AVIONICS GPB CONTROL SYSTEM ANALYSIS
FINAL REPORT

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A STUDY OF THE CRYOGENIC/SUPERFLUID HELIUM INTERACTION WITH THE GPB SPACECRAFT SIMULATION AND ANALYSIS

1.0 INTRODUCTION:

Gravity Probe B is a Satellite being developed by Lockheed/Martin under NASA contract through MSFC and managed by Stanford University. The goal of the satellite experiment is to test the accuracy of drift predictions made using Einstein's General Theory of Relativity. The drift in the direction of the spin axes of 4 highly precise quartz spherical gyroscopes induced by motion in the earth's gravitational field will be measured over a year's duration with the known, non-relativistic effects removed. The expected angles of drift for a one year period are approximately 6.6 arcsec for drift in the orbit plane called geodetic drift and 0.033 arcsec of drift normal to the orbit plane called frame dragging. The aerodynamic drag force on the GPB Satellite is compensated by a translation control system. It is pointed at a guide star and maintained in spin at a rate to be selected in the range 0.1-1 rpm. The purpose of our task is to update the TREETOPS GPB spacecraft simulation and to assist MSFC in assessing the affect of Helium slosh dynamics on spacecraft pointing performance.

The bd Systems Control Dynamics Division Gravity Probe B (GPB) simulation was originally constructed as a part of Control Dynamics support to Fairchild Space in their contracted Phase B Study of GPB for Stanford and NASA. It was built using the multi-body simulation program called TREETOPS. This effort lasted through the late 80's and into the early 90's. The study was completed and Phase C-D down-selections were made between the Phase B competitors Lockheed and Fairchild. Lockheed (now Lockheed-Martin) was the winner. In the mid 90's, bd Systems was asked to update the GP-B simulation to provide support to NASA/MSFC in the performance of flexible body and slosh dynamics investigations of the Lockheed-Martin (L-M) configuration. This update consisted of mass and geometry properties and a change from the Fairchild 12 thruster configuration to the L-M 16 thruster setup. Additionally, the control system design was also changed to match the L-M design. Besides an update to the GP-B model an update to the version of TREETOPS being used to the double precision Version 10 was also made. Version 9 had been in use. This had also been double precision but was a special version done for us only. The GPB attitude and translation controllers were implemented in a special TREETOPS user controller written for GPB. Gravity gradient torques, forces and cryogenic disturbances were implemented through the user controller. Orbital dynamics were implemented through the nearly circular orbit perturbation equations built into TREETOPS. Control Dynamics added an aerodynamic drag force and torque model capable of accepting the aerodynamic coefficients supplied by NASA/MSFC. This model was used to perform the required analysis and published a report on the results. Some preliminary slosh analyses were performed using a 4 spring-mass model in which the springs and masses were adjusted to match expected frequencies and masses of GPB slosh. A Computational Fluid Dynamics (CFD) model of helium slosh was being prepared by UAH for MSFC. The plan was to adjust masses and frequencies of the GPB simulation to match these results when they were available. However, these results were never available and the studies were never done. The next phase of activity for the GPB simulation was to generate a full year long simulated science data stream including representative outputs for four science gyro

Superconducting Quantum Interference Devices (SQUIDs). Each gyro has a single axis of outputs with two in the x-z plane and two in the y-z plane.

Recently, we have been asked to support the MSFC GPB helium slosh studies continuing efforts. We have chosen to revive our GPB TREETOPS simulation. Our choice was to update the TREETOPS simulation to our enhanced Version 10. Numerous enhancements have been made to Version 10. The following is a summary list of these enhancements:

a. Addition of a general gravity module along with a fully dynamic orbit including gravity gradient moments as an alternative to the nearly circular orbit perturbation equations logic. This also included definition of an inertial frame related to either B1950 or J2000 Vernal Equinox
b. Solar Pressure Model, which takes input in the form of reflecting surfaces through an auxiliary file
c. Fix for restart capability
d. Fix for Sandia Integration
e. RK78 Integration added
f. Addition of surface contact force model with contact surfaces input through auxiliary file.
g. Addition of air/water drag and static pressure force model with drag and static pressure surfaces input through auxiliary file.
h. Completion of function generator definitions to include derivatives and integrals
i. Addition of user defined, piece-wise linear function with auto-computed derivative and integral
j. User defined, piecewise-linear spring with breakaway value
k. Addition of non-linear controller element, a product junction analogous to a summing junction
l. Additional sensors and actuators defined including sensors defined for output only
m. Redimensioning/resizing for more bodies, sensors, etc.
n. Treeset modified to accommodate most (but not all) additions
o. Additional and more descriptive error messages to help diagnose gimbal lock and topology problems

This task is for the purpose of using our previously developed GPB simulation to investigate the potential of the relatively large amount of liquid helium on board the spacecraft to adversely affect the fine pointing performance of the system by sloshing interactions. Complicating this investigation is the superfluid behavior exhibited by cryogenic helium IV. Lockheed-Martin's investigations had concuded that analytically, instability was not going to be a problem. This resumed effort is to take results from CFD simulations of a helium-like fluid in a rotating dewar to help calibrate the frequencies present in a spring-mass model to be built-into the TREETOPS GPB simulation. The original CFD investigation was never completed due to the illness and ultimate death of the investigator.
The NASA/MSFC CFD study was expanded to include contractor support. A new CFD analysis is being performed by The Aerospace Corporation in parallel with the MSFC study. The plan for the ultimate use of the GPB simulation is to employ the CFD simulations of a rotating dewar in a manner like a structural test and develop a modal model of the fluid. The modes and frequencies of these measurements can be used to build the flexible body model required by TREETOPS. Alternately, Dr. Howard Snyder at the University of Colorado is taking an analytical approach. He computes the solution to the Navier-Stokes

equation in cylindrical coordinates for a spinning dewar with the geometry of the GPB Spacecraft. He next computes system transfer functions from this approach. The transfer functions are then be added to the TREETOPS GPB simulation producing an alternate approach. Sensor models in TREETOPS of angular accelerometers provide the inputs to the transfer functions and actuator models provide the force and torque outputs upon the spacecraft.

2.0 Review of Work Accomplished During the Study:

In June, the work on this task was kicked off with a meeting at NASA/MSFC. Technical efforts were focused on reactivating and updating our Treetops (TT) simulation of the GPB spacecraft. The TT GPB simulation had previously been used to generate a stream of simulated science data in the format and order expected from the flight. A full year's worth of simulated science data. That simulation was a rigid body model. The TT model of GPB used for that work was reestablished and brought to a running condition. The previous helium slosh model development was completed with a primitive spring/mass model. The previous GPB input files have been converted to the current Treetops format. Additional modifications and inputs are required to convert to use of the fully dynamic orbit option. These changes were nearly completed in June. One of the items required is the location of the guide star. Presently, we are assuming the guide star is Rigel and its position is right ascension 78.025° and declination –8.25°. This position was obtained from Burnham's Celestial Handbook and is probably out of date now. We will update this position when more current information is obtained.

During the month of July, the Treetops GPB model updating was continued. New GPB mass properties received from Lockheed/Martin through MSFC were input along with updated control gains. The previous Treetops model was built largely around user defined controllers. The updated version was converted to the fully dynamic orbit from the perturbed circular orbit used previously. It was also converted to use of the ECI frame as the inertial reference from the previous Treetops defined spacecraft inertial frame. This has complicated the initialization of the model but is a more realistic representation of the dynamics. The updating of the Treetops GPB model was also a good opportunity to refamiliarize with the spacecraft system and start the other activity of assisting MSFC and Professor Howard Snyder/University of Colorado in developing a model for the Helium slosh in the helium dewar. In addition, we updated the aerodynamic force & moments model. This helped refresh us of the special considerations associated with the signs and coordinate directions associated with aerodynamic models.

In August, the TREETOPS GPB model updating was completed, bringing the mass properties and control gains to currently defined values provided by MSFC. The updated GPB model uses built-in gravity gradient torque disturbance models whereas, the previous earlier model used subroutines in the user defined controller to add in gravity gradient torque.

The efforts expended in updating the GPB model were useful in restoring our insights and understanding of the GPB operation and dynamic model. This helped us advise MSFC and their helium slosh dynamics modeling contractors Aerospace Corporation and University of Colorado on GPB spacecraft dynamic model and its control system. We refreshed our understanding of the aerodynamic force and torque model, its coordinate system and the assumptions going into it. Some questions remain from our review: 1. How does the aero coordinate system relate to the GPB body system, 2. Are the aero coefficients significantly affected by changing altitudes from 400 to 640 km? We assumed based on earlier aero data that the transformation from aero to GPB body frame is given by [BA] = eul3[135°] eul2[90°]

In late September, bd Systems Control Dynamics Principal Investigator experienced medical problems which caused him to be sidelined unable to work for over a month. Part-time efforts resumed in November with the definition of a random excitation definition function for each of the six input degrees of freedom. This was provided to NASA/MSFC and by them passed on to the other study contractors. This was a set of time functions defined from the input spectra. This input spectrum was flat to a maximum frequency of 1 Hertz and zero beyond. The CFD model was to be excited with this set of random functions and the results were to be processed as a structural dynamics model to determine a set of modes, frequencies and modal gains. These would be provided to define the characteristics for the helium dewar to go into TT. MSFC was to process the output and provide us with the results. However, processing of the results proved to be much harder than expected. This was unexpected initially but later was found to be due to the extremely low damping of the fluid.

Work resumed in earnest in December with formulation of an alternate approach to the spring mass model. This approach was based on the premise that the GPB helium fluid in the dewar is very quiet. It essentially behaves like a solid. In any event, at the microscopic level, it behaves like a very soft solid jello-like material. We decided we could capture the mass properties and the modal behavior by treating it as a solid with a very low E (Young's modulus). The fluid density is known and the material is assumed to fill the dewar with a cylindrical hole down the middle along the symmetry axis. The diameter of the hole is determined by volume of fluid which makes up the mass appropriate to the specified fill level. The structural model is built up with Nastran and is reduced according to which modes are most excitable. The spinning nature of the GPB requires the inclusion of certain mass integrals normally not needed in the non-spinning case. The usual structural model is based on a small displacements assumption and a linearized model. Here, the translations and z rotations are not small and terms which are 2nd order in spin and 1st order in structural deformation are required to be retained. Treetops is equipped to do this as an option in the structural model if the required modal mass integrals can be provided. However, the present form of TREEFLEX has calculated zeros and we are certain at least some of the integrals should not be zero. This is apparently because of the use of generalized degrees of freedom rather that physical, i.e. modal variables rather than nodes except for the single node required to couple to the spacecraft. We still believe the model can be instructive and is useful but with zeros for modal integrals, we do not get the splitting in modal frequencies and centrifugal loading and consequent increase in frequencies with spin.

We have changed the GP-B simulation from the nearly circular orbit perturbation model to use of the general gravity and fully dynamic orbit. Also, we have incorporated the built-in gravity gradient torque model and the aerodynamic model. Since TREETOPS still does not contain a built-in spacecraft induced magnetic moment module, we are using the continuous user controller to model this. The gravity gradient and aero disturbances are now being generated automatically as part of the TREETOPS environment models. The corresponding feed forward modules for these and the cryogenic disturbances are being generated as part of the user defined discrete controller module in TREETOPS. Auxiliary files GAINS.INP, THRUSTERS.INP, and ERRORS.INP provide the control gains, the thruster mounting matrix, and the noise, quantization values and saturation limits. The model definition file, the so-called –.int file defines the properties of the GP-B model and is included as appendix A at the end of this memorandum. The fortran source file for the user discrete controller and the user continuous controller is included as appendix B at the end of this memorandum. The auxiliary files named above are included in appendices C, D, and E. The aerodynamic coefficients are defined by the file NEWTTAE.DAT. This file is included in appendix F.

3.0 RESULTS AND CONCLUSIONS OF ANALYSIS OF GPB CONTROL SYSTEM PERFORMANCE:

The GP-B simulation as presently devised according to the definition files contained in appendices A-F has been run to produce the following output files. The first plot shown below in figure 1 is a plot of the orbit angle from the ascending node to the position in orbit at time t. This orbit angle is calculated from other simulation data and is periodically reset in order to be maintained in the range from –180 to 180°. An unwrapped variation on this orbit angle is used in place of time as the abscissa for the remaining plots. It is unwrapped to be single valued.

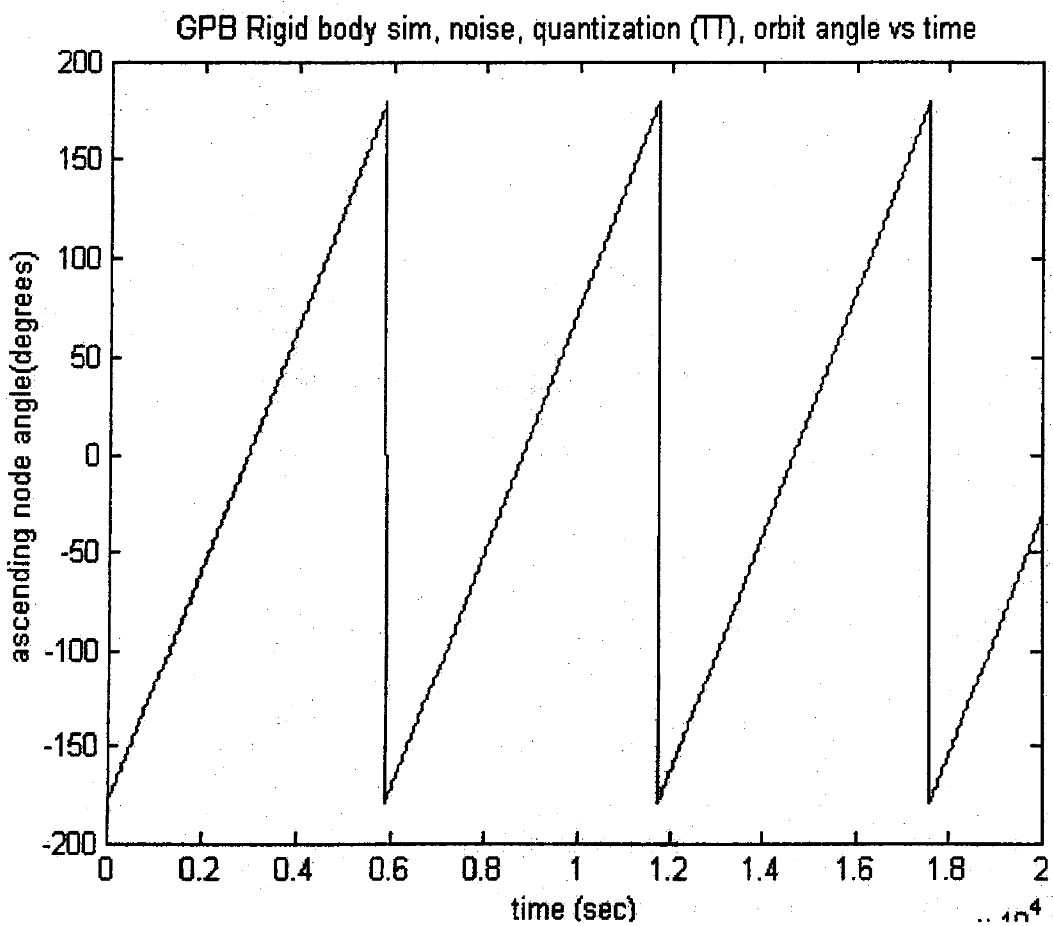

Figure 1. Plot of orbit angle measured from ascending node in orbit at time t.

angle. These orbit conditions were determined by making minor adjustments in the initial orbit velocity until the variations in altitude around the orbit were nominally small. No active control of orbital properties is being applied. The translation control compensates for the drag but does not circularize the orbit.

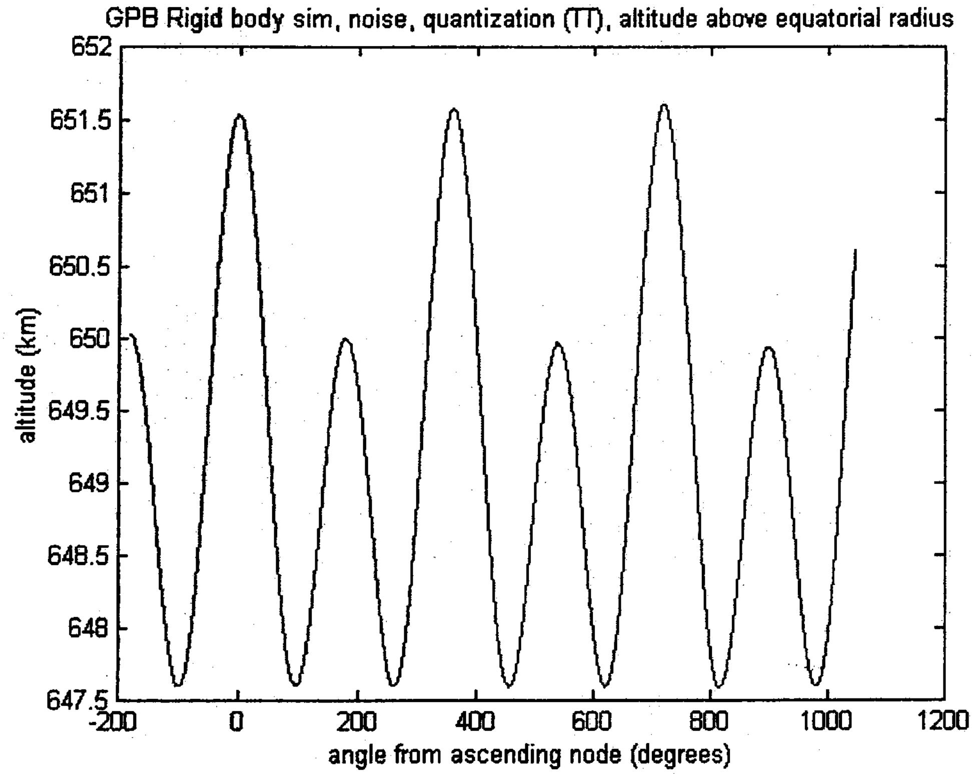

Figure 2. Plot of orbital altitude above equatorial radius vs angle from first ascending node.

