1000	FU	10	Pulse width (sec)	
1001	FU	10	Second pulse start time (sec)	
1002	FU	11	Function generator ID number	11
1003	FU	11	Type (ST,RA,PU,SA,SI,US,NO,DO)	NO
1004	FU	11	Amplitude	
1005	FU	11	Slope	
1006	FU	11	Start time (sec)	
1007	FU	11	Stop time (sec)	
1008	FU	11	Frequency (rad/sec)	
1009	FU	11	Phase shift (deg)	
1010	FU	11	Array location	
1011	FU	11	Mean,Seed	1,2

1012	FU	11	Variance	1
1013	FU	11	Pulse width (sec)	
1014	FU	11	Second pulse start time (sec)	
1015	FU	12	Function generator ID number	12
1016	FU	12	Type (ST,RA,PU,SA,SI,US,NO,DO)	NO
1017	FU	12	Amplitude	
1018	FU	12	Slope	
1019	FU	12	Start time (sec)	
1020	FU	12	Stop time (sec)	
1021	FU	12	Frequency (rad/sec)	
1022	FU	12	Phase shift (deg)	
1023	FU	12	Array location	
1024	FU	12	Mean,Seed	1,3
1025	FU	12	Variance	1
1026	FU	12	Pulse width (sec)	
1027	FU	12	Second pulse start time (sec)	
1028	FU	13	Function generator ID number	13
1029	FU	13	Type (ST,RA,PU,SA,SI,US,NO,DO)	NO
1030	FU	13	Amplitude	
1031	FU	13	Slope	
1032	FU	13	Start time (sec)	
1033	FU	13	Stop time (sec)	
1034	FU	13	Frequency (rad/sec)	
1035	FU	13	Phase shift (deg)	
1036	FU	13	Array location	
1037	FU	13	Mean,Seed	1,4
1038	FU	13	Variance	1
1039	FU	13	Pulse width (sec)	
1040	FU	13	Second pulse start time (sec)	
1041	FU	14	Function generator ID number	14
1042	FU	14	Type (ST,RA,PU,SA,SI,US,NO,DO)	NO
1043	FU	14	Amplitude	
1044	FU	14	Slope	
1045	FU	14	Start time (sec)	
1046	FU	14	Stop time (sec)	
1047	FU	14	Frequency (rad/sec)	
1048	FU	14	Phase shift (deg)	
1049	FU	14	Array location	
1050	FU	14	Mean,Seed	1,5
1051	FU	14	Variance	1
1052	FU	14	Pulse width (sec)	
1053	FU	14	Second pulse start time (sec)	
1054	FU	15	Function generator ID number	15
1055	FU	15	Type (ST,RA,PU,SA,SI,US,NO,DO)	NO
1056	FU	15	Amplitude	
1057	FU	15	Slope	
1058	FU	15	Start time (sec)	
1059	FU	15	Stop time (sec)	
1060	FU	15	Frequency (rad/sec)	
1061	FU	15	Phase shift (deg)	
1062	FU	15	Array location	
1063	FU	15	Mean,Seed	1,6
1064	FU	15	Variance	1
1065	FU	15	Pulse width (sec)	
1066	FU	15	Second pulse start time (sec)	
1067	FU	16	Function generator ID number	16
1068	FU	16	Type (ST,RA,PU,SA,SI,US,NO,DO)	ST
1069	FU	16	Amplitude	0
1070	FU	16	Slope	
1071	FU	16	Start time (sec)	0
1072	FU	16	Stop time (sec)	
1073	FU	16	Frequency (rad/sec)	
1074	FU	16	Phase shift (deg)	
1075	FU	16	Array location	
1076	FU	16	Mean,Seed	
1077	FU	16	Variance	
1078	FU	16	Pulse width (sec)	
1079	FU	16	Second pulse start time (sec)	
1080	FU	17	Function generator ID number	17
1081	FU	17	Type (ST,RA,PU,SA,SI,US,NO,DO)	ST

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1082 FU  17 Amplitude                                                0
1083 FU  17 Slope
1084 FU  17 Start time (sec)                                         0
1085 FU  17 Stop time (sec)
1086 FU  17 Frequency (rad/sec)
1087 FU  17 Phase shift (deg)
1088 FU  17 Array location
1089 FU  17 Mean,Seed
1090 FU  17 Variance
1091 FU  17 Pulse width (sec)
1092 FU  17 Second pulse start time (sec)

1093 FU  18 Function generator ID number                             18
1094 FU  18 Type (ST,RA,PU,SA,SI,US,NO,DO)                           ST
1095 FU  18 Amplitude                                                0
1096 FU  18 Slope
1097 FU  18 Start time (sec)                                         0
1098 FU  18 Stop time (sec)
1099 FU  18 Frequency (rad/sec)
1100 FU  18 Phase shift (deg)
1101 FU  18 Array location
1102 FU  18 Mean,Seed
1103 FU  18 Variance
1104 FU  18 Pulse width (sec)
1105 FU  18 Second pulse start time (sec)

1106 FU 100 Function generator ID number                             100
1107 FU 100 Type (ST,RA,PU,SA,SI,US,NO,DO)                           SI
1108 FU 100 Amplitude                                                98
1109 FU 100 Slope
1110 FU 100 Start time (sec)                                         0
1111 FU 100 Stop time (sec)                                          1000
1112 FU 100 Frequency (rad/sec)                                      6.28
1113 FU 100 Phase shift (deg)                                        0
1114 FU 100 Array location
1115 FU 100 Mean,Seed
1116 FU 100 Variance
1117 FU 100 Pulse width (sec)
1118 FU 100 Second pulse start time (sec)

            INTERCONNECT

1119 IN   1 Interconnect ID number                                   1
1120 IN   1 Source type(S,C, or F),Source ID,Source row #            F,100,1
1121 IN   1 Destination type(A or C),Dest ID,Dest row #              A,1,1
1122 IN   1 Gain                                                     1

1123 IN   2 Interconnect ID number                                   2
1124 IN   2 Source type(S,C, or F),Source ID,Source row #            F,100,1
1125 IN   2 Destination type(A or C),Dest ID,Dest row #              A,2,1
1126 IN   2 Gain                                                     1

1127 IN   3 Interconnect ID number                                   3
1128 IN   3 Source type(S,C, or F),Source ID,Source row #            F,100,1
1129 IN   3 Destination type(A or C),Dest ID,Dest row #              A,3,1
1130 IN   3 Gain                                                     1

1131 IN  11 Interconnect ID number                                   11
1132 IN  11 Source type(S,C, or F),Source ID,Source row #            C,1,1
1133 IN  11 Destination type(A or C),Dest ID,Dest row #              A,101,1
1134 IN  11 Gain                                                     1

1135 IN  12 Interconnect ID number                                   12
1136 IN  12 Source type(S,C, or F),Source ID,Source row #            C,1,2
1137 IN  12 Destination type(A or C),Dest ID,Dest row #              A,102,1
1138 IN  12 Gain                                                     1

1139 IN  13 Interconnect ID number                                   13
1140 IN  13 Source type(S,C, or F),Source ID,Source row #            C,1,3
1141 IN  13 Destination type(A or C),Dest ID,Dest row #              A,201,1
1142 IN  13 Gain                                                     1

1143 IN  14 Interconnect ID number                                   14
1144 IN  14 Source type(S,C, or F),Source ID,Source row #            C,1,4
1145 IN  14 Destination type(A or C),Dest ID,Dest row #              A,202,1
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1146 IN  14 Gain                                                 1

1147 IN  15 Interconnect ID number                               15
1148 IN  15 Source type(S,C, or F),Source ID,Source row #        C,1,5
1149 IN  15 Destination type(A or C),Dest ID,Dest row #          A,301,1
1150 IN  15 Gain                                                 1