The spacecraft is controlled in attitude to point the line of sight of the science telescope at the guide star which for this simulation is modeled as the star Rigel (RA = 78.025°, Dec = -8.25°). Since the GP-B simulation was defined, a new guide star has been designated. This new guide star has not yet been installed at the guide star in the TREETOPS simulation. The new guide star is the star IM Peg, HR 8703 (RA = 343.2592°, Dec = 16.8411°). The position is as specified in the Bright Star Catalog. Since this star is considerably dimmer than Rigel, it is expected that greater noise will attend this change in guide star. No new noise values have been provided as yet. The effect of this change on the performance if any has not yet been assessed

The line of sight pointing errors are plotted in figure 3 in milli-arcseconds. The guide star valid and guide star invalid modes in the science data-taking phase of GP-B operations are evident in the pointing error behavior shown in this figure. During guide star valid operation, the guide star is visible and its output data is available for use in the feedback control. The star apparent position is perturbed by the velocity aberration which results from the finite speed of light and the variation in direction of orbital velocity. This results in an approximately sinusoidal variation in pointing direction to the guide star taking place at orbital frequency. There is also an annual component to this variation as the earth-moon system orbits the sun and carries the GP-B spacecraft (along with all of us) with it.

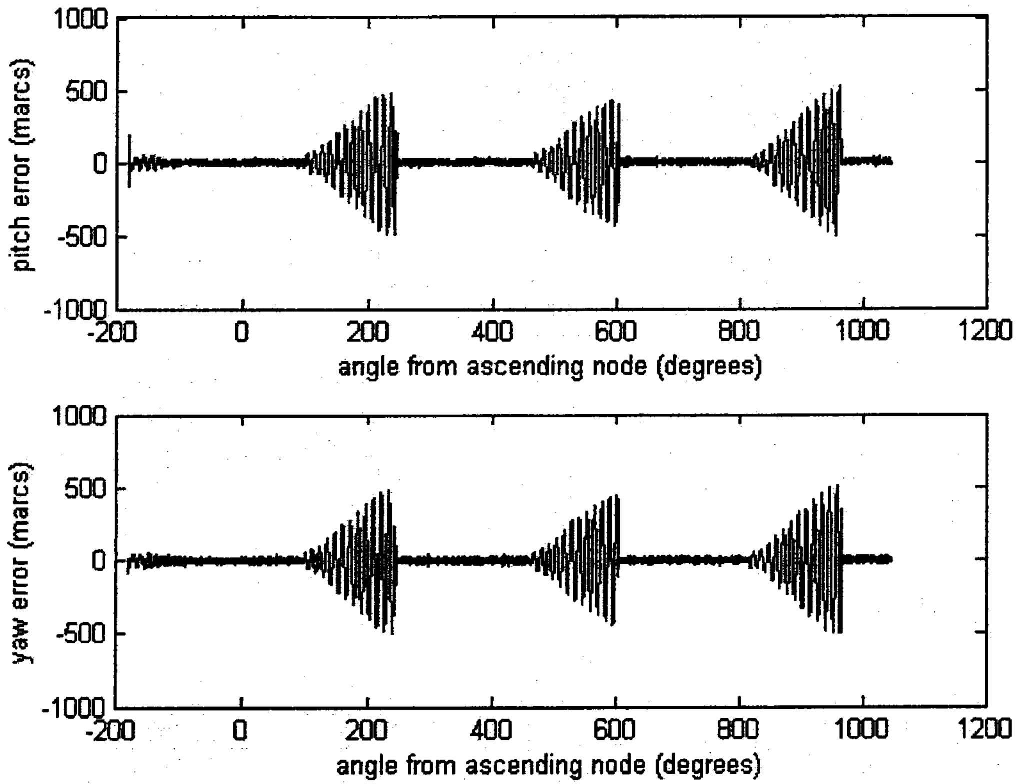

Figure 3. Science telescope pitch and yaw pointing errors vs orbit angle from first ascending node.

The simulation which generated these results was based on rigid body (no flex and no slosh) dynamics but included sensor and thruster noise and quantization. The simulated vehicle spin rate was 0.3 RPM. The simulated altitude is 650 km and the gravity is modeled through j4. As stated previously, velocity aberration is modeled and feed forward for this effect is included in the control. Gravity gradient, cryogenic and aerodynamic forces and torques are also included as part of the environmental disturbances but have not been included as part of the feed forward compensation. The proof mass has been used as the drag free sensor. This needs to be updated to science gyro number 1 or other science gyro if specified. It is presently understood that a separate proof mass is no longer being planned. This is easily changed as new information becomes available. The simulated mass properties used for this run are based on beginning of life conditions. Also, helium mass and moment of inertia contributions are included in the rigid body properties. Additionally, product of inertia terms are assumed to include a negative sign in their definitions so that they can be used directly in the moment of inertia matrix elements in the TREETOPS -.INT file. It has been determined since this run was completed that the products of inertia specified in the mass properties memorandum use the positive integral definition and must therefore be

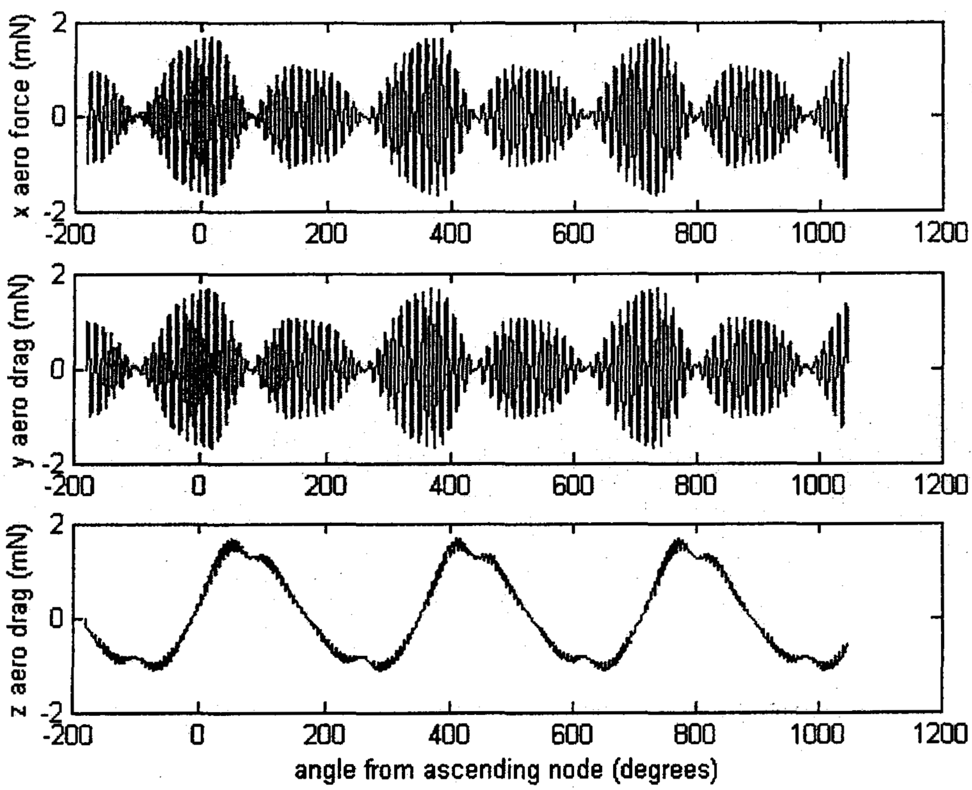

Figure 4. Aerodynamic drag forces expressed in spacecraft body frame vs orbit angle from first ascending node.

reversed before use in TREETOPS. The values are small so that the effect of the change is not expected to be large but will be made and used in all future simulations. Figure 4 shows the aerodynamic drag force calculated by TREETOPS and expressed in the body coordinate frame.

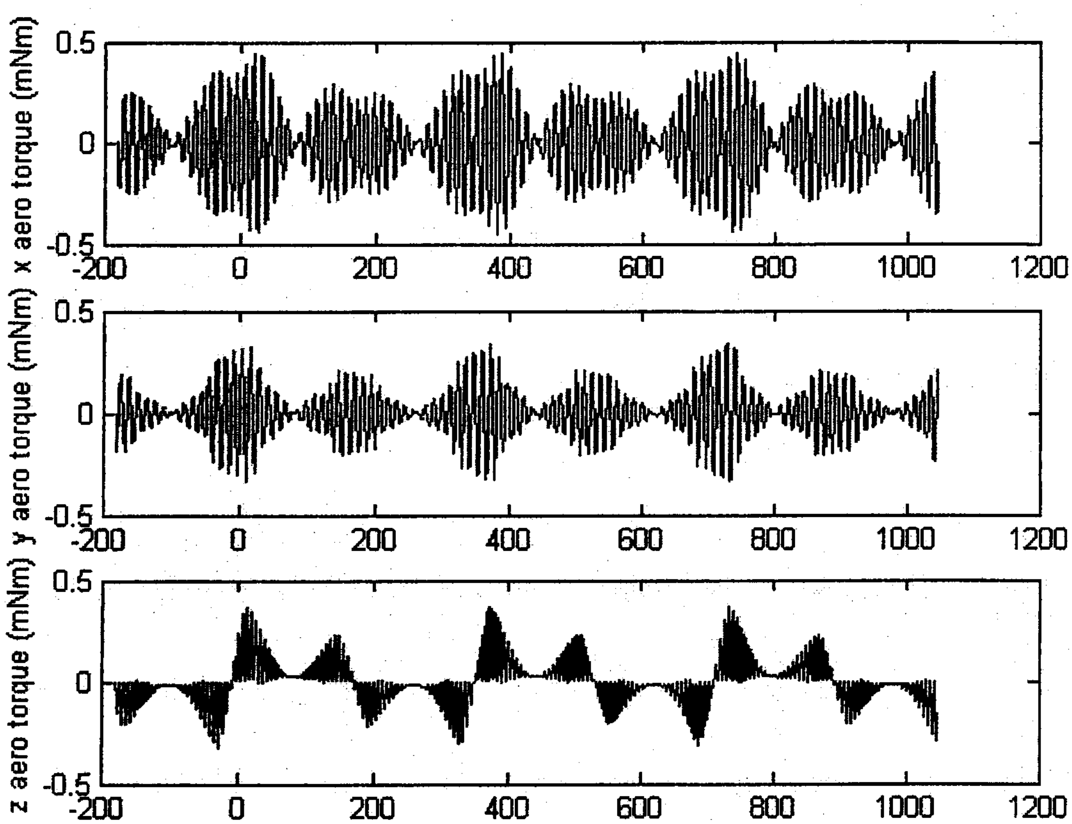

Figure 5. Aerodynamic drag torques expressed in spacecraft body frame vs orbit angle from first ascending node.

The present TREETOPS GP-B simulation calculates a total gravitational force on the spacecraft and on each of the science gyros and the proof mass. The gravity gradient force must therefore be calculated using the proof mass as a reference. The calculated gravity gradient force is therefore calculated using the proof mass position and subtracting the gravity force on the proof mass scaled by the ratio of spacecraft-to-proof mass masses. This result is plotted in figure 6. The gravity gradient force is the primary disturbance which is counteracted by the helium thrusters as well as the aerodynamic force. By the action of the translation control system, the spacecraft is forced to follow the drag free orbit of the proof mass. This force is proportional to the vector distance of the spacecraft center of mass from the center of the proof mass cavity.

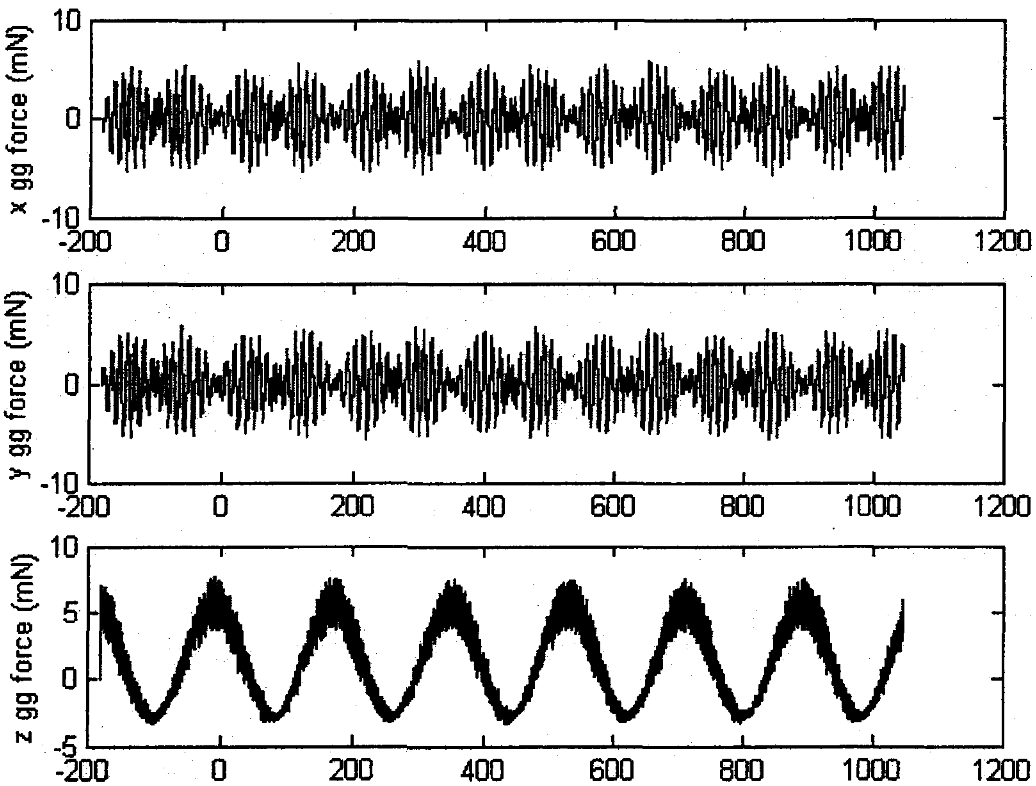

Figure 6. Calculated gravity gradient force vs orbit angle from first ascending node.

The gravity gradient torque is computed about the body origin in TREETOPS. The result is output and plotted below. The output forces and moments from TREETOPS simulations are produced by calculation of constraints where constraints are defined or where degrees of freedom at a hinge are locked. To output forces and moments where constraints are not defined, a force-moment sensor is defined and assigned to the appropriate body and node numbers. The action of the force-moment sensor is to sum all external forces and moments which are applied to the body, at the node where the sensor is located. These force and moment components are expressed in the inertial coordinate frame. The moments are computed relative to the origin of the coordinate system of the body on which the sensor is defined. Aerodynamic forces and moments are referenced to a center of pressure which is assigned to a body node for TREETOPS purposes. This is node 13 on body 1 of the GP-B model. Gravity Forces and moments are referred to the body center of mass which is located at node 1 on each body of a TREETOPS model. Cryogenic moments are assigned to magnetic moment actuators which are located on body 1, node 2. A force-moment sensor located at node 2 collects this information for output. A post process uses body 1 quaternions to transform force and moment components into the body 1 coordinate frame.

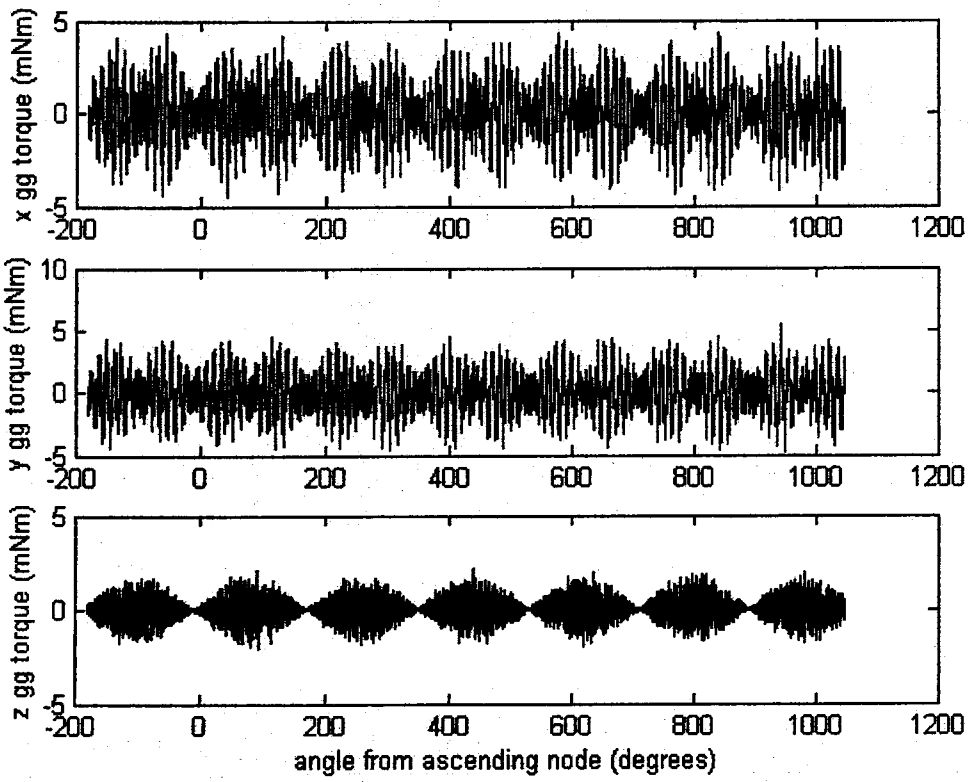

Figure 7. Calculated gravity gradient torque vs orbit angle from first ascending node.