1151 IN  16 Interconnect ID number                               16
1152 IN  16 Source type(S,C, or F),Source ID,Source row #        C,1,6
1153 IN  16 Destination type(A or C),Dest ID,Dest row #          A,302,1
1154 IN  16 Gain                                                 1

1155 IN 101 Interconnect ID number                               101
1156 IN 101 Source type(S,C, or F),Source ID,Source row #        S,101,1
1157 IN 101 Destination type(A or C),Dest ID,Dest row #          C,1,1
1158 IN 101 Gain                                                 1

1159 IN 102 Interconnect ID number                               102
1160 IN 102 Source type(S,C, or F),Source ID,Source row #        S,102,1
1161 IN 102 Destination type(A or C),Dest ID,Dest row #          C,1,2
1162 IN 102 Gain                                                 1

1163 IN 103 Interconnect ID number                               103
1164 IN 103 Source type(S,C, or F),Source ID,Source row #        S,201,1
1165 IN 103 Destination type(A or C),Dest ID,Dest row #          C,1,3
1166 IN 103 Gain                                                 1

1167 IN 104 Interconnect ID number                               104
1168 IN 104 Source type(S,C, or F),Source ID,Source row #        S,202,1
1169 IN 104 Destination type(A or C),Dest ID,Dest row #          C,1,4
1170 IN 104 Gain                                                 1

1171 IN 105 Interconnect ID number                               105
1172 IN 105 Source type(S,C, or F),Source ID,Source row #        S,301,1
1173 IN 105 Destination type(A or C),Dest ID,Dest row #          C,1,5
1174 IN 105 Gain                                                 1

1175 IN 106 Interconnect ID number                               106
1176 IN 106 Source type(S,C, or F),Source ID,Source row #        S,302,1
1177 IN 106 Destination type(A or C),Dest ID,Dest row #          C,1,6
1178 IN 106 Gain                                                 1

1179 IN 107 Interconnect ID number                               107
1180 IN 107 Source type(S,C, or F),Source ID,Source row #        F,4,1
1181 IN 107 Destination type(A or C),Dest ID,Dest row #          C,1,7
1182 IN 107 Gain                                                 0

1183 IN 108 Interconnect ID number                               108
1184 IN 108 Source type(S,C, or F),Source ID,Source row #        F,5,1
1185 IN 108 Destination type(A or C),Dest ID,Dest row #          C,1,8
1186 IN 108 Gain                                                 0

1187 IN 109 Interconnect ID number                               109
1188 IN 109 Source type(S,C, or F),Source ID,Source row #        F,6,1
1189 IN 109 Destination type(A or C),Dest ID,Dest row #          C,1,9
1190 IN 109 Gain                                                 0

1191 IN 110 Interconnect ID number                               110
1192 IN 110 Source type(S,C, or F),Source ID,Source row #        F,7,1
1193 IN 110 Destination type(A or C),Dest ID,Dest row #          C,1,10
1194 IN 110 Gain                                                 0

1195 IN 111 Interconnect ID number                               111
1196 IN 111 Source type(S,C, or F),Source ID,Source row #        F,8,1
1197 IN 111 Destination type(A or C),Dest ID,Dest row #          C,1,11
1198 IN 111 Gain                                                 0

1199 IN 112 Interconnect ID number                               112
1200 IN 112 Source type(S,C, or F),Source ID,Source row #        F,9,1
1201 IN 112 Destination type(A or C),Dest ID,Dest row #          C,1,12
1202 IN 112 Gain                                                 0

1203 IN 113 Interconnect ID number                               113
1204 IN 113 Source type(S,C, or F),Source ID,Source row #        F,10,1
1205 IN 113 Destination type(A or C),Dest ID,Dest row #          C,1,13
1206 IN 113 Gain                                                 0
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1207 IN 114 Interconnect ID number                                   114
1208 IN 114 Source type(S,C, or F),Source ID,Source row #           F,11,1
1209 IN 114 Destination type(A or C),Dest ID,Dest row #             C,1,14
1210 IN 114 Gain                                                     0