Magnetic field components are determined for each body that has a magnetic moment actuator located on it. A magnetic field sensor (magnetometer) gathers this information for use in a control system or for output. An atmospheric density sensor (densitometer) collects aerodynamic density information, also for output. The figure below shows the magnetic field

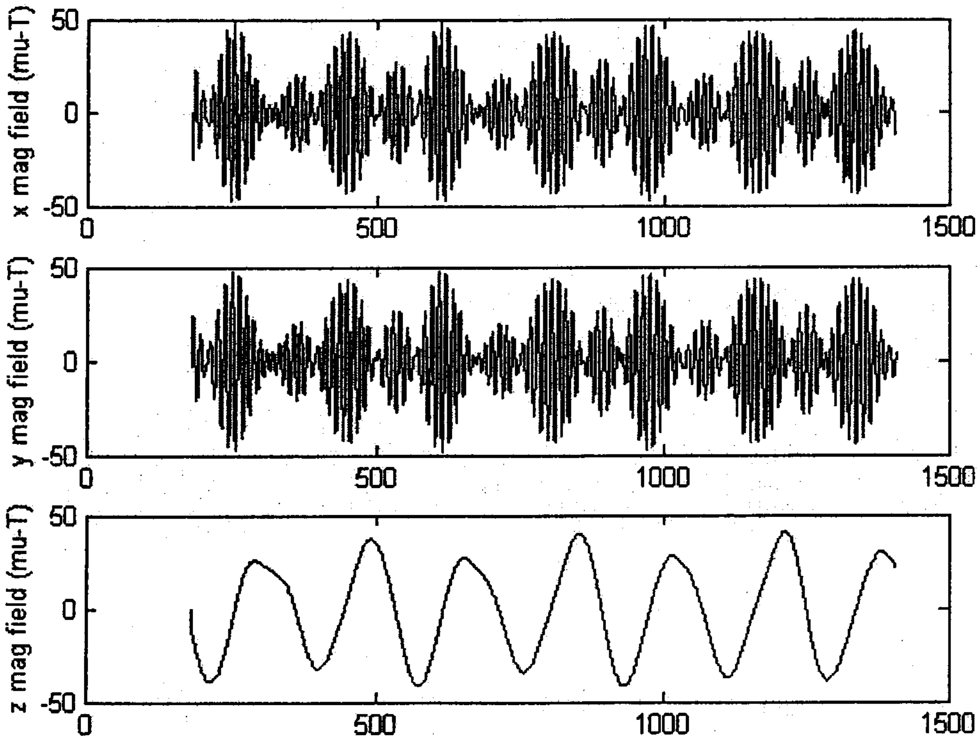

Figure 8. GP-B spacecraft magnetic flux density (micro-Tesla) field components expressed in body coordinates.

The aerodynamic forces and moments are directly proportional to the atmospheric density. The density is calculated using the TREETOPS Jacchia atmosphere model. Figure 9 in the following shows the density calculated at each point in the GP-B orbit.

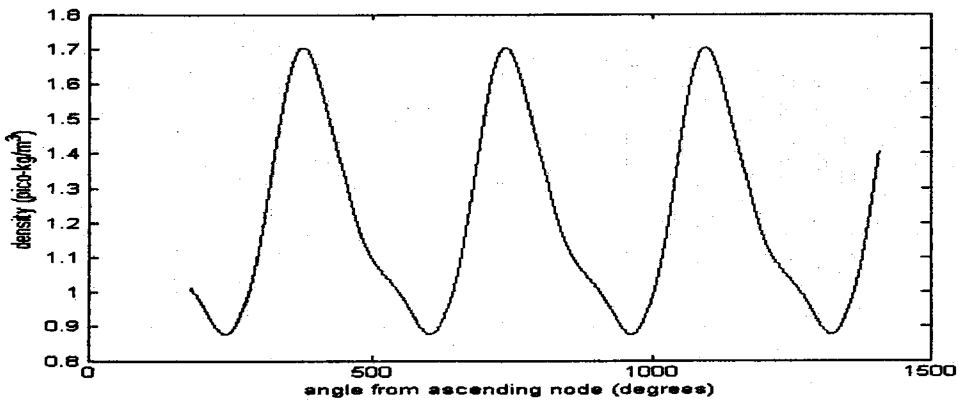

Figure 9. Atmospheric density expressed in pico-kg/m^3 i.e. 10^{-12} kg/m^3 at GP-B spacecraft location vs orbit angle from first ascending node.

The magnetic field coefficients are slowly time varying and the atmospheric model also includes date and time dependent information as well as information that depends on solar activity which varies with sunspot activity and position. For these reasons a date and time must be selected for the start of the simulation. The reference time chosen for the above simulation run is Greenwich noon on June 21, 2003. The solar activity parameters used by the atmosphere model are solar flux F10 number = 230, 81 day average F10B = 230, geomagnetic index GEAP = 400. These numbers have not been adjusted to reflect current sunspot activity.

4.0 TREETOPS UPDATE AND DEVELOPMENT OF THE HELIUM SLOSH MODEL:

In January and later, techniques were developed for incorporating the helium slosh dynamics into the TREETOPS model using the transfer function approach and the flexible structure body model which is a generalization of the spring/mass model. Construction of a model from the CFD codes continued to elude us. So we concentrated on the transfer function approach. In this, the Navier-Stokes equations for the liquid helium was reduced to Laplaces equation and since the geometry possesses cylindrical symmetry, it is expressed in cylindrical coordinates. This is then solved by the method of separation of variables and development of a superposition of eigenfunctions which are the continuous domain equivalent of modes. The solutions are determined as an expansion in terms of Bessel functions of radius, trigonometric functions of the azimuth variable and hyberbolic functions of the lengthwise variable. We shall not go further into this approach which is being developed and expounded upon by Dr. Howard Snyder of the University of Colorado. This approach leads to a set of transfer functions which can then be incorporated into TREETOPS. During the period from December through the present time the transfer function approach and the flexible body approach were implemented. Also, the guide star was changed from Rigel to IM Pegasus. Change in guide stars will change noise characteristics in the signal from the science telescopes but presumably, that has already been assessed and will not be treated here. The noise data being used in the model has not changed from the Rigel values since no new data was available. Also, no definition was available to us of the feed forward compensation for velocity aberration, that feature as well as the other feed forward compensations was turned off. Appendix F contains the new model definition file for the transfer function model. This consists of the file called IMPEG_GPB_TF.INT and also an auxiliary file called XFERFN.DAT. The auxiliary file allows us to define values for the transfer function polynomials to more digits of accuracy which is critical to properly capturing the extremely small damping of the modes. Appendix G contains the corresponding model definition file for the structural flexibility, spring/damper model. There is also a second file to define the flexible structure but that is too big to be included here. It will be provided elsewhere in electronic form. The performance of these updated models which include the effects of slosh dynamics at 0.3 RPM are shown in the following. First, figure 10 shows a 20,000 second response with the present version of the transfer fimction approach.

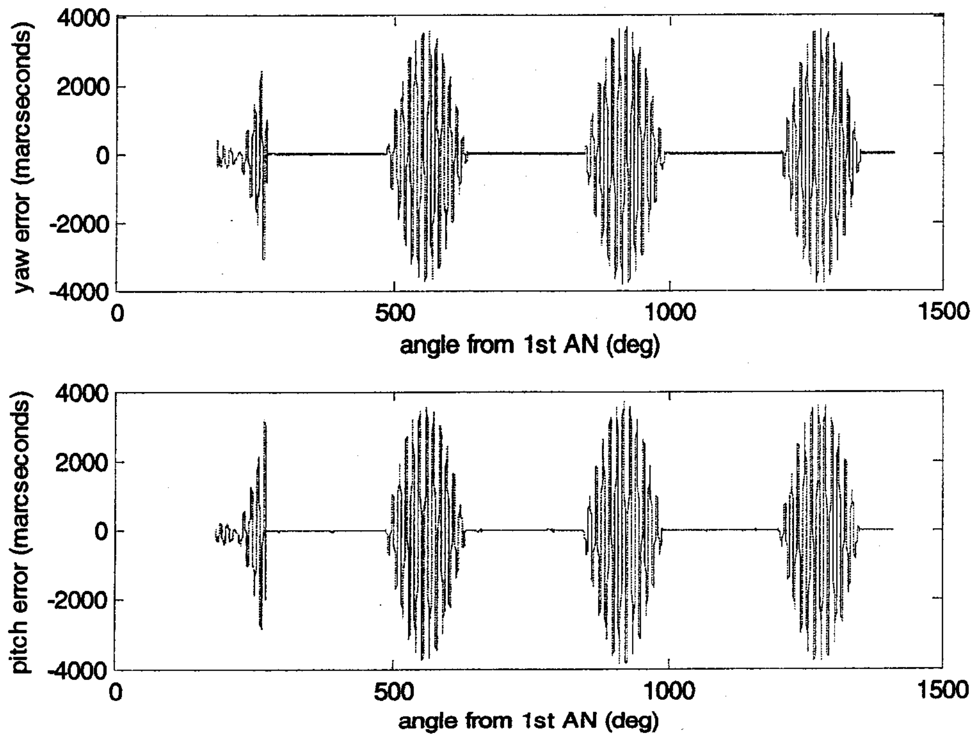

Figure 10. Pitch and yaw errors for slosh transfer function approach plotted versus orbit angle from first ascending node.

As can be seen with figure 10, the is no apparent growth amplitude growth as would be expected if there were a significant response to the slosh dynamics transfer functions. This is not conclusive however, sensitivities need to be looked at and also, the effects of more transfer functions. Reinforcing this result is the flexible structure slosh model. These are shown in figure 11 below:

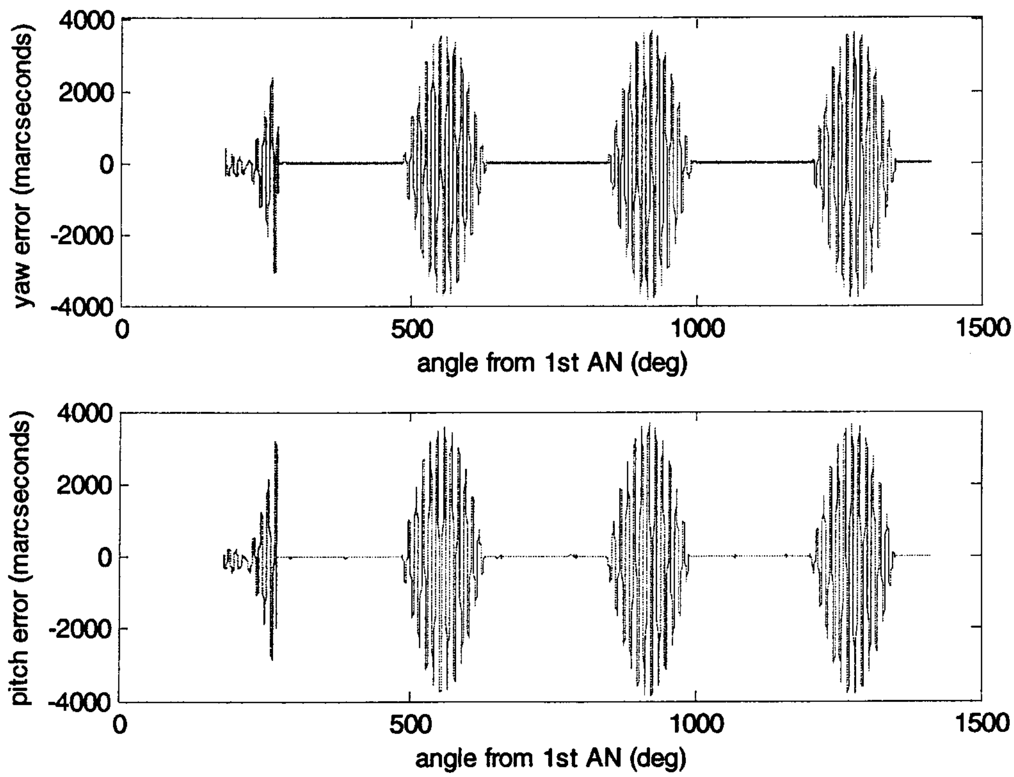

Figure 11. Pitch and yaw errors for flexible body model slosh dynamics plotted against orbit angle from first AN (deg).

5.0 MODEL REACTIVATION AND UPDATE SUMMARY AND CONCLUSIONS:

The bd Systems TREETOPS based simulation of the GP-B spacecraft on orbit in science data taking mode has been successfully updated to the present bd Systems version of TREETOPS called Version 10X. The modifications and additions incorporated into Version 10X from Version 10 were summarized in the introduction. Biggest changes have consisted of conversion to a fully dynamic orbit from a perturbation model, switchover to the generic gravity gradient torque models, an updated version of the sensor model for a star trackers, a local vertical local horizontal sensor, update of the aerodynamic forces and torque model including a detailed review of the implementation of the aero model with an re-assessment of the definition of the aero disturbance frame to assure both our own proper understanding as well as a proper understanding to provide to the Aerospace Corporation Computational Fluid Dynamics GPB spacecraft

Dynamics model. We have also updated the GPB Dynaic model to include 2 versions, a transfer function version and a flexible body version. The transfer function is currently only partially defined because only two of the maximum of 36 possible functions have been defined. Those have been implemented and to date, have not shown any tendency toward instability over a 20,000 second simulated period. The flexible body model has been implemented but is currently using only a partial set of modal mass integrals. Likewise, it also does not show any tendencies toward instability over the same 20,000second period. Greater lengths of time should be looked at and more transfer functions included with a study of parameter variations to be expected from these models.