1211 IN 115 Interconnect ID number                                   115
1212 IN 115 Source type(S,C, or F),Source ID,Source row #           F,12,1
1213 IN 115 Destination type(A or C),Dest ID,Dest row #             C,1,15
1214 IN 115 Gain                                                     0

1215 IN 116 Interconnect ID number                                   116
1216 IN 116 Source type(S,C, or F),Source ID,Source row #           F,13,1
1217 IN 116 Destination type(A or C),Dest ID,Dest row #             C,1,16
1218 IN 116 Gain                                                     0

1219 IN 117 Interconnect ID number                                   117
1220 IN 117 Source type(S,C, or F),Source ID,Source row #           F,14,1
1221 IN 117 Destination type(A or C),Dest ID,Dest row #             C,1,17
1222 IN 117 Gain                                                     0

1223 IN 118 Interconnect ID number                                   118
1224 IN 118 Source type(S,C, or F),Source ID,Source row #           F,15,1
1225 IN 118 Destination type(A or C),Dest ID,Dest row #             C,1,18
1226 IN 118 Gain                                                     0

1227 IN 119 Interconnect ID number                                   119
1228 IN 119 Source type(S,C, or F),Source ID,Source row #           C,2,1
1229 IN 119 Destination type(A or C),Dest ID,Dest row #             C,1,19
1230 IN 119 Gain                                                     1

1231 IN 120 Interconnect ID number                                   120
1232 IN 120 Source type(S,C, or F),Source ID,Source row #           C,2,2
1233 IN 120 Destination type(A or C),Dest ID,Dest row #             C,1,20
1234 IN 120 Gain                                                     1

1235 IN 121 Interconnect ID number                                   121
1236 IN 121 Source type(S,C, or F),Source ID,Source row #           C,2,3
1237 IN 121 Destination type(A or C),Dest ID,Dest row #             C,1,21
1238 IN 121 Gain                                                     1

1239 IN 122 Interconnect ID number                                   122
1240 IN 122 Source type(S,C, or F),Source ID,Source row #           C,2,4
1241 IN 122 Destination type(A or C),Dest ID,Dest row #             C,1,22
1242 IN 122 Gain                                                     1

1243 IN 123 Interconnect ID number                                   123
1244 IN 123 Source type(S,C, or F),Source ID,Source row #           C,2,5
1245 IN 123 Destination type(A or C),Dest ID,Dest row #             C,1,23
1246 IN 123 Gain                                                     1

1247 IN 124 Interconnect ID number                                   124
1248 IN 124 Source type(S,C, or F),Source ID,Source row #           C,2,6
1249 IN 124 Destination type(A or C),Dest ID,Dest row #             C,1,24
1250 IN 124 Gain                                                     1

1251 IN 201 Interconnect ID number                                   201
1252 IN 201 Source type(S,C, or F),Source ID,Source row #           C,3,7
1253 IN 201 Destination type(A or C),Dest ID,Dest row #             C,2,1
1254 IN 201 Gain                                                     1

1255 IN 202 Interconnect ID number                                   202
1256 IN 202 Source type(S,C, or F),Source ID,Source row #           C,3,8
1257 IN 202 Destination type(A or C),Dest ID,Dest row #             C,2,2
1258 IN 202 Gain                                                     1

1259 IN 203 Interconnect ID number                                   203
1260 IN 203 Source type(S,C, or F),Source ID,Source row #           C,3,9
1261 IN 203 Destination type(A or C),Dest ID,Dest row #             C,2,3
1262 IN 203 Gain                                                     1