Appendix A

GP-B Simulation Definition File
GPB.INT

```
TREETOPS REV 10X   1/10/02

SIM CONTROL

SI   0 Title                                                 GPB MODEL FOR 2002
SI   0 Simulation stop time                                  20000
SI   0 Plot data interval                                    2
SI   0 Integration type (R,S or U)                           R
SI   0 Step size (sec)                                       0.10
SI   0 Sandia integration absolute and relative error
SI   0 RK78 ODE solver absolute error and first step size
SI   0 Linearization option  (L,Z or N)                      N
SI   0 Restart option        (Y/N)                           N
SI   0 Contact force computation option     (Y/N)            N
SI   0 Constraint force computation option  (Y/N)            N
SI   0 Small angle speedup option (All,Bypass,First,Nth)     A
SI   0 Mass matrix speedup option (All,Bypass,First,Nth)     A
SI   0 Non-Linear  speedup option (All,Bypass,First,Nth)     A
SI   0 Constraint  speedup option (All,Bypass,First,Nth)     A
SI   0 Constraint stabilization option  (Y/N)                N
SI   0 Stabilization epsilon

GENGRAV

GG  18 Gravity, earth sphere/nonsphere/user (S/N/U)?         N
GG   1 Input gravity constants:  GME, ERAD, EMASS
GG   1 Spherical or Nonspherical (S/N)?
GG   1 Gravity Potential Harmonics J2,J3,J4
GG  18 English (ft-slug-s) or metric (m-kg-s)    (E/M)?      M
GG  18 Day, Month, Year,                                     21 6 2003
GG  18 GMT @ sim time 0 (minutes past midnight,              720
GG  18 Solar Pressure forces Y/N?                            N
GG  18 Input new data for aero model? (Y/N)                  Y
GG  18   Solar flux F10 for aero model                       230
GG  18   Solar flux, 81 day average F10B                     230
GG  18   Geomagnetic index, GEAP                             400

BODY

BO   1 Body ID number                                        1
BO   1 Type (Rigid,Flexible,NASTRAN)                         R
BO   1 Number of modes
BO   1 Modal calculation option (0, 1 or 2)
BO   1 Foreshortening Option (Y/N)
BO   1 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   1 NASTRAN data file FORTRAN unit number (40 - 60)
BO   1 Number of augmented nodes (0 if none)
BO   1 Damping matrix option (NS,CD,HL,SD)
BO   1 Constant damping ratio
BO   1 Low frequency, High frequency ratios
BO   1 Mode ID number, damping ratio
BO   1 Conversion factors: Length,Mass,Force
BO   1 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)    1
BO   1 Moments of inertia (kg-m2) Ixx,Iyy,Izz                5230.2 5147.5 3693.4
BO   1 Products of inertia (kg-m2) Ixy,Ixz,Iyz               19.3 -6 0
BO   1 Mass (kg)                                             3182.8
```

```
BO   1 Number of Nodes                                          13
BO   1 Node ID, Node coord. (meters) x,y,z                      1 0 -0.0002 0.8647
BO   1 Node ID, Node coord. (meters) x,y,z                      2 0 -0.0002 0.8647
BO   1 Node ID, Node coord. (meters) x,y,z                      3 0 1.0467 0.6380
BO   1 Node ID, Node coord. (meters) x,y,z                      4 0 0 0.10033
BO   1 Node ID, Node coord. (meters) x,y,z                      5 -1.19 0 2.51
BO   1 Node ID, Node coord. (meters) x,y,z                      6 1.19 0 2.51
BO   1 Node ID, Node coord. (meters) x,y,z                      7 -1.19 0 -1.9
BO   1 Node ID, Node coord. (meters) x,y,z                      8 1.19 0 -1.9
BO   1 Node ID, Node coord. (meters) x,y,z                      9 0 0 -.10033
BO   1 Node ID, Node coord. (meters) x,y,z                      10 0 0 -.18283
BO   1 Node ID, Node coord. (meters) x,y,z                      11 0 0 -.26533
BO   1 Node ID, Node coord. (meters) x,y,z                      12 0 0 -.34783
BO   1 Node ID, Node coord. (meters) x,y,z                      13 0 0 0.10937
BO   1 Node ID, Node structual joint ID

BO   2 Body ID number                                           2
BO   2 Type (Rigid,Flexible,NASTRAN)                            R
BO   2 Number of modes
BO   2 Modal calculation option (0, 1 or 2)
BO   2 Foreshortening Option (Y/N)
BO   2 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   2 NASTRAN data file FORTRAN unit number (40 - 60)
BO   2 Number of augmented nodes (0 if none)
BO   2 Damping matrix option (NS,CD,HL,SD)
BO   2 Constant damping ratio
BO   2 Low frequency, High frequency ratios
BO   2 Mode ID number, damping ratio
BO   2 Conversion factors: Length,Mass,Force
BO   2 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)       1
BO   2 Moments of inertia (kg-m2) Ixx,Iyy,Izz                   .00001 .00001 .00001
BO   2 Products of inertia (kg-m2) Ixy,Ixz,Iyz                  0 0 0
BO   2 Mass (kg)                                                .076
BO   2 Number of Nodes                                          1
BO   2 Node ID, Node coord. (meters) x,y,z                      1 0 0 0
BO   2 Node ID, Node structual joint ID

BO   3 Body ID number                                           3
BO   3 Type (Rigid,Flexible,NASTRAN)                            R
BO   3 Number of modes
BO   3 Modal calculation option (0, 1 or 2)
BO   3 Foreshortening option (Y/N)
BO   3 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   3 NASTRAN data file FORTRAN unit number (40 - 60)
BO   3 Number of augmented nodes (0 if none)
BO   3 Damping matrix option (NS,CD,HL,SD)
BO   3 Constant damping ratio
BO   3 Low frequency, High frequency ratios
BO   3 Mode ID number, damping ratio
BO   3 Conversion factors: Length,Mass,Force
BO   3 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)       1
BO   3 Moments of inertia (kg-m2) Ixx,Iyy,Izz                   9.1999324E-6 9.199954E-6 9.2E-6
BO   3 Products of inertia (kg-m2) Ixy,Ixz,Iyz                  0 0 0
BO   3 Mass (kg)                                                0.06335
BO   3 Number of Nodes                                          2
BO   3 Node ID, Node coord. (meters) x,y,z                      1 0 0 0
BO   3 Node ID, Node coord. (meters) x,y,z                      2 0 0 -5.08E-8
BO   3 Node ID, Node structual joint ID

BO   4 Body ID number                                           4
BO   4 Type (Rigid,Flexible,NASTRAN)                            R
BO   4 Number of modes
BO   4 Modal calculation option (0, 1 or 2)
BO   4 Foreshortening option (Y/N)
BO   4 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   4 NASTRAN data file FORTRAN unit number (40 - 60)
BO   4 Number of augmented nodes (0 if none)
BO   4 Damping matrix option (NS,CD,HL,SD)
BO   4 Constant damping ratio
BO   4 Low frequency, High frequency ratios
BO   4 Mode ID number, damping ratio
```

```
BO   4 Conversion factors: Length,Mass,Force
BO   4 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)          1
BO   4 Moments of inertia (kg-m2) Ixx,Iyy,Izz                       9.1999324E-6 9.199954E-6 9.2E-6
BO   4 Products of inertia (kg-m2) Ixy,Ixz,Iyz                      0 0 0
BO   4 Mass (kg)                                                    .06335
BO   4 Number of Nodes                                              2
BO   4 Node ID, Node coord. (meters) x,y,z                          1 0 0 0
BO   4 Node ID, Node coord. (meters) x,y,z                          2 0 0 -5.08E-8
BO   4 Node ID, Node structual joint ID

BO   5 Body ID number                                               5
BO   5 Type (Rigid,Flexible,NASTRAN)                                R
BO   5 Number of modes
BO   5 Modal calculation option (0, 1 or 2)
BO   5 Foreshortening option (Y/N)
BO   5 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   5 NASTRAN data file FORTRAN unit number (40 - 60)
BO   5 Number of augmented nodes (0 if none)
BO   5 Damping matrix option (NS,CD,HL,SD)
BO   5 Constant damping ratio
BO   5 Low frequency, High frequency ratios
BO   5 Mode ID number, damping ratio
BO   5 Conversion factors: Length,Mass,Force
BO   5 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)          1
BO   5 Moments of inertia (kg-m2) Ixx,Iyy,Izz                       9.1999324E-6 9.199954E-6 9.2E-6
BO   5 Products of inertia (kg-m2) Ixy,Ixz,Iyz                      0 0 0
BO   5 Mass (kg)                                                    .06335
BO   5 Number of Nodes                                              2
BO   5 Node ID, Node coord. (meters) x,y,z                          1 0 0 0
BO   5 Node ID, Node coord. (meters) x,y,z                          2 0 0 -5.08E-8
BO   5 Node ID, Node structual joint ID

BO   6 Body ID number                                               6
BO   6 Type (Rigid,Flexible,NASTRAN)                                R
BO   6 Number of modes
BO   6 Modal calculation option (0, 1 or 2)
BO   6 Foreshortening option (Y/N)
BO   6 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   6 NASTRAN data file FORTRAN unit number (40 - 60)
BO   6 Number of augmented nodes (0 if none)
BO   6 Damping matrix option (NS,CD,HL,SD)
BO   6 Constant damping ratio
BO   6 Low frequency, High frequency ratios
BO   6 Mode ID number, damping ratio
BO   6 Conversion factors: Length,Mass,Force
BO   6 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)          1
BO   6 Moments of inertia (kg-m2) Ixx,Iyy,Izz                       9.1999324E-6 9.199954E-6 9.2E-6
BO   6 Products of inertia (kg-m2) Ixy,Ixz,Iyz                      0 0 0
BO   6 Mass (kg)                                                    .06335
BO   6 Number of Nodes                                              2
BO   6 Node ID, Node coord. (meters) x,y,z                          1 0 0 0
BO   6 Node ID, Node coord. (meters) x,y,z                          2 0 0 -5.08E-8
BO   6 Node ID, Node structual joint ID

     HINGE

HI   1 Hinge ID number                                              1
HI   1 Inboard body ID, Outboard body ID                            0 1
HI   1 "p" node ID, "q" node ID                                     0 4
HI   1 Number of rotation DOFs, Rotation option (F or G)            3 F
HI   1 L1 unit vector in inboard body coord. x,y,z                  0 1 0
HI   1 L1 unit vector in outboard body coord. x,y,z                 0 0 1
HI   1 L2 unit vector in inboard body coord. x,y,z
HI   1 L2 unit vector in outboard body coord. x,y,z
HI   1 L3 unit vector in inboard body coord. x,y,z                  1 0 0
HI   1 L3 unit vector in outboard body coord. x,y,z                 0 1 0
HI   1 Initial rotation angles (deg)              78.025 0.0 98.25  78.01947099188411 0.0
98.25124323660548
HI   1 Initial rotation rates (deg/sec)-0.2582867196 1.7813724963 0 0 0 1.8
HI   1 Rotation stiffness (newton-meters/rad)                       0 0 0
```

```
HI   1 Rotation damping (newton-meters/rad/sec)                     0 0 0
HI   1 Null torque angles (deg)                                     0 0 0
HI   1 Number of translation DOFs                                   3
HI   1 First translation unit vector   g1                           1 0 0
HI   1 Second translation unit vector  g2                           0 1 0
HI   1 Third translation unit vector   g3                           0 0 1
HI   1 Initial translation (meters)                                 -6875220.6 0 -1458238.2
HI   1 Initial translation velocity (meters/sec)                    0 -7533.0 0
HI   1 Translation stiffness (newtons/meters)                       0 0 0
HI   1 Translation damping (newtons/meter/sec)                      0 0 0
HI   1 Null force translations                                      0 0 0

HI   2 Hinge ID number                                              2
HI   2 Inboard body ID, Outboard body ID                            1 2
HI   2 "p" node ID, "q" node ID                                     4 1
HI   2 Number of rotation DOFs, Rotation option (F or G)            0
HI   2 L1 unit vector in inboard body coord. x,y,z                  1 0 0
HI   2 L1 unit vector in outboard body coord. x,y,z                 1 0 0
HI   2 L2 unit vector in inboard body coord. x,y,z
HI   2 L2 unit vector in outboard body coord. x,y,z
HI   2 L3 unit vector in inboard body coord. x,y,z                  0 0 1
HI   2 L3 unit vector in outboard body coord. x,y,z                 0 0 1
HI   2 Initial rotation angles (deg)                                0 0 0
HI   2 Initial rotation rates (deg/sec)
HI   2 Rotation stiffness (newton-meters/rad)
HI   2 Rotation damping (newton-meters/rad/sec)
HI   2 Null torque angles (deg)
HI   2 Number of translation DOFs                                   3
HI   2 First translation unit vector   g1                           1 0 0
HI   2 Second translation unit vector  g2                           0 1 0
HI   2 Third translation unit vector   g3                           0 0 1
HI   2 Initial translation (meters)                                 0 0 0
HI   2 Initial translation velocity (meters/sec)                    0 0 0
HI   2 Translation stiffness (newtons/meters)                       0 0 0
HI   2 Translation damping (newtons/meter/sec)                      0 0 0
HI   2 Null force translations                                      0 0 0

HI   3 Hinge ID number                                              3
HI   3 Inboard body ID, Outboard body ID                            1 3
HI   3 "p" node ID, "q" node ID                                     9 2
HI   3  No of rotation DOFs, Hinge 1 rotation option(F/G)           0
HI   3 L1 unit vector in inboard body coord. x,y,z                  1 0 0
HI   3 L1 unit vector in outboard body coord. x,y,z                 1 0 0
HI   3 L2 unit vector in inboard body coord. x,y,z
HI   3 L2 unit vector in outboard body coord. x,y,z
HI   3 L3 unit vector in inboard body coord. x,y,z                  0 0 1
HI   3 L3 unit vector in outboard body coord. x,y,z                 0 0 1
HI   3 Initial rotation angles (deg)                                0 0 0
HI   3 Initial rotation rates (deg/sec)
HI   3 Rotation stiffness (newton-meters/rad)
HI   3 Rotation damping (newton-meters/rad/sec)
HI   3 Null torque angles (deg)
HI   3 Number of translation DOFs                                   3
HI   3 First translation unit vector   g1                           1 0 0
HI   3 Second translation unit vector  g2                           0 1 0
HI   3 Third translation unit vector   g3                           0 0 1
HI   3 Initial translation (meters)                                 0 0 0
HI   3 Initial translation velocity (meters/sec)                    0 0 0
HI   3 Translation stiffness (newtons/meters)                       10. 10. 10.
HI   3 Translation damping (newtons/meter/sec)                      1.125 1.125 1.125
HI   3 Null force translations                                      0 0 0

HI   4 Hinge ID number                                              4
HI   4 Inboard body ID, Outboard body ID                            1 4
HI   4 "p" node ID, "q" node ID                                     10 2
HI   4 Number of rotation DOFs, Rotation option (F or G)            0
HI   4 L1 unit vector in inboard body coord. x,y,z                  1 0 0
HI   4 L1 unit vector in outboard body coord. x,y,z                 1 0 0
HI   4 L2 unit vector in inboard body coord. x,y,z
HI   4 L2 unit vector in outboard body coord. x,y,z
HI   4 L3 unit vector in inboard body coord. x,y,z                  0 0 1
```

```
HI   4 L3 unit vector in outboard body coord. x,y,z        0 0 1
HI   4 Initial rotation angles (deg)                       0 0 0
HI   4 Initial rotation rates (deg/sec)
HI   4 Rotation stiffness (newton-meters/rad)
HI   4 Rotation damping (newton-meters/rad/sec)
HI   4 Null torque angles (deg)
HI   4 Number of translation DOFs                          3
HI   4 First translation unit vector   g1                  1 0 0
HI   4 Second translation unit vector  g2                  0 1 0
HI   4 Third translation unit vector   g3                  0 0 1
HI   4 Initial translation (meters)                        0 0 0
HI   4 Initial translation velocity (meters/sec)           0 0 0
HI   4 Translation stiffness (newtons/meters)              10 10 10
HI   4 Translation damping (newtons/meter/sec)             1.125 1.125 1.125
HI   4 Null force translations                             0 0 0

HI   5 Hinge ID number                                     5
HI   5 Inboard body ID, Outboard body ID                   1 5
HI   5 "p" node ID, "q" node ID                            11 2
HI   5  Number of rotation DOFs                            0
HI   5 L1 unit vector in inboard body coord. x,y,z         1 0 0
HI   5 L1 unit vector in outboard body coord. x,y,z        1 0 0
HI   5 L2 unit vector in inboard body coord. x,y,z
HI   5 L2 unit vector in outboard body coord. x,y,z
HI   5 L3 unit vector in inboard body coord. x,y,z         0 0 1
HI   5 L3 unit vector in outboard body coord. x,y,z        0 0 1
HI   5 Initial rotation angles (deg)                       0 0 0
HI   5 Initial rotation rates (deg/sec)
HI   5 Rotation stiffness (newton-meters/rad)
HI   5 Rotation damping (newton-meters/rad/sec)
HI   5 Null torque angles (deg)
HI   5 Number of translation DOFs                          3
HI   5 First translation unit vector   g1                  1 0 0
HI   5 Second translation unit vector  g2                  0 1 0
HI   5 Third translation unit vector   g3                  0 0 1
HI   5 Initial translation (meters)                        0 0 0
HI   5 Initial translation velocity (meters/sec)           0 0 0
HI   5 Translation stiffness (newtons/meters)              10 10 10
HI   5 Translation damping (newtons/meter/sec)             1.125 1.125 1.125
HI   5 Null force translations                             0 0 0

HI   6 Hinge ID number                                     6
HI   6 Inboard body ID, Outboard body ID                   1 6
HI   6 "p" node ID, "q" node ID                            12 2
HI   6  Number of rotation DOFs                            0
HI   6 L1 unit vector in inboard body coord. x,y,z         1 0 0
HI   6 L1 unit vector in outboard body coord. x,y,z        1 0 0
HI   6 L2 unit vector in inboard body coord. x,y,z
HI   6 L2 unit vector in outboard body coord. x,y,z
HI   6 L3 unit vector in inboard body coord. x,y,z         0 0 1
HI   6 L3 unit vector in outboard body coord. x,y,z        0 0 1
HI   6 Initial rotation angles (deg)                       0 0 0
HI   6 Initial rotation rates (deg/sec)
HI   6 Rotation stiffness (newton-meters/rad)
HI   6 Rotation damping (newton-meters/rad/sec)
HI   6 Null torque angles (deg)
HI   6 Number of translation DOFs                          3
HI   6 First translation unit vector   g1                  1 0 0
HI   6 Second translation unit vector  g2                  0 1 0
HI   6 Third translation unit vector   g3                  0 0 1
HI   6 Initial translation (meters)                        0 0 0
HI   6 Initial translation velocity (meters/sec)           0 0 0
HI   6 Translation stiffness (newtons/meters)              10 10 10
HI   6 Translation damping (newtons/meter/sec)             1.125 1.125 1.125
HI   6 Null force translations                             0 0 0

       SENSOR

SE   1 Sensor ID number                                    1
SE   1 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  G
```

```
    SE   1 Mounting point body ID, Mounting point node ID                  1 3
    SE   1 Second mounting point body ID, Second node ID
    SE   1 Input axis unit vector (IA) x,y,z                               0 0 1
    SE   1 Mounting point Hinge index, Axis index
    SE   1 First focal plane unit vector  (Fp1) x,y,z
    SE   1 Second focal plane unit vector (Fp2) x,y,z
    SE   1 Sun/Star unit vector (Us) x,y,z
    SE   1 Velocity Aberration Option (Y/N)
    SE   1 Euler Angle Sequence (1-6)
    SE   1 CMG ID number and Gimbal number
    SE   1 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

    SE   2 Sensor ID number                                                2
    SE   2 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      G
    SE   2 Mounting point body ID, Mounting point node ID                  1 3
    SE   2 Second mounting point body ID, Second node ID
    SE   2 Input axis unit vector (IA) x,y,z                               0 1 0
    SE   2 Mounting point Hinge index, Axis index
    SE   2 First focal plane unit vector  (Fp1) x,y,z
    SE   2 Second focal plane unit vector (Fp2) x,y,z
    SE   2 Sun/Star unit vector (Us) x,y,z
    SE   2 Velocity Aberration Option (Y/N)
    SE   2 Euler Angle Sequence (1-6)
    SE   2 CMG ID number and Gimbal number
    SE   2 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

    SE   3 Sensor ID number                                                3
    SE   3 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      G
    SE   3 Mounting point body ID, Mounting point node ID                  1 3
    SE   3 Second mounting point body ID, Second node ID
    SE   3 Input axis unit vector (IA) x,y,z                               1 0 0
    SE   3 Mounting point Hinge index, Axis index
    SE   3 First focal plane unit vector  (Fp1) x,y,z
    SE   3 Second focal plane unit vector (Fp2) x,y,z
    SE   3 Sun/Star unit vector (Us) x,y,z
    SE   3 Velocity Aberration Option (Y/N)
    SE   3 Euler Angle Sequence (1-6)
    SE   3 CMG ID number and Gimbal number
    SE   3 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

    SE   4 Sensor ID number                                                4
    SE   4 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      ST
    SE   4 Mounting point body ID, Mounting point node ID                  1 2
    SE   4 Second mounting point body ID, Second node ID
    SE   4 Input axis unit vector (IA) x,y,z
    SE   4 Mounting point Hinge index, Axis index
    SE   4 First focal plane unit vector  (Fp1) x,y,z                      1 0 0
    SE   4 Second focal plane unit vector (Fp2) x,y,z                      0 1 0
    SE   4 Sun/Star unit vector (Us) x,y,z                                 .968114817 -0.143492622
0.205337693
    SE   4 Velocity Aberration Option (Y/N)                                Y
    SE   4 Euler Angle Sequence (1-6)
    SE   4 CMG ID number and Gimbal number
    SE   4 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

    SE   5 Sensor ID number                                                5
    SE   5 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      P3
    SE   5 Mounting point body ID, Mounting point node ID                  1 4
    SE   5 Second mounting point body ID, Second node ID                   2 1
    SE   5 Input axis unit vector (IA) x,y,z
    SE   5 Mounting point Hinge index, Axis index
    SE   5 First focal plane unit vector  (Fp1) x,y,z
    SE   5 Second focal plane unit vector (Fp2) x,y,z
    SE   5 Sun/Star unit vector (Us) x,y,z
    SE   5 Velocity Aberration Option (Y/N)
    SE   5 Euler Angle Sequence (1-6)
    SE   5 CMG ID number and Gimbal number
    SE   5 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

    SE   6 Sensor ID number                                                6
    SE   6 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      AC
```

```
SE   6 Mounting point body ID, Mounting point node ID             2 1
SE   6 Second mounting point body ID, Second node ID
SE   6 Input axis unit vector (IA) x,y,z                          1 0 0
SE   6 Mounting point Hinge index, Axis index
SE   6 First focal plane unit vector  (Fp1) x,y,z
SE   6 Second focal plane unit vector (Fp2) x,y,z
SE   6 Sun/Star unit vector (Us) x,y,z
SE   6 Velocity Aberration Option (Y/N)
SE   6 Euler Angle Sequence (1-6)
SE   6 CMG ID number and Gimbal number
SE   6 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   7 Sensor ID number                                           7
SE   7 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  AC
SE   7 Mounting point body ID, Mounting point node ID             2 1
SE   7 Second mounting point body ID, Second node ID
SE   7 Input axis unit vector (IA) x,y,z                          0 1 0
SE   7 Mounting point Hinge index, Axis index
SE   7 First focal plane unit vector  (Fp1) x,y,z
SE   7 Second focal plane unit vector (Fp2) x,y,z
SE   7 Sun/Star unit vector (Us) x,y,z
SE   7 Velocity Aberration Option (Y/N)
SE   7 Euler Angle Sequence (1-6)
SE   7 CMG ID number and Gimbal number
SE   7 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   8 Sensor ID number                                           8
SE   8 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  AC
SE   8 Mounting point body ID, Mounting point node ID             2 1
SE   8 Second mounting point body ID, Second node ID
SE   8 Input axis unit vector (IA) x,y,z                          0 0 1
SE   8 Mounting point Hinge index, Axis index
SE   8 First focal plane unit vector  (Fp1) x,y,z
SE   8 Second focal plane unit vector (Fp2) x,y,z
SE   8 Sun/Star unit vector (Us) x,y,z
SE   8 Velocity Aberration Option (Y/N)
SE   8 Euler Angle Sequence (1-6)
SE   8 CMG ID number and Gimbal number
SE   8 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   9 Sensor ID number                                           9
SE   9 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  I
SE   9 Mounting point body ID, Mounting point node ID             1 3
SE   9 Second mounting point body ID, Second node ID
SE   9 Input axis unit vector (IA) x,y,z                          0 0 1
SE   9 Mounting point Hinge index, Axis index
SE   9 First focal plane unit vector  (Fp1) x,y,z
SE   9 Second focal plane unit vector (Fp2) x,y,z
SE   9 Sun/Star unit vector (Us) x,y,z
SE   9 Velocity Aberration Option (Y/N)
SE   9 Euler Angle Sequence (1-6)
SE   9 CMG ID number and Gimbal number
SE   9 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  10 Sensor ID number                                           10
SE  10 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  P3
SE  10 Mounting point body ID, Mounting point node ID             1 9
SE  10 Second mounting point body ID, Second node ID              3 1
SE  10 Input axis unit vector (IA) x,y,z
SE  10 Mounting point Hinge index, Axis index
SE  10 First focal plane unit vector  (Fp1) x,y,z
SE  10 Second focal plane unit vector (Fp2) x,y,z
SE  10 Sun/Star unit vector (Us) x,y,z
SE  10 Velocity Aberration Option (Y/N)
SE  10 Euler Angle Sequence (1-6)
SE  10 CMG ID number and Gimbal number
SE  10 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  11 Sensor ID number                                           11
SE  11 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  V3
SE  11 Mounting point body ID, Mounting point node ID             1 9
```

```
SE  11 Second mounting point body ID, Second node ID          3 1
SE  11 Input axis unit vector (IA) x,y,z
SE  11 Mounting point Hinge index, Axis index
SE  11 First focal plane unit vector  (Fp1) x,y,z
SE  11 Second focal plane unit vector (Fp2) x,y,z
SE  11 Sun/Star unit vector (Us) x,y,z
SE  11 Velocity Aberration Option (Y/N)
SE  11 Euler Angle Sequence (1-6)
SE  11 CMG ID number and Gimbal number
SE  11 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  12 Sensor ID number                                       12
SE  12 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  FM
SE  12 Mounting point body ID, Mounting point node ID         1 1
SE  12 Second mounting point body ID, Second node ID
SE  12 Input axis unit vector (IA) x,y,z
SE  12 Mounting point Hinge index, Axis index
SE  12 First focal plane unit vector  (Fp1) x,y,z
SE  12 Second focal plane unit vector (Fp2) x,y,z
SE  12 Sun/Star unit vector (Us) x,y,z
SE  12 Velocity Aberration Option (Y/N)
SE  12 Euler Angle Sequence (1-6)
SE  12 CMG ID number and Gimbal number
SE  12 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  13 Sensor ID number                                       13
SE  13 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  FM
SE  13 Mounting point body ID, Mounting point node ID         1 2
SE  13 Second mounting point body ID, Second node ID
SE  13 Input axis unit vector (IA) x,y,z
SE  13 Mounting point Hinge index, Axis index
SE  13 First focal plane unit vector  (Fp1) x,y,z
SE  13 Second focal plane unit vector (Fp2) x,y,z
SE  13 Sun/Star unit vector (Us) x,y,z
SE  13 Velocity Aberration Option (Y/N)
SE  13 Euler Angle Sequence (1-6)
SE  13 CMG ID number and Gimbal number
SE  13 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  14 Sensor ID number                                       14
SE  14 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  FM
SE  14 Mounting point body ID, Mounting point node ID         1 13
SE  14 Second mounting point body ID, Second node ID
SE  14 Input axis unit vector (IA) x,y,z
SE  14 Mounting point Hinge index, Axis index
SE  14 First focal plane unit vector  (Fp1) x,y,z
SE  14 Second focal plane unit vector (Fp2) x,y,z
SE  14 Sun/Star unit vector (Us) x,y,z
SE  14 Velocity Aberration Option (Y/N)
SE  14 Euler Angle Sequence (1-6)
SE  14 CMG ID number and Gimbal number
SE  14 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  15 Sensor ID number                                       15
SE  15 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  DN
SE  15 Mounting point body ID, Mounting point node ID         1 1
SE  15 Second mounting point body ID, Second node ID
SE  15 Input axis unit vector (IA) x,y,z                      1 0 0
SE  15 Mounting point Hinge index, Axis index
SE  15 First focal plane unit vector  (Fp1) x,y,z
SE  15 Second focal plane unit vector (Fp2) x,y,z
SE  15 Sun/Star unit vector (Us) x,y,z
SE  15 Velocity Aberration Option (Y/N)
SE  15 Euler Angle Sequence (1-6)
SE  15 CMG ID number and Gimbal number
SE  15 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  16 Sensor ID number                                       16
SE  16 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  MG
SE  16 Mounting point body ID, Mounting point node ID         1 1
SE  16 Second mounting point body ID, Second node ID
```

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SE  16 Input axis unit vector (IA) x,y,z                                1 0 0
SE  16 Mounting point Hinge index, Axis index
SE  16 First focal plane unit vector  (Fp1) x,y,z
SE  16 Second focal plane unit vector (Fp2) x,y,z
SE  16 Sun/Star unit vector (Us) x,y,z
SE  16 Velocity Aberration Option (Y/N)
SE  16 Euler Angle Sequence (1-6)
SE  16 CMG ID number and Gimbal number
SE  16 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  17 Sensor ID number                                                 17
SE  17 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)          LV
SE  17 Mounting point body ID, Mounting point node ID                   1,1
SE  17 Second mounting point body ID, Second node ID
SE  17 Input axis unit vector (IA) x,y,z
SE  17 Mounting point Hinge index, Axis index
SE  17 First focal plane unit vector  (Fp1) x,y,z
SE  17 Second focal plane unit vector (Fp2) x,y,z
SE  17 Sun/Star unit vector (Us) x,y,z
SE  17 Velocity Aberration Option (Y/N)
SE  17 Euler Angle Sequence (1-6)
SE  17 CMG ID number and Gimbal number
SE  17 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  18 Sensor ID number                                                 18
SE  18 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)          FM
SE  18 Mounting point body ID, Mounting point node ID                   2 1
SE  18 Second mounting point body ID, Second node ID
SE  18 Input axis unit vector (IA) x,y,z
SE  18 Mounting point Hinge index, Axis index
SE  18 First focal plane unit vector  (Fp1) x,y,z
SE  18 Second focal plane unit vector (Fp2) x,y,z
SE  18 Sun/Star unit vector (Us) x,y,z
SE  18 Velocity Aberration Option (Y/N)
SE  18 Euler Angle Sequence (1-6)
SE  18 CMG ID number and Gimbal number
SE  18 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

        ACTR

AC   1 Actuator ID number                                               1
AC   1 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                              J
AC   1 Actuator location; Node or Hinge (N or H)
AC   1 Mounting point body ID number, node ID number                    1 5
AC   1 Second mounting point body ID, second node ID
AC   1 Output axis unit vector x,y,z                                    1 0 0
AC   1 Mounting point Hinge index, Axis index
AC   1 Rotor spin axis unit vector x,y,z
AC   1 Initial rotor momentum, H
AC   1 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   1 Outer gimbal axis unit vector x,y,z
AC   1 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   1 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   1 Inner gimbal axis unit vector x,y,z
AC   1 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   1 Initial length and rate, y(to) and ydot(to)
AC   1 Constants; K1 or wo, n or zeta, Kg, Jm
AC   1 Non-linearities; TLim, Tco, Dz

AC   2 Actuator ID number                                               2
AC   2 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                              J
AC   2 Actuator location; Node or Hinge (N or H)
AC   2 Mounting point body ID number, node ID number                    1 6
AC   2 Second mounting point body ID, second node ID
AC   2 Output axis unit vector x,y,z                                    -1 0 0
AC   2 Mounting point Hinge index, Axis index
AC   2 Rotor spin axis unit vector x,y,z
AC   2 Initial rotor momentum, H
AC   2 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   2 Outer gimbal axis unit vector x,y,z
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AC   2 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   2 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   2 Inner gimbal axis unit vector x,y,z
AC   2 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   2 Initial length and rate, y(to) and ydot(to)
AC   2 Constants; K1 or wo, n or zeta, Kg, Jm
AC   2 Non-linearities; TLim, Tco, Dz

AC   3 Actuator ID number                                     3
AC   3 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                    J
AC   3 Actuator location; Node or Hinge (N or H)
AC   3 Mounting point body ID number, node ID number          1 7
AC   3 Second mounting point body ID, second node ID
AC   3 Output axis unit vector x,y,z                          1 0 0
AC   3 Mounting point Hinge index, Axis index
AC   3 Rotor spin axis unit vector x,y,z
AC   3 Initial rotor momentum, H
AC   3 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   3 Outer gimbal axis unit vector x,y,z
AC   3 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   3 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   3 Inner gimbal axis unit vector x,y,z
AC   3 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   3 Initial length and rate, y(to) and ydot(to)
AC   3 Constants; K1 or wo, n or zeta, Kg, Jm
AC   3 Non-linearities; TLim, Tco, Dz

AC   4 Actuator ID number                                     4
AC   4 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                    J
AC   4 Actuator location; Node or Hinge (N or H)
AC   4 Mounting point body ID number, node ID number          1 8
AC   4 Second mounting point body ID, second node ID
AC   4 Output axis unit vector x,y,z                          -1 0 0
AC   4 Mounting point Hinge index, Axis index
AC   4 Rotor spin axis unit vector x,y,z
AC   4 Initial rotor momentum, H
AC   4 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   4 Outer gimbal axis unit vector x,y,z
AC   4 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   4 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   4 Inner gimbal axis unit vector x,y,z
AC   4 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   4 Initial length and rate, y(to) and ydot(to)
AC   4 Constants; K1 or wo, n or zeta, Kg, Jm
AC   4 Non-linearities; TLim, Tco, Dz

AC   5 Actuator ID number                                     5
AC   5 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                    J
AC   5 Actuator location; Node or Hinge (N or H)
AC   5 Mounting point body ID number, node ID number          1 8
AC   5 Second mounting point body ID, second node ID
AC   5 Output axis unit vector x,y,z                          0 1 0
AC   5 Mounting point Hinge index, Axis index
AC   5 Rotor spin axis unit vector x,y,z
AC   5 Initial rotor momentum, H
AC   5 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   5 Outer gimbal axis unit vector x,y,z
AC   5 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   5 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   5 Inner gimbal axis unit vector x,y,z
AC   5 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   5 Initial length and rate, y(to) and ydot(to)
AC   5 Constants; K1 or wo, n or zeta, Kg, Jm
AC   5 Non-linearities; TLim, Tco, Dz

AC   6 Actuator ID number                                     6
AC   6 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                    J
AC   6 Actuator location; Node or Hinge (N or H)
AC   6 Mounting point body ID number, node ID number          1 8
AC   6 Second mounting point body ID, second node ID
AC   6 Output axis unit vector x,y,z                          0 -1 0
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AC   6 Mounting point Hinge index, Axis index
AC   6 Rotor spin axis unit vector x,y,z
AC   6 Initial rotor momentum, H
AC   6 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   6 Outer gimbal axis unit vector x,y,z
AC   6 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   6 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   6 Inner gimbal axis unit vector x,y,z
AC   6 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   6 Initial length and rate, y(to) and ydot(to)
AC   6 Constants; K1 or wo, n or zeta, Kg, Jm
AC   6 Non-linearities; TLim, Tco, Dz

AC   7 Actuator ID number                                7
AC   7 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)               J
AC   7 Actuator location; Node or Hinge (N or H)
AC   7 Mounting point body ID number, node ID number     1 5
AC   7 Second mounting point body ID, second node ID
AC   7 Output axis unit vector x,y,z                     0 1 0
AC   7 Mounting point Hinge index, Axis index
AC   7 Rotor spin axis unit vector x,y,z
AC   7 Initial rotor momentum, H
AC   7 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   7 Outer gimbal axis unit vector x,y,z
AC   7 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   7 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   7 Inner gimbal axis unit vector x,y,z
AC   7 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   7 Initial length and rate, y(to) and ydot(to)
AC   7 Constants; K1 or wo, n or zeta, Kg, Jm
AC   7 Non-linearities; TLim, Tco, Dz

AC   8 Actuator ID number                                8
AC   8 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)               J
AC   8 Actuator location; Node or Hinge (N or H)
AC   8 Mounting point body ID number, node ID number     1 5
AC   8 Second mounting point body ID, second node ID
AC   8 Output axis unit vector x,y,z                     0 -1 0
AC   8 Mounting point Hinge index, Axis index
AC   8 Rotor spin axis unit vector x,y,z
AC   8 Initial rotor momentum, H
AC   8 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   8 Outer gimbal axis unit vector x,y,z
AC   8 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   8 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   8 Inner gimbal axis unit vector x,y,z
AC   8 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   8 Initial length and rate, y(to) and ydot(to)
AC   8 Constants; K1 or wo, n or zeta, Kg, Jm
AC   8 Non-linearities; TLim, Tco, Dz

AC   9 Actuator ID number                                9
AC   9 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)               J
AC   9 Actuator location; Node or Hinge (N or H)
AC   9 Mounting point body ID number, node ID number     1 7
AC   9 Second mounting point body ID, second node ID
AC   9 Output axis unit vector x,y,z                     0 1 0
AC   9 Mounting point Hinge index, Axis index
AC   9 Rotor spin axis unit vector x,y,z
AC   9 Initial rotor momentum, H
AC   9 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   9 Outer gimbal axis unit vector x,y,z
AC   9 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   9 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   9 Inner gimbal axis unit vector x,y,z
AC   9 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   9 Initial length and rate, y(to) and ydot(to)
AC   9 Constants; K1 or wo, n or zeta, Kg, Jm
AC   9 Non-linearities; TLim, Tco, Dz

AC  10 Actuator ID number                                10
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AC  10 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
AC  10 Actuator location; Node or Hinge (N or H)
AC  10 Mounting point body ID number, node ID number        1 7
AC  10 Second mounting point body ID, second node ID
AC  10 Output axis unit vector x,y,z                         0 -1 0
AC  10 Mounting point Hinge index, Axis index
AC  10 Rotor spin axis unit vector x,y,z
AC  10 Initial rotor momentum, H
AC  10 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  10 Outer gimbal axis unit vector x,y,z
AC  10 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  10 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  10 Inner gimbal axis unit vector x,y,z
AC  10 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  10 Initial length and rate, y(to) and ydot(to)
AC  10 Constants; K1 or wo, n or zeta, Kg, Jm
AC  10 Non-linearities; TLim, Tco, Dz

AC  11 Actuator ID number                                    11
AC  11 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
AC  11 Actuator location; Node or Hinge (N or H)
AC  11 Mounting point body ID number, node ID number        1 6
AC  11 Second mounting point body ID, second node ID
AC  11 Output axis unit vector x,y,z                         0 1 0
AC  11 Mounting point Hinge index, Axis index
AC  11 Rotor spin axis unit vector x,y,z
AC  11 Initial rotor momentum, H
AC  11 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  11 Outer gimbal axis unit vector x,y,z
AC  11 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  11 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  11 Inner gimbal axis unit vector x,y,z
AC  11 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  11 Initial length and rate, y(to) and ydot(to)
AC  11 Constants; K1 or wo, n or zeta, Kg, Jm
AC  11 Non-linearities; TLim, Tco, Dz