1263 IN 204 Interconnect ID number                                   204
1264 IN 204 Source type(S,C, or F),Source ID,Source row #           C,3,10
1265 IN 204 Destination type(A or C),Dest ID,Dest row #             C,2,4
1266 IN 204 Gain                                                     1
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1267 IN 205 Interconnect ID number                                   205
1268 IN 205 Source type(S,C, or F),Source ID,Source row #           C,3,11
1269 IN 205 Destination type(A or C),Dest ID,Dest row #             C,2,5
1270 IN 205 Gain                                                     1

1271 IN 206 Interconnect ID number                                   206
1272 IN 206 Source type(S,C, or F),Source ID,Source row #           C,3,12
1273 IN 206 Destination type(A or C),Dest ID,Dest row #             C,2,6
1274 IN 206 Gain                                                     1

1275 IN 301 Interconnect ID number                                   301
1276 IN 301 Source type(S,C, or F),Source ID,Source row #           S,701,1
1277 IN 301 Destination type(A or C),Dest ID,Dest row #             C,3,1
1278 IN 301 Gain                                                     1

1279 IN 302 Interconnect ID number                                   302
1280 IN 302 Source type(S,C, or F),Source ID,Source row #           S,701,2
1281 IN 302 Destination type(A or C),Dest ID,Dest row #             C,3,2
1282 IN 302 Gain                                                     1

1283 IN 303 Interconnect ID number                                   303
1284 IN 303 Source type(S,C, or F),Source ID,Source row #           S,701,3
1285 IN 303 Destination type(A or C),Dest ID,Dest row #             C,3,3
1286 IN 303 Gain                                                     1

1287 IN 304 Interconnect ID number                                   304
1288 IN 304 Source type(S,C, or F),Source ID,Source row #           S,801,1
1289 IN 304 Destination type(A or C),Dest ID,Dest row #             C,3,4
1290 IN 304 Gain                                                     1

1291 IN 305 Interconnect ID number                                   305
1292 IN 305 Source type(S,C, or F),Source ID,Source row #           S,801,2
1293 IN 305 Destination type(A or C),Dest ID,Dest row #             C,3,5
1294 IN 305 Gain                                                     1

1295 IN 306 Interconnect ID number                                   306
1296 IN 306 Source type(S,C, or F),Source ID,Source row #           S,801,3
1297 IN 306 Destination type(A or C),Dest ID,Dest row #             C,3,6
1298 IN 306 Gain                                                     1

1299 IN 307 Interconnect ID number                                   307
1300 IN 307 Source type(S,C, or F),Source ID,Source row #           S,901,1
1301 IN 307 Destination type(A or C),Dest ID,Dest row #             C,3,7
1302 IN 307 Gain                                                     1

1303 IN 308 Interconnect ID number                                   308
1304 IN 308 Source type(S,C, or F),Source ID,Source row #           S,901,2
1305 IN 308 Destination type(A or C),Dest ID,Dest row #             C,3,8
1306 IN 308 Gain                                                     1

1307 IN 309 Interconnect ID number                                   309
1308 IN 309 Source type(S,C, or F),Source ID,Source row #           S,901,3
1309 IN 309 Destination type(A or C),Dest ID,Dest row #             C,3,9
1310 IN 309 Gain                                                     1

1311 IN 310 Interconnect ID number                                   310
1312 IN 310 Source type(S,C, or F),Source ID,Source row #           S,912,1
1313 IN 310 Destination type(A or C),Dest ID,Dest row #             C,3,10
1314 IN 310 Gain                                                     1

1315 IN 311 Interconnect ID number                                   311
1316 IN 311 Source type(S,C, or F),Source ID,Source row #           S,912,2
1317 IN 311 Destination type(A or C),Dest ID,Dest row #             C,3,11
1318 IN 311 Gain                                                     1

1319 IN 312 Interconnect ID number                                   312
1320 IN 312 Source type(S,C, or F),Source ID,Source row #           S,912,3
1321 IN 312 Destination type(A or C),Dest ID,Dest row #             C,3,12
1322 IN 312 Gain                                                     1

1323 IN 313 Interconnect ID number                                   313
1324 IN 313 Source type(S,C, or F),Source ID,Source row #           F,1,1
1325 IN 313 Destination type(A or C),Dest ID,Dest row #             C,3,13
1326 IN 313 Gain                                                     1

1327 IN 314 Interconnect ID number                                   314
```

1328	IN	314	Source type(S,C, or F),Source ID,Source row #	F,2,1
1329	IN	314	Destination type(A or C),Dest ID,Dest row #	C,3,14
1330	IN	314	Gain	1
1331	IN	315	Interconnect ID number	315
1332	IN	315	Source type(S,C, or F),Source ID,Source row #	F,3,1
1333	IN	315	Destination type(A or C),Dest ID,Dest row #	C,3,15
1334	IN	315	Gain	1
1335	IN	316	Interconnect ID number	316
1336	IN	316	Source type(S,C, or F),Source ID,Source row #	F,16,1
1337	IN	316	Destination type(A or C),Dest ID,Dest row #	C,3,16
1338	IN	316	Gain	1
1339	IN	317	Interconnect ID number	317
1340	IN	317	Source type(S,C, or F),Source ID,Source row #	F,17,1
1341	IN	317	Destination type(A or C),Dest ID,Dest row #	C,3,17
1342	IN	317	Gain	1
1343	IN	318	Interconnect ID number	318
1344	IN	318	Source type(S,C, or F),Source ID,Source row #	F,18,1
1345	IN	318	Destination type(A or C),Dest ID,Dest row #	C,3,18
1346	IN	318	Gain	1

DEVICE

1347	DE	1	Device ID number	1
1348	DE	1	Device Type (LI,QU,SD,CO,UH,LH)	LI
1349	DE	1	Device location (Node or Hinge)	N
1350	DE	1	Hinge ID no., Hinge axis no.(1-6)	
1351	DE	1	Node 1 Body ID no., Node 1 Node ID no.	1,7
1352	DE	1	Node 2 Body ID no., Node 2 Node ID no.	2,12
1353	DE	1	Hardstop Location, Initial force	
1354	DE	1	Stiffness Coefficient (Kqe)	0
1355	DE	1	Damping Coefficient (Bqe)	0
1356	DE	1	Unstreched spring/cable length	10
1357	DE	2	Device ID number	2
1358	DE	2	Device Type (LI,QU,SD,CO,UH,LH)	LI
1359	DE	2	Device location (Node or Hinge)	N
1360	DE	2	Hinge ID no., Hinge axis no.(1-6)	
1361	DE	2	Node 1 Body ID no., Node 1 Node ID no.	1,8
1362	DE	2	Node 2 Body ID no., Node 2 Node ID no.	2,12
1363	DE	2	Hardstop Location, Initial force	
1364	DE	2	Stiffness Coefficient (Kqe)	0.
1365	DE	2	Damping Coefficient (Bqe)	0
1366	DE	2	Unstreched spring/cable length	10
1367	DE	3	Device ID number	3
1368	DE	3	Device Type (LI,QU,SD,CO,UH,LH)	LI
1369	DE	3	Device location (Node or Hinge)	N
1370	DE	3	Hinge ID no., Hinge axis no.(1-6)	
1371	DE	3	Node 1 Body ID no., Node 1 Node ID no.	1,9
1372	DE	3	Node 2 Body ID no., Node 2 Node ID no.	2,12
1373	DE	3	Hardstop Location, Initial force	
1374	DE	3	Stiffness Coefficient (Kqe)	0
1375	DE	3	Damping Coefficient (Bqe)	0
1376	DE	3	Unstreched spring/cable length	10
1377	DE	4	Device ID number	4
1378	DE	4	Device Type (LI,QU,SD,CO,UH,LH)	LI
1379	DE	4	Device location (Node or Hinge)	N
1380	DE	4	Hinge ID no., Hinge axis no.(1-6)	
1381	DE	4	Node 1 Body ID no., Node 1 Node ID no.	1,10