AC  12 Actuator ID number                                    12
AC  12 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
AC  12 Actuator location; Node or Hinge (N or H)
AC  12 Mounting point body ID number, node ID number        1 6
AC  12 Second mounting point body ID, second node ID
AC  12 Output axis unit vector x,y,z                         0 -1 0
AC  12 Mounting point Hinge index, Axis index
AC  12 Rotor spin axis unit vector x,y,z
AC  12 Initial rotor momentum, H
AC  12 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  12 Outer gimbal axis unit vector x,y,z
AC  12 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  12 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  12 Inner gimbal axis unit vector x,y,z
AC  12 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  12 Initial length and rate, y(to) and ydot(to)
AC  12 Constants; K1 or wo, n or zeta, Kg, Jm
AC  12 Non-linearities; TLim, Tco, Dz

AC  13 Actuator ID number                                    13
AC  13 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
AC  13 Actuator location; Node or Hinge (N or H)
AC  13 Mounting point body ID number, node ID number        1 7
AC  13 Second mounting point body ID, second node ID
AC  13 Output axis unit vector x,y,z                         0 0 1
AC  13 Mounting point Hinge index, Axis index
AC  13 Rotor spin axis unit vector x,y,z
AC  13 Initial rotor momentum, H
AC  13 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  13 Outer gimbal axis unit vector x,y,z
AC  13 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  13 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  13 Inner gimbal axis unit vector x,y,z
AC  13 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  13 Initial length and rate, y(to) and ydot(to)
AC  13 Constants; K1 or wo, n or zeta, Kg, Jm
AC  13 Non-linearities; TLim, Tco, Dz

AC  14 Actuator ID number                                   14
AC  14 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                 J
AC  14 Actuator location; Node or Hinge (N or H)
AC  14 Mounting point body ID number, node ID number        1 5
AC  14 Second mounting point body ID, second node ID
AC  14 Output axis unit vector x,y,z                        0 0 -1
AC  14 Mounting point Hinge index, Axis index
AC  14 Rotor spin axis unit vector x,y,z
AC  14 Initial rotor momentum, H
AC  14 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  14 Outer gimbal axis unit vector x,y,z
AC  14 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  14 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  14 Inner gimbal axis unit vector x,y,z
AC  14 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  14 Initial length and rate, y(to) and ydot(to)
AC  14 Constants; K1 or wo, n or zeta, Kg, Jm
AC  14 Non-linearities; TLim, Tco, Dz

AC  15 Actuator ID number                                   15
AC  15 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                 J
AC  15 Actuator location; Node or Hinge (N or H)
AC  15 Mounting point body ID number, node ID number        1 8
AC  15 Second mounting point body ID, second node ID
AC  15 Output axis unit vector x,y,z                        0 0 1
AC  15 Mounting point Hinge index, Axis index
AC  15 Rotor spin axis unit vector x,y,z
AC  15 Initial rotor momentum, H
AC  15 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  15 Outer gimbal axis unit vector x,y,z
AC  15 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  15 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  15 Inner gimbal axis unit vector x,y,z
AC  15 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  15 Initial length and rate, y(to) and ydot(to)
AC  15 Constants; K1 or wo, n or zeta, Kg, Jm
AC  15 Non-linearities; TLim, Tco, Dz

AC  16 Actuator ID number                                   16
AC  16 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                 J
AC  16 Actuator location; Node or Hinge (N or H)
AC  16 Mounting point body ID number, node ID number        1 6
AC  16 Second mounting point body ID, second node ID
AC  16 Output axis unit vector x,y,z                        0 0 -1
AC  16 Mounting point Hinge index, Axis index
AC  16 Rotor spin axis unit vector x,y,z
AC  16 Initial rotor momentum, H
AC  16 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  16 Outer gimbal axis unit vector x,y,z
AC  16 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  16 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  16 Inner gimbal axis unit vector x,y,z
AC  16 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  16 Initial length and rate, y(to) and ydot(to)
AC  16 Constants; K1 or wo, n or zeta, Kg, Jm
AC  16 Non-linearities; TLim, Tco, Dz

AC  17 Actuator ID number                                   17
AC  17 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                 J
AC  17 Actuator location; Node or Hinge (N or H)
AC  17 Mounting point body ID number, node ID number        1 2
AC  17 Second mounting point body ID, second node ID
AC  17 Output axis unit vector x,y,z                        1 0 0
AC  17 Mounting point Hinge index, Axis index
AC  17 Rotor spin axis unit vector x,y,z
AC  17 Initial rotor momentum, H
AC  17 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
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AC  17 Outer gimbal axis unit vector x,y,z
AC  17 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  17 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  17 Inner gimbal axis unit vector x,y,z
AC  17 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  17 Initial length and rate, y(to) and ydot(to)
AC  17 Constants; K1 or wo, n or zeta, Kg, Jm
AC  17 Non-linearities; TLim, Tco, Dz

AC  18 Actuator ID number                                        18
AC  18 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       J
AC  18 Actuator location; Node or Hinge (N or H)
AC  18 Mounting point body ID number, node ID number             1 2
AC  18 Second mounting point body ID, second node ID
AC  18 Output axis unit vector x,y,z                             0 1 0
AC  18 Mounting point Hinge index, Axis index
AC  18 Rotor spin axis unit vector x,y,z
AC  18 Initial rotor momentum, H
AC  18 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  18 Outer gimbal axis unit vector x,y,z
AC  18 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  19 Mounting point body ID number, node ID number             1 2
AC  19 Second mounting point body ID, second node ID
AC  19 Output axis unit vector x,y,z                             0 0 1
AC  19 Mounting point Hinge index, Axis index
AC  19 Rotor spin axis unit vector x,y,z
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AC  19 Inner gimbal axis unit vector x,y,z
AC  19 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  19 Initial length and rate, y(to) and ydot(to)
AC  19 Constants; K1 or wo, n or zeta, Kg, Jm
AC  19 Non-linearities; TLim, Tco, Dz

AC  20 Actuator ID number                                        20
AC  20 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       MO
AC  20 Actuator location; Node or Hinge (N or H)
AC  20 Mounting point body ID number, node ID number             1 2
AC  20 Second mounting point body ID, second node ID
AC  20 Output axis unit vector x,y,z                             1 0 0
AC  20 Mounting point Hinge index, Axis index
AC  20 Rotor spin axis unit vector x,y,z
AC  20 Initial rotor momentum, H
AC  20 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  20 Outer gimbal axis unit vector x,y,z
AC  20 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  20 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  20 Inner gimbal axis unit vector x,y,z
AC  20 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  20 Constants; K1 or wo, n or zeta, Kg, Jm
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AC  21 Actuator ID number                                        21
AC  21 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       MO
AC  21 Actuator location; Node or Hinge (N or H)
AC  21 Mounting point body ID number, node ID number             1 2
AC  21 Second mounting point body ID, second node ID
```

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AC  21 Output axis unit vector x,y,z                                   0 1 0
AC  21 Mounting point Hinge index, Axis index
AC  21 Rotor spin axis unit vector x,y,z
AC  21 Initial rotor momentum, H
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AC  21 Constants; K1 or wo, n or zeta, Kg, Jm
AC  21 Non-linearities; TLim, Tco, Dz

AC  22 Actuator ID number                                              22
AC  22 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                             MO
AC  22 Actuator location; Node or Hinge (N or H)
AC  22 Mounting point body ID number, node ID number                   1 2
AC  22 Second mounting point body ID, second node ID
AC  22 Output axis unit vector x,y,z                                   0 0 1
AC  22 Mounting point Hinge index, Axis index
AC  22 Rotor spin axis unit vector x,y,z
AC  22 Initial rotor momentum, H
AC  22 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
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AC  22 Constants; K1 or wo, n or zeta, Kg, Jm
AC  22 Non-linearities; TLim, Tco, Dz

AC  23 Actuator ID number                                              23
AC  23 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                             MA
AC  23 Actuator location; Node or Hinge (N or H)
AC  23 Mounting point body ID number, node ID number                   1 2
AC  23 Second mounting point body ID, second node ID
AC  23 Output axis unit vector x,y,z                                   1 0 0
AC  23 Mounting point Hinge index, Axis index
AC  23 Rotor spin axis unit vector x,y,z
AC  23 Initial rotor momentum, H
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AC  24 Actuator ID number                                              24
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AC  24 Second mounting point body ID, second node ID
AC  24 Output axis unit vector x,y,z                                   0 1 0
AC  24 Mounting point Hinge index, Axis index
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AC  25 Actuator ID number                                    25
AC  25 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                   MA
AC  25 Actuator location; Node or Hinge (N or H)
AC  25 Mounting point body ID number, node ID number         1 2
AC  25 Second mounting point body ID, second node ID
AC  25 Output axis unit vector x,y,z                         0 0 1
AC  25 Mounting point Hinge index, Axis index
AC  25 Rotor spin axis unit vector x,y,z
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AC  25 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
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AC  25 Inner gimbal axis unit vector x,y,z
AC  25 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  25 Initial length and rate, y(to) and ydot(to)
AC  25 Constants; K1 or wo, n or zeta, Kg, Jm
AC  25 Non-linearities; TLim, Tco, Dz

AC  26 Actuator ID number                                    26
AC  26 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                   J
AC  26 Actuator location; Node or Hinge (N or H)
AC  26 Mounting point body ID number, node ID number         3 2
AC  26 Second mounting point body ID, second node ID
AC  26 Output axis unit vector x,y,z                         1 0 0
AC  26 Mounting point Hinge index, Axis index
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AC  26 Initial rotor momentum, H
AC  26 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
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AC  26 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  27 Actuator ID number                                    27
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AC  28 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                   J
AC  28 Actuator location; Node or Hinge (N or H)
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AC  28 Output axis unit vector x,y,z                         0 0 1
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AC  28 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  28 Outer gimbal axis unit vector x,y,z
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AC  28 Inner gimbal axis unit vector x,y,z
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AC  28 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  28 Initial length and rate, y(to) and ydot(to)
AC  28 Constants; K1 or wo, n or zeta, Kg, Jm
AC  28 Non-linearities; TLim, Tco, Dz

       CONTROLLER

CO   1 Controller ID number                                 1
CO   1 Controller type (CB,CM,DB,DM,UC,UD)                  UD
CO   1 Sample time (sec)                                    0.10
CO   1 Number of inputs, Number of outputs                  21 16
CO   1 Number of states
CO   1 Output No., Input type (I,S,T), Input ID, Gain

CO   2 Controller ID number                                 2
CO   2 Controller type (CB,CM,DB,DM,UC,UD)                  UC
CO   2 Sample time (sec)
CO   2 Number of inputs, Number of outputs                  6,6
CO   2 Number of states                                     0
CO   2 Output No., Input type (I,S,T), Input ID, Gain

       INTERCONNECT

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

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

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

IN   4 Interconnect ID number                               4
IN   4 Source type(S,C, or F),Source ID,Source row #        C 1 4
IN   4 Destination type(A or C),Dest ID,Dest row #          A 4 1
IN   4 Gain                                                 1

IN   5 Interconnect ID number                               5
IN   5 Source type(S,C, or F),Source ID,Source row #        C 1 5
IN   5 Destination type(A or C),Dest ID,Dest row #          A 5 1
IN   5 Gain                                                 1

IN   6 Interconnect ID number                               6
IN   6 Source type(S,C, or F),Source ID,Source row #        C 1 6
IN   6 Destination type(A or C),Dest ID,Dest row #          A 6 1
IN   6 Gain                                                 1

IN   7 Interconnect ID number                               7
IN   7 Source type(S,C, or F),Source ID,Source row #        C 1 7
IN   7 Destination type(A or C),Dest ID,Dest row #          A 7 1
IN   7 Gain                                                 1

IN   8 Interconnect ID number                               8
IN   8 Source type(S,C, or F),Source ID,Source row #        C 1 8
IN   8 Destination type(A or C),Dest ID,Dest row #          A 8 1
IN   8 Gain                                                 1

IN   9 Interconnect ID number                               9
IN   9 Source type(S,C, or F),Source ID,Source row #        C 1 9
IN   9 Destination type(A or C),Dest ID,Dest row #          A 9 1
IN   9 Gain                                                 1

IN  10 Interconnect ID number                               10
```

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IN  10 Source type(S,C, or F),Source ID,Source row #        C 1 10
IN  10 Destination type(A or C),Dest ID,Dest row #          A 10 1
IN  10 Gain                                                 1

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

IN  12 Interconnect ID number                               12
IN  12 Source type(S,C, or F),Source ID,Source row #        C 1 12
IN  12 Destination type(A or C),Dest ID,Dest row #          A 12 1
IN  12 Gain                                                 1

IN  13 Interconnect ID number                               13
IN  13 Source type(S,C, or F),Source ID,Source row #        C 1 13
IN  13 Destination type(A or C),Dest ID,Dest row #          A 13 1
IN  13 Gain                                                 1

IN  14 Interconnect ID number                               14
IN  14 Source type(S,C, or F),Source ID,Source row #        C 1 14
IN  14 Destination type(A or C),Dest ID,Dest row #          A 14 1
IN  14 Gain                                                 1

IN  15 Interconnect ID number                               15
IN  15 Source type(S,C, or F),Source ID,Source row #        C 1 15
IN  15 Destination type(A or C),Dest ID,Dest row #          A 15 1
IN  15 Gain                                                 1

IN  16 Interconnect ID number                               16
IN  16 Source type(S,C, or F),Source ID,Source row #        C 1 16
IN  16 Destination type(A or C),Dest ID,Dest row #          A 16 1
IN  16 Gain                                                 1

IN  26 Interconnect ID number                               26
IN  26 Source type(S,C, or F),Source ID,Source row #        S 1 1
IN  26 Destination type(A or C),Dest ID,Dest row #          C 1 1
IN  26 Gain                                                 1

IN  27 Interconnect ID number                               27
IN  27 Source type(S,C, or F),Source ID,Source row #        S 2 1
IN  27 Destination type(A or C),Dest ID,Dest row #          C 1 2
IN  27 Gain                                                 1

IN  28 Interconnect ID number                               28
IN  28 Source type(S,C, or F),Source ID,Source row #        S 3 1
IN  28 Destination type(A or C),Dest ID,Dest row #          C 1 3
IN  28 Gain                                                 1

IN  29 Interconnect ID number                               29
IN  29 Source type(S,C, or F),Source ID,Source row #        S 4 1
IN  29 Destination type(A or C),Dest ID,Dest row #          C 1 4
IN  29 Gain                                                 1

IN  30 Interconnect ID number                               30
IN  30 Source type(S,C, or F),Source ID,Source row #        S 4 2
IN  30 Destination type(A or C),Dest ID,Dest row #          C 1 5
IN  30 Gain                                                 1

IN  31 Interconnect ID number                               31
IN  31 Source type(S,C, or F),Source ID,Source row #        S 5 1
IN  31 Destination type(A or C),Dest ID,Dest row #          C 1 6
IN  31 Gain                                                 1

IN  32 Interconnect ID number                               32
IN  32 Source type(S,C, or F),Source ID,Source row #        S 5 2
IN  32 Destination type(A or C),Dest ID,Dest row #          C 1 7
IN  32 Gain                                                 1

IN  33 Interconnect ID number                               33
IN  33 Source type(S,C, or F),Source ID,Source row #        S 5 3
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IN  33 Destination type(A or C),Dest ID,Dest row #        C 1 8
IN  33 Gain                                                1

IN  34 Interconnect ID number                              34
IN  34 Source type(S,C, or F),Source ID,Source row #       S 6 1
IN  34 Destination type(A or C),Dest ID,Dest row #         C 1 9
IN  34 Gain                                                1

IN  35 Interconnect ID number                              35
IN  35 Source type(S,C, or F),Source ID,Source row #       S 7 1
IN  35 Destination type(A or C),Dest ID,Dest row #         C 1 10
IN  35 Gain                                                1

IN  36 Interconnect ID number                              36
IN  36 Source type(S,C, or F),Source ID,Source row #       S 8 1
IN  36 Destination type(A or C),Dest ID,Dest row #         C 1 11
IN  36 Gain                                                1

IN  37 Interconnect ID number                              37
IN  37 Source type(S,C, or F),Source ID,Source row #       S 9 1
IN  37 Destination type(A or C),Dest ID,Dest row #         C 1 12
IN  37 Gain                                                1

IN  38 Interconnect ID number                              38
IN  38 Source type(S,C, or F),Source ID,Source row #       S 10 1
IN  38 Destination type(A or C),Dest ID,Dest row #         C 2 1
IN  38 Gain                                                1

IN  39 Interconnect ID number                              39
IN  39 Source type(S,C, or F),Source ID,Source row #       S 10 2
IN  39 Destination type(A or C),Dest ID,Dest row #         C 2 2
IN  39 Gain                                                1

IN  40 Interconnect ID number                              40
IN  40 Source type(S,C, or F),Source ID,Source row #       S 10 3
IN  40 Destination type(A or C),Dest ID,Dest row #         C 2 3
IN  40 Gain                                                1

IN  41 Interconnect ID number                              41
IN  41 Source type(S,C, or F),Source ID,Source row #       S 11 1
IN  41 Destination type(A or C),Dest ID,Dest row #         C 2 4
IN  41 Gain                                                1

IN  42 Interconnect ID number                              42
IN  42 Source type(S,C, or F),Source ID,Source row #       S 11 2
IN  42 Destination type(A or C),Dest ID,Dest row #         C 2 5
IN  42 Gain                                                1

IN  43 Interconnect ID number                              43
IN  43 Source type(S,C, or F),Source ID,Source row #       S 11 3
IN  43 Destination type(A or C),Dest ID,Dest row #         C 2 6
IN  43 Gain                                                1

IN  17 Interconnect ID number                              17
IN  17 Source type(S,C, or F),Source ID,Source row #       C 2 1
IN  17 Destination type(A or C),Dest ID,Dest row #         A 26 1
IN  17 Gain                                                0

IN  18 Interconnect ID number                              18
IN  18 Source type(S,C, or F),Source ID,Source row #       C 2 2
IN  18 Destination type(A or C),Dest ID,Dest row #         A 27 1
IN  18 Gain                                                0

IN  19 Interconnect ID number                              19
IN  19 Source type(S,C, or F),Source ID,Source row #       C 2 3
IN  19 Destination type(A or C),Dest ID,Dest row #         A 28 1
IN  19 Gain                                                0

IN  20 Interconnect ID number                              20
IN  20 Source type(S,C, or F),Source ID,Source row #       C 2 4
IN  20 Destination type(A or C),Dest ID,Dest row #         A 23 1
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IN  20 Gain                                                   1

IN  21 Interconnect ID number                                 21
IN  21 Source type(S,C, or F),Source ID,Source row #          C 2 5
IN  21 Destination type(A or C),Dest ID,Dest row #            A 24 1
IN  21 Gain                                                   1

IN  22 Interconnect ID number                                 22
IN  22 Source type(S,C, or F),Source ID,Source row #          C 2 6
IN  22 Destination type(A or C),Dest ID,Dest row #            A 25 1
IN  22 Gain                                                   1

IN  23 Interconnect ID number                                 23
IN  23 Source type(S,C, or F),Source ID,Source row #          S 17 1
IN  23 Destination type(A or C),Dest ID,Dest row #            C 1 13
IN  23 Gain                                                   1

IN  24 Interconnect ID number                                 24
IN  24 Source type(S,C, or F),Source ID,Source row #          S 17 2
IN  24 Destination type(A or C),Dest ID,Dest row #            C 1 14
IN  24 Gain                                                   1

IN  25 Interconnect ID number                                 25
IN  25 Source type(S,C, or F),Source ID,Source row #          S 17 3
IN  25 Destination type(A or C),Dest ID,Dest row #            C 1 15
IN  25 Gain                                                   1

IN  44 Interconnect ID number                                 44
IN  44 Source type(S,C, or F),Source ID,Source row #          S 17 4
IN  44 Destination type(A or C),Dest ID,Dest row #            C 1 16
IN  44 Gain                                                   1

IN  45 Interconnect ID number                                 45
IN  45 Source type(S,C, or F),Source ID,Source row #          S 17 5
IN  45 Destination type(A or C),Dest ID,Dest row #            C 1 17
IN  45 Gain                                                   1

IN  46 Interconnect ID number                                 46
IN  46 Source type(S,C, or F),Source ID,Source row #          S 17 6
IN  46 Destination type(A or C),Dest ID,Dest row #            C 1 18
IN  46 Gain                                                   1

IN  47 Interconnect ID number                                 47
IN  47 Source type(S,C, or F),Source ID,Source row #          S 17 7
IN  47 Destination type(A or C),Dest ID,Dest row #            C 1 19
IN  47 Gain                                                   1

IN  48 Interconnect ID number                                 48
IN  48 Source type(S,C, or F),Source ID,Source row #          S 17 8
IN  48 Destination type(A or C),Dest ID,Dest row #            C 1 20
IN  48 Gain                                                   1

IN  49 Interconnect ID number                                 49
IN  49 Source type(S,C, or F),Source ID,Source row #          S 17 9
IN  49 Destination type(A or C),Dest ID,Dest row #            C 1 21
IN  49 Gain                                                   1

       AEROD

AE   1 Aerodynamic Model ID #                                 1
AE   1 Body ID, Center of Pressure Node ID                    1 13
AE   1 Atmosphere Type (C,J,M)                                J
AE   1 Constant Density for Atmosphere Type=C
AE   1 Model Type (P,C,T,B)                                   T
AE   1 Dimensions D,L (meters)
AE   1 Unit Normal Vector x,y,z
AE   1 Aero Ref Area, Ref Length (meters)                     16.6051 2.2990
AE   1 Name of Aero Coefficient Table Input File              .\newttae.dat
AE   1 Axial unit vector in body (alpha=0,phi=0)              0. 0. 1.
AE   1 Vert  unit vector in body (alpha=90,phi=0)             .7071 -.7071 0.
```

```
AE   1 Horiz unit vector in body (alpha=90,phi=90)          .7071 .7071 0.
```

Appendix B

USER CONTINUOUS AND DISCRETE CONTROL LERS AUXILIARY SUBROUTINES UCONTROL.FOR

```
C*******************************************************************************
C  File Name: USCC.FOR
C  Description: User continuous controllers to be used with Treetops
C
C  U : controller inputs (sensors)
C  R : controller outputs (actuators)
C
C       u(1) = relative inertial position (x) from spacecraft to SG#2
C       u(2) = relative inertial position (y) from spacecraft to SG#2
C       u(3) = relative inertial position (z) from spacecraft to SG#2
C       u(4) = relative inertial velocity (x) from spacecraft to SG#2
C       u(5) = relative inertial velocity (y) from spacecraft to SG#2
C       u(6) = relative inertial velocity (z) from spacecraft to SG#2
C     r(1-3) = SG#2 Suspension Force Commands (N)
C     r(4-6) = Cryoperm shield induced magnetic moment torque (N-m)
C*******************************************************************************
       SUBROUTINE USCC(KRKPAS,T,U,X,R,XDOT)
       IMPLICIT NONE

       include 'DBP.F'
       include 'DBB.F'
       include 'DBSP.F'

       INTEGER*4 KRKPAS,I
       REAL*8 T,XDOT(3),U(6),R(6),X(6)

       real*8 usus(3),psus(3),vsus(3),psg2i_ix,psg2i_iy,psg2i_iz
       real*8 psg2i(3),psg2b(3),vsg2i(3),vsg2b(3),KSUS1,KSUS2,usat
       real*8 mmom(3),bmagb(3)

       real*8 dto,Told,L1,L2,x1o(3),x1o_o(3),x2o(3),x2o_o(3),psus_o(3)

       logical first_pass
       data first_pass / .true. /

       if (first_pass) then
         first_pass = .false.
         psg2i_ix = u(1)
         psg2i_iy = u(2)
         psg2i_iz = u(3)
       endif

CSUS
C  For gyro suspension, convert the relative position and velocity from
C  spacecraft to SG#2 from inertial to body coordinates and apply noise
C  and quantization
C    Position
       psg2i(1) = u(1) - psg2i_ix
       psg2i(2) = u(2) - psg2i_iy
       psg2i(3) = u(3) - psg2i_iz
       call intobo (psg2i,psg2b,1) !jrg uses ctrans for body 1
CASH
C  No noise on position sensors right now
C      psus(1) = psg2b(1) + RNORM (seed_dfx, std_dfs, 0.0D0)
C      psus(2) = psg2b(2) + RNORM (seed_dfy, std_dfs, 0.0D0)
C      psus(3) = psg2b(3) + RNORM (seed_dfz, std_dfs, 0.0D0)
C      psus(1) = ORDQUAN(psus(1),lsb_dfs)
C      psus(2) = ORDQUAN(psus(2),lsb_dfs)
C      psus(3) = ORDQUAN(psus(3),lsb_dfs)
       psus(1) = psg2b(1)
       psus(2) = psg2b(2)
       psus(3) = psg2b(3)
```

```
c
cash
c
c  Observer from dissertation
c
       L1 = 0.539d0
       L2 = 17.26d0
       dto = T - Told
       Told = T
c
       x1o(1) =
     &x1o_o(1)+dto*x2o_o(1)+dto*dto/2.d0*usus(1)+L1*(psus_o(1)-x1o_o(1))
       x1o(2) =
     &x1o_o(2)+dto*x2o_o(2)+dto*dto/2.d0*usus(2)+L1*(psus_o(2)-x1o_o(2))
       x1o(3) =
     &x1o_o(3)+dto*x2o_o(3)+dto*dto/2.d0*usus(3)+L1*(psus_o(3)-x1o_o(3))
       x2o(1) = x2o_o(1) + dto*usus(1) + L2*(psus_o(1) - x1o_o(1))
       x2o(2) = x2o_o(2) + dto*usus(2) + L2*(psus_o(2) - x1o_o(2))
       x2o(3) = x2o_o(3) + dto*usus(3) + L2*(psus_o(3) - x1o_o(3))
c
       x1o_o(1) = x1o(1)
       x1o_o(2) = x1o(2)
       x1o_o(3) = x1o(3)
       x2o_o(1) = x2o(1)
       x2o_o(2) = x2o(2)
       x2o_o(3) = x2o(3)
       psus_o(1) = psus(1)
       psus_o(2) = psus(2)
       psus_o(3) = psus(3)
cash
c
C    Velocity
       vsg2i(1) = u(4)
       vsg2i(2) = u(5)
       vsg2i(3) = u(6)
       call intobo (vsg2i,vsg2b,1)
CASH
C  No sensor errors right now
C      vsus(1) = vsg2b(1) + RNORM (seed_dfx, std_dfs, 0.0D0)
C      vsus(2) = vsg2b(2) + RNORM (seed_dfy, std_dfs, 0.0D0)
C      vsus(3) = vsg2b(3) + RNORM (seed_dfz, std_dfs, 0.0D0)
C      vsus(1) = ORDQUAN(vsus(1),lsb_dfs)
C      vsus(2) = ORDQUAN(vsus(2),lsb_dfs)
C      vsus(3) = ORDQUAN(vsus(3),lsb_dfs)
       vsus(1) = vsg2b(1)
       vsus(2) = vsg2b(2)
       vsus(3) = vsg2b(3)

C************************    SUSPENSION CONTROL **********************

CSUS  Gain switching logic
C      if (  ) then
          KSUS1 = 1.5D8
          KSUS2 = 4.2D6
          usat = 9.81d-4    ! 1.d-4 g's
C      elseif (  ) then
C         KSUS1 =
C         KSUS2 =
C      endif

c
c  below is for perfect position,velocity, not observer inputs
c      usus(1) = -psus(1)*(1.d0 + KSUS1*dabs(psus(1)))
c     &          - vsus(1)*(1.4d0 + KSUS2*dabs(vsus(1)))
c      usus(2) = -psus(2)*(1.d0 + KSUS1*dabs(psus(2)))
c     &          - vsus(2)*(1.4d0 + KSUS2*dabs(vsus(2)))
c      usus(3) = -psus(3)*(1.d0 + KSUS1*dabs(psus(3)))
c     &          - vsus(3)*(1.4d0 + KSUS2*dabs(vsus(3)))
c
cash
c  below uses observer inputs
```

```
         usus(1) = -x1o(1)*(1.d0 + KSUS1*dabs(x1o(1)))
     &             - x2o(1)*(1.4d0 + KSUS2*dabs(x2o(1)))
         usus(2) = -x1o(2)*(1.d0 + KSUS1*dabs(x1o(2)))
     &             - x2o(2)*(1.4d0 + KSUS2*dabs(x2o(2)))
         usus(3) = -x1o(3)*(1.d0 + KSUS1*dabs(x1o(3)))
     &             - x2o(3)*(1.4d0 + KSUS2*dabs(x2o(3)))
cash
c

CSUS  Send the suspension forces to output
c
c  observer requirements assumes that u is specific force (acc)
         usus(1) = dsign(dmin1(dabs(usus(1)),usat),usus(1))
         usus(2) = dsign(dmin1(dabs(usus(2)),usat),usus(2))
         usus(3) = dsign(dmin1(dabs(usus(3)),usat),usus(3))
         r(1) = usus(1)*BMASS(3)
         r(2) = usus(2)*BMASS(3)
         r(3) = usus(3)*BMASS(3)
c
cash assume u is force     r(1) = dsign(dmin1(dabs(usus(1)),usat),usus(1))
cash assume u is force     r(2) = dsign(dmin1(dabs(usus(2)),usat),usus(2))
cash assume u is force     r(3) = dsign(dmin1(dabs(usus(3)),usat),usus(3))
c       r(1) = 0.d0
c       r(2) = 0.d0
c       r(3) = 0.d0

c       if (icount .lt. iplot) then
c        icount = icount + 1
c        return
c       endif
c       icount = 1

c        write(16) T,(u(i),i=1,6),
c      & (psus(i),i=1,3),(vsus(i),i=1,3),
c      & (r(i),i=1,3),(usus(i),i=1,3),(psg2i(i),i=1,3),(vsg2i(i),i=1,3)
c        nrows = nrows + 1
c        call adj_msiz(ncols,nrows,16,hdrpos,wtflg)
C Cryoperm shield torque
c  Transform B to body 1 frame
         bmagb(1) = ctrans(1,1,1)*bmagi(1)
     1          + ctrans(2,1,1)*bmagi(2) + ctrans(3,1,1)*bmagi(3)
         bmagb(2) = ctrans(1,2,1)*bmagi(1)
     1          + ctrans(2,2,1)*bmagi(2) + ctrans(3,2,1)*bmagi(3)
         bmagb(3) = ctrans(1,3,1)*bmagi(1)
     1          + ctrans(2,3,1)*bmagi(2) + ctrans(3,3,1)*bmagi(3)
         mmom(1) = 1.7632D5*bmagb(1)
         mmom(2) = 1.6032D5*bmagb(2)
         mmom(3) = 2.1600D6*bmagb(3)
         do i=1,3
           r(3+i) = ctrans(i,1,1)*mmom(1) + ctrans(i,2,1)*mmom(2) +
     &      ctrans(i,3,1)*mmom(3)
         enddo
         return
         end

*****************************************************************************
C   This is a user defined DOUBLE PRECISION discrete controller subroutine
C
C   Inputs:
C       u(1) = roll rate from rate gyro (rad/sec)
C       u(2) = pitch rate from rate gyro (rad/sec)
C       u(3) = yaw rate from rate gyro (rad/sec)
C       u(4) = pitch error angle from science telescope (ST)
C       u(5) = yaw error angle from science telescope (ST)
C       u(6) = relative inertial position (x) from spacecraft to SG#1
C       u(7) = relative inertial position (y) from spacecraft to SG#1
C       u(8) = relative inertial position (z) from spacecraft to SG#1
C       u(9) = SG#1 acceleration X (body)
C       u(10) = SG#1 acceleration Y (body)
C       u(11) = SG#1 acceleration Z (body)
C       u(12) = roll angle from integrating rate gyro (rad)
```

```
C      u(13) ... u(21) 9 elements of LVLH-to-body matrix
C
C   Outputs:
C      r(1-16) =  Sixteen Thruster Forces (N)
C      r(17-19) = disturbance forces at cg (N)
C      r(20-22) = disturbance torques at cg (N-M)
C      r(23-25) = Three Magnetic Torquer Bar Commands (A-m^2)

       SUBROUTINE USDC(TIME,U,R)
       implicit none ! double precision (a-h,o-z)
CSUS       real*8 TIME, U(12), R(25)
       real*8 TIME, U(36), R(16)

       include 'DBP.F'
       include 'DBSP.F'
       include 'DBS.F'
       include 'DBB.F'
       include 'RSTRT.F'
       include 'XFRM.F'

       logical init, RV
       real*8 dtcont,thrctrl,r_mflow,rnorm

C Earth orbit rate and commanded vehicle roll rate
       real*8 w_orbit, w_roll
       common / rates / w_orbit, w_roll

C Attitude control variables
       real*8 phi(5), theta(5), psi(5)
       real*8 uf_pit(3), uf_yaw(3), rf_pit(3), rf_yaw(3)
       real*8 uf_rol(3), rf_rol(3)
       real*8 phi_c, phi_a,n_r_revs
       real*8 Kpy_rv(5), limpy_rv(8), Ipy
       real*8 Kroll(5), limroll(8), Iroll
       common / attcont / Kpy_rv, limpy_rv, Ipy, Kroll, limroll, Iroll

C Translational control variables
       real*8 x(3), y(3), z(3)
       real*8 uf_x(3), uf_y(3), uf_z(3), rf_x(3), rf_y(3), rf_z(3)
       real*8 f_na(3), f_bo(3), bona(3,3)
       real*8 K_trans(3), lim_trans(2), m_trans
       common / transcon / K_trans, lim_trans, m_trans

C Quaternion Propagation variables
       real*8 w_act(3), a_err(3),w_errx(3),a_act(3)

C Sciençe Gyro position (inertial, body, nadir)
       real*8 psg1i(3), psg1b(3), psg1n(3)
       real*8 da_ns(4), da_ew(4)
cash integ
       common / testint / da_ns,da_ew
cash integ

C Sensor signals (Science Telescope, Roll Star Tracker, Control Gyro, and
C                Drag Free Sensor)
       real*8 st_roll, st_pitch, st_yaw
       real*8 cg_roll, cg_pitch, cg_yaw, cgi_pitch, cgi_yaw
       real*8 dfs(3)

C Environmental Disturbance On Flags & closed loop controller on flag
       logical GG_ON, CRYO_ON, VAB_ON, CLOSED_LOOP
       common / env_flag / GG_ON, CRYO_ON, VAB_ON, CLOSED_LOOP

C Sensor & actuator disturbance input data
C (seeds, standard deviations, least significant bit weights, drifts)
       integer seed_str, seed_stp, seed_sty
       integer seed_cgr, seed_cgp, seed_cgy
       integer seed_dfx, seed_dfy, seed_dfz
       integer seed_thr(16), seedthr
       integer i,mplot,nplot
       real*8 std_str, std_sct, std_cg, std_dfs, std_thr
```

```
      real*8 lsb_str, lsb_sct, lsb_cgr, lsb_cgpy, lsb_dfs, lsb_thr
      real*8 mean_cgr, mean_cgp, mean_cgy
cjrg  These commons are only used within user controllers
      common / disturb1 / seed_thr, seed_dfx, seed_dfy, seed_dfz,
     &   seed_str, seed_stp, seed_sty, seed_cgr, seed_cgp, seed_cgy
      common / disturb2 / std_str, std_sct, std_cg, std_dfs, std_thr,
     &   lsb_str, lsb_sct, lsb_cgr, lsb_cgpy, lsb_dfs, lsb_thr,
     &   mean_cgr, mean_cgp, mean_cgy


C Commanded forces, torques, flow
      real*8 tcom(3),tcom_ff(3),tcryo_ff(3),t_sp_gg(3),f_sp_gg(3)
      real*8 t_j2_gg(3),f_j2_gg(3),thrust(16), f(7)
      real*8 mdot, thrtot