1382	DE	4	Node 2 Body ID no., Node 2 Node ID no.	2,13
1383	DE	4	Hardstop Location, Initial force	
1384	DE	4	Stiffness Coefficient (Kqe)	18
1385	DE	4	Damping Coefficient (Bqe)	0
1386	DE	4	Unstreched spring/cable length	10
1387	DE	5	Device ID number	5
1388	DE	5	Device Type (LI,QU,SD,CO,UH,LH)	LI
1389	DE	5	Device location (Node or Hinge)	N
1390	DE	5	Hinge ID no., Hinge axis no.(1-6)	
1391	DE	5	Node 1 Body ID no., Node 1 Node ID no.	1,11

1392	DE	5 Node 2 Body ID no., Node 2 Node ID no.	2,13
1393	DE	5 Hardstop Location, Initial force	
1394	DE	5 Stiffness Coefficient (Kqe)	13.5
1395	DE	5 Damping Coefficient (Bqe)	0
1396	DE	5 Unstreched spring/cable length	10
1397	DE	6 Device ID number	6
1398	DE	6 Device Type (LI,QU,SD,CO,UH,LH)	LI
1399	DE	6 Device location (Node or Hinge)	N
1400	DE	6 Hinge ID no., Hinge axis no.(1-6)	
1401	DE	6 Node 1 Body ID no., Node 1 Node ID no.	1,12
1402	DE	6 Node 2 Body ID no., Node 2 Node ID no.	2,13
1403	DE	6 Hardstop Location, Initial force	
1404	DE	6 Stiffness Coefficient (Kqe)	20
1405	DE	6 Damping Coefficient (Bqe)	0
1406	DE	6 Unstreched spring/cable length	10
1407	DE	7 Device ID number	7
1408	DE	7 Device Type (LI,QU,SD,CO,UH,LH)	QU
1409	DE	7 Device location (Node or Hinge)	N
1410	DE	7 Hinge ID no., Hinge axis no.(1-6)	
1411	DE	7 Node 1 Body ID no., Node 1 Node ID no.	1,9
1412	DE	7 Node 2 Body ID no., Node 2 Node ID no.	2,12
1413	DE	7 Hardstop Location, Initial force	
1414	DE	7 Stiffness Coefficient (Kqe)	0.
1415	DE	7 Damping Coefficient (Bqe)	0
1416	DE	7 Unstreched spring/cable length	10
1417	DE	8 Device ID number	8
1418	DE	8 Device Type (LI,QU,SD,CO,UH,LH)	QU
1419	DE	8 Device location (Node or Hinge)	N
1420	DE	8 Hinge ID no., Hinge axis no.(1-6)	
1421	DE	8 Node 1 Body ID no., Node 1 Node ID no.	1,12
1422	DE	8 Node 2 Body ID no., Node 2 Node ID no.	2,13
1423	DE	8 Hardstop Location, Initial force	
1424	DE	8 Stiffness Coefficient (Kqe)	0
1425	DE	8 Damping Coefficient (Bqe)	0
1426	DE	8 Unstreched spring/cable length	10

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15. Supplementary Notes

16. Abstract

The mathematical models of Glovebox Integrated Microgravity Isolation Technology (g-LIMIT) dynamics/control system, which include six degrees of freedom (DOF) equations of motion, mathematical models of position sensors, accelerometers and actuators, and acceleration and position controller, were developed using MATLAB and TREETOPS simulations. Optimal control parameters of g-LIMIT control system were determined through sensitivity studies and its performance were evaluated with the TREETOPS model of g-LIMIT dynamics and control system. The functional operation and performance of the Tektronix DTM920 digital thermometer were studied and the inputs to the crew procedures and training of the DTM920 were documented.

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