C Constants
      real*8 pi_loc, arcrad, radarc
      parameter (pi_loc = 3.14159265358979323844d0)
      parameter (arcrad = pi_loc / (180.0d0*3600.0d0))
      parameter (radarc = 1.0d0 / arcrad)

C Thruster model variables
      real*8 Thys(2), thsave(16), th_delay(16)
      real*8 Th, Tl, Tmax
      common / thrhys1 / Th, Tl, Tmax

C Magnetic torquer variables and magnetic field vector
      real*8 bb(3)
      real*8 Mh, Mmax
      common / maghys1 / Mh, Mmax
c     real*8 bbxtcom(3), bbmag2
c     real*8 mcom(3), magmax, mcomxbb(3)
c     real*8 mcom1(2), mcom2(2), mcom3(2)

cash  velocity aberration
cash     real*8 vaber(2),dvaber(2)
cash    common / velab / vaber,dvaber
cash
      real*8 fp1i(3),fp2i(3),vaber(3),vaber0(3),vab_old(2)
      real*8 r_orbit,dvab(3),thabc(3),thabcd(3),sroll,croll,vmag
      real*8 phr(3),gyrquan,ordquan,clight,cstar_n(3,3)

      PARAMETER (CLIGHT = 2.99792458D8)
      PARAMETER (R_ORBIT = 6.378165D6 + 650.D3)

      COMMON /FP12I/ FP1I,FP2I,VABER

      equivalence (usdc_rs(1),vab_old),(usdc_rs(3),vaber0(1)),
     $    (usdc_rs(12),phi),(usdc_rs(17),theta),
     $    (usdc_rs(22),psi),(usdc_rs(27),x),
     $    (usdc_rs(30),y),(usdc_rs(33),z),
     $    (usdc_rs(36),th_delay),(usdc_rs(52),thsave),
     $    (usdc_rs(68),phr)

c Local variable initialization
      data init / .true. /
cjrg  Star assumed to be Rigel at Decl = -8.25 deg, RA = 78.025 deg.
cjrg  Orbit is polar

      if (init) call initcont (dtcont, mdot, nplot, mplot)

cjrg  Define bona body from nadir transform
      bona(1,1) = u(13)
      bona(2,1) = u(14)
      bona(3,1) = u(15)
      bona(1,2) = u(16)
      bona(2,2) = u(17)
      bona(3,2) = u(18)
      bona(1,3) = u(19)
      bona(2,3) = u(20)
      bona(3,3) = u(21)
```

```
      if (.not. vab_on) then
        vaber(1) = 0.d0
        vaber(2) = 0.d0
        vaber(3) = 0.d0
      else
c Calculate guide star velocity abberation in treetops ECI
        cstar_n(3,1) =   bona(3,1)
        cstar_n(3,2) =   bona(3,2)
        cstar_n(3,3) =   bona(3,3)
        vmag = dsqrt(bona(3,1)**2 + bona(3,3)**2)
        cstar_n(1,1) =   bona(3,3) / vmag
        cstar_n(1,2) =   0.d0
        cstar_n(1,3) = - bona(3,1) / vmag
        cstar_n(2,1) =
     $       cstar_n(3,2)*cstar_n(1,3) - cstar_n(3,3)*cstar_n(1,2)
        cstar_n(2,2) =
     $       cstar_n(3,3)*cstar_n(1,1) - cstar_n(3,1)*cstar_n(1,3)
        cstar_n(2,3) =
     $       cstar_n(3,1)*cstar_n(1,2) - cstar_n(3,2)*cstar_n(1,1)
        vmag = w_orbit * r_orbit / clight
        vaber(1) = vmag * cstar_n(1,1)
        vaber(2) = vmag * cstar_n(2,1)
        vaber(3) = 0.d0
      endif
C Initial control variables
      if (init) then
        init = .false.
        if (.not. rs_flag) then
          vaber0(1) = vaber(1)
          vaber0(2) = vaber(2)
          vaber0(3) = vaber(3)
          vab_old(1) = vaber(1)
          vab_old(2) = vaber(2)
        endif
      endif

cjrg  Compute body gravity gradient torques (spherical and j2).  Now only
cjrg  used in controller to compute GG feedforward terms.
cjrg  (Data hard coded for minor axis spinner, 650 Km circular orbit)

      if (GG_ON) call gg_body(time,t_sp_gg,t_j2_gg,f_sp_gg,f_j2_gg,bona)

C ************************* SENSOR ERRORS **************************

C  For Drag Free Sensor, convert relative spacecraft to (/ SG#1 /) PM
C  from inertial to body coordinates and add noise and quantization
      psg1i(1) = u(6)
      psg1i(2) = u(7)
      psg1i(3) = u(8)
      call intobo (psg1i,psg1b,1)
      dfs(1) = psg1b(1)      + RNORM (seed_dfx, std_dfs, 0.0D0)
      dfs(2) = psg1b(2)      + RNORM (seed_dfy, std_dfs, 0.0D0)
      dfs(3) = psg1b(3)      + RNORM (seed_dfz, std_dfs, 0.0D0)
      dfs(1) = ORDQUAN(dfs(1),lsb_dfs)
      dfs(2) = ORDQUAN(dfs(2),lsb_dfs)
      dfs(3) = ORDQUAN(dfs(3),lsb_dfs)

C Apply noise and quantization to the Star Tracker data
      st_roll = u(12) + RNORM (seed_str, std_str, 0.0D0)
      st_roll = ORDQUAN(st_roll,lsb_str)
C Apply noise and quantization to the Science Telescope data
      st_pitch = -u(4) + RNORM (seed_stp, std_sct, 0.0D0)
      st_yaw   =  u(5) + RNORM (seed_sty, std_sct, 0.0D0)
      st_pitch = ORDQUAN(st_pitch,lsb_sct)
      st_yaw   = ORDQUAN(st_yaw,lsb_sct)
C Apply noise and drift to the Control Gyro data
      cg_roll  = (u(1) + RNORM (seed_cgr, std_cg, mean_cgr))*dtcont
      cg_pitch = (u(2) + RNORM (seed_cgp, std_cg, mean_cgp))*dtcont
      cg_yaw   = (u(3) + RNORM (seed_cgy, std_cg, mean_cgy))*dtcont
C Apply quantization to the Control Gyro data
```

```
        cg_roll  = gyrquan(phr(3),cg_roll, lsb_cgr)   ! jrg gyro
        cg_pitch = gyrquan(phr(2),cg_pitch,lsb_cgpy)  ! quantization model
        cg_yaw   = gyrquan(phr(1),cg_yaw,  lsb_cgpy)  ! added 11-25-97
        w_act(1) = cg_yaw/dtcont
        w_act(2) = cg_pitch/dtcont
        w_act(3) = cg_roll/dtcont
c Compute Science Gyro drift angle
        call sg_drift (dtcont, da_ns, da_ew, time, st_roll,st_pitch)

c  CALCULATE THE DISTURBANCES ON THE SPACECRAFT

c  Compute magnetic field in the body frame
c  Transform B to body 1 frame
        do i = 1,3
          bb(i) = ctrans(1,i,1)*bmagi(1) + ctrans(2,i,1)*bmagi(2) +
     &    ctrans(3,i,1)*bmagi(3)
        enddo

C Compute cryoperm shield feed forward torque
        if (CRYO_ON) then
          tcryo_ff(1) = 200.0D4*bb(2)*bb(3)
          tcryo_ff(2) = -200.0D4*bb(1)*bb(3)
          tcryo_ff(3) = 0.0
        endif

C Determine if Rigel is Valid or Invalid
        call rigel(orbang, RV)

cash  include velocity aberration into rate loop
        croll = dcos(st_roll)
        sroll = dsin(st_roll)
        dvab(1) = vaber(1)-vab_old(1)
        dvab(2) = vaber(2)-vab_old(2)
        thabcd(2) =  (croll*dvab(1) + sroll*dvab(2))/dtcont
        thabcd(1) =  (sroll*dvab(1) - croll*dvab(2))/dtcont
        w_errx(1) = w_act(1) - thabcd(1) ! cjrg
        w_errx(2) = w_act(2) - thabcd(2) ! cjrg
        cg_roll  = w_act(3) *dtcont
        cg_pitch = w_errx(2)*dtcont
        cg_yaw   = w_errx(1)*dtcont
cash
C Compute pitch/yaw attitude from Control Gyro data during Rigel Invalid
C Update the attitude quaternion during Rigel Valid

        if (RV) then
          cgi_pitch = st_pitch
          cgi_yaw   = st_yaw
          call caerr (dtcont,w_act,a_act,RV,vaber,vaber0,cstar_n)
        else
          call caerr (dtcont,w_act,a_act,RV,vaber,vaber0,cstar_n)
          dvab(1) = vaber(1) - vaber0(1)
          dvab(2) = vaber(2) - vaber0(2)
          thabc(2) =  croll*dvab(1) + sroll*dvab(2)
          thabc(1) =  sroll*dvab(1) - croll*dvab(2)
          a_err(1)  = a_act(1) - thabc(1)   ! cjrg
          a_err(2)  = a_act(2) - thabc(2)   ! cjrg
          cgi_pitch = a_err(2)
          cgi_yaw   = a_err(1)
        endif
        vab_old(1) = vaber(1)
        vab_old(2) = vaber(2)

C*************************   ROLL CONTROL **********************
c  Compute actual roll phase in 0 to 2*pi (Tpi) range (rad)
        phi_c = w_roll * time
        n_r_revs = dint(phi_c/Tpi)
        phi_a = st_roll - n_r_revs*Tpi
c  Compute commanded roll angle in 0 to 2*pi range  (rads)
        phi_c = phi_c - n_r_revs*Tpi
        phi(1) = phi_c - phi_a
        phi(2) = w_roll*dtcont - cg_roll
```

```
       call pid_att (phi, tcom(3), uf_rol, rf_rol, dtcont,
     &               Kroll, limroll, Iroll, w_roll)

C  ****** POINTING AND TRANSLATION CONTROLLERS (CALLED AT 10 Hz) ******

C RIGEL VALID CONTROL
       if (RV) then

C************************   PITCH CONTROL **********************
         theta(1) = -st_pitch
         theta(2) = -cg_pitch
         call pid_att (theta, tcom(2), uf_pit, rf_pit, dtcont,
     &               Kpy_rv, limpy_rv, Ipy, w_roll)

C************************   YAW CONTROL **********************
         psi(1) = -st_yaw
         psi(2) = -cg_yaw
         call pid_att (psi, tcom(1), uf_yaw, rf_yaw, dtcont,
     &               Kpy_rv, limpy_rv, Ipy, w_roll)
       endif

C RIGEL INVALID CONTROL
       if (.not.RV) then

C************************   PITCH CONTROL **********************
       theta(1) = -cgi_pitch
       theta(2) = -cg_pitch
       call pid_att (theta, tcom(2), uf_pit, rf_pit, dtcont,
     &               Kpy_rv, limpy_rv, Ipy, w_roll)

C************************   YAW CONTROL **********************
       psi(1) = -cgi_yaw
       psi(2) = -cg_yaw
       call pid_att (psi, tcom(1), uf_yaw, rf_yaw, dtcont,
     &               Kpy_rv, limpy_rv, Ipy, w_roll)

       endif

c  Gravity gradient feedforward of sperical earth effects & feedforward of
c  Cryoperm shield torque disturbance

       do i=1,3
         tcom_ff(i) = - t_sp_gg(i) + tcryo_ff(i)
       enddo

C  Compute the attitude torque commands to be generated by magnetic torquers

c      call vcross(bb,tcom_ff,bbxtcom)
c      bbmag2 = bb(1)*bb(1) + bb(2)*bb(2) + bb(3)*bb(3)
c      mcom(1) = bbxtcom(1) / bbmag2
c      mcom(2) = bbxtcom(2) / bbmag2
c      mcom(3) = bbxtcom(3) / bbmag2
c
C Check for MTB saturation and scale commands if saturation occurs
c      magmax = 0.0
c      do i = 1,3
c        if (abs(mcom(i)) .gt. magmax) magmax = abs(mcom(i))
c      enddo
c      if (magmax .gt. Mmax) then
c        do i = 1,3
c          mcom(i) = mcom(i)*Mmax/magmax
c        enddo
c      endif

c      mcom1(1) = mcom(1)
c      mcom2(1) = mcom(2)
c      mcom3(1) = mcom(3)

C Apply hysteresis and limit to magnetic torquer bar commands
c      call maghys(mcom1)
c      call maghys(mcom2)
```

```
c       call maghys(mcom3)

C Apply scale factor errors (1% uniform distribution) to MTB's
c       r(23) = mcom1(2)*0.9913061d0
c       r(24) = mcom2(2)*1.0023300d0
c       r(25) = mcom3(2)*0.9996117d0

C  Compute the attitude torque commands to be generated by thrusters
c       call vcross(mcom,bb,mcomxbb)
c       do i = 1,3
c        f(i+3) = tcom_ff(i) - mcomxbb(i) + tcom(i)
c       enddo
        do i = 1,3
          f(i+3) = tcom_ff(i) + tcom(i)
        enddo

C***********************   TRANSLATION CONTROL **********************

C  Convert drag free sensor measurement from body to nadir frame for control
c       call botona (dfs,psgln,time) ! botona uses w_roll and w_orbit is approx.

        psgln(1) = bona(1,1)*dfs(1) + bona(2,1)*dfs(2) + bona(3,1)*dfs(3)
        psgln(2) = bona(1,2)*dfs(1) + bona(2,2)*dfs(2) + bona(3,2)*dfs(3)
        psgln(3) = bona(1,3)*dfs(1) + bona(2,3)*dfs(2) + bona(3,3)*dfs(3)

                                    ! It is used only for control.  Is OK!

C  X Translational Controller
        x(1) = psgln(1)
        call pid_trans(x, uf_x, rf_x, dtcont, K_trans, lim_trans,
     &               m_trans, w_roll)

C  Y Translational Controller
        y(1) = psgln(2)
        call pid_trans(y, uf_y, rf_y, dtcont, K_trans, lim_trans,
     &               m_trans, w_roll)

C  Z Translational Controller
        z(1) = psgln(3)
        call pid_trans(z, uf_z, rf_z, dtcont, K_trans, lim_trans,
     &               m_trans, w_roll)

        f_na(1) = rf_x(1)
        f_na(2) = rf_y(1)
        f_na(3) = rf_z(1)

c       call natobo (f_na,f_bo,time)
        f_bo(1) = bona(1,1)*f_na(1)+bona(1,2)*f_na(2)+bona(1,3)*f_na(3)
        f_bo(2) = bona(2,1)*f_na(1)+bona(2,2)*f_na(2)+bona(2,3)*f_na(3)
        f_bo(3) = bona(3,1)*f_na(1)+bona(3,2)*f_na(2)+bona(3,3)*f_na(3)

        do i=1,3
          f(i) = f_bo(i)
          if (abs(f(i)).gt.lim_trans(2)) f(i) = sign(lim_trans(2),f(i))
        enddo

C  Flow Rate Command
        f(7) = mdot

C  Call Jet Thruster Selection Logic - Lockheed (Pseudo Inverse)
        call THRSEL(time, f, thrust, r_mflow)

C****** THRUSTER MODEL ******
C  Quantize the thruster commands
        do i = 1,16
          thrust(i) = ORDQUAN(thrust(i),lsb_thr)
        enddo

C  Thruster hysteresis model (includes leakage and limiting)
        do i = 1,16
          Thys(1) = th_delay(i)
```

```
          Thys(2) = thsave(i)
          call thrhys(Thys)
          r(i) = Thys(2)
          thsave(i) = Thys(2)
        enddo

C  Delay the thruster commands
        do i = 1,16
          th_delay(i) = thrust(i)
        enddo

C  Add noise to the thrust and get total thrust
        thrtot = 0.0
        do i = 1,16
          seedthr = seed_thr(i)
          r(i) = r(i) + RNORM (seedthr, std_thr, 0.0D0)
          seed_thr(i) = seedthr
          thrtot = thrtot + r(i)
        enddo
        thrctrl = thrtot - r_mflow

C  If no closed loop control, then set thrusters to zero
        if (.not. CLOSED_LOOP) then
          do i = 1,16
            r(i) = 0.0d0
          enddo
        endif

        RETURN
        END

C**********************************************************************
C
C   GB-B Attitude and Translation Controllers Initialization

        subroutine initcont (dtcont, mdot, nplot, mplot)
        implicit none
        real*8 dtcont, mdot
        integer nplot, mplot, i

        real*8 Kpy_rv(5), limpy_rv(8), Ipy
        real*8 Kroll(5), limroll(8), Iroll
        common / attcont / Kpy_rv, limpy_rv, Ipy, Kroll, limroll, Iroll

        real*8 K_trans(3), lim_trans(2), m_trans
        common / transcon / K_trans, lim_trans, m_trans

        real*8 Th, Tl, Tmax
        common / thrhys1 / Th, Tl, Tmax

        real*8 Mh, Mmax
        common / maghys1 / Mh, Mmax

        real*8 w_orbit, w_roll
        common / rates / w_orbit, w_roll

        logical GG_ON, CRYO_ON, VAB_ON, CLOSED_LOOP
        common / env_flag / GG_ON, CRYO_ON, VAB_ON, CLOSED_LOOP

        real*8 i_body(3,3)
        common / ggfeedf / i_body

        real*8 pi, arcrad, radarc

C Sensor & actuator disturbance input data
C (seeds, standard deviations, least significant bit weights, drifts)
        integer seed_str, seed_stp, seed_sty
        integer seed_cgr, seed_cgp, seed_cgy
        integer seed_dfx, seed_dfy, seed_dfz
        integer seed_thr(16)
        integer njunk
```

```
      real*8 std_str, std_sct, std_cg, std_dfs, std_thr
      real*8 lsb_str, lsb_sct, lsb_cgr, lsb_cgpy, lsb_dfs, lsb_thr
      real*8 mean_cgr, mean_cgp, mean_cgy
      common / disturbl / seed_thr, seed_dfx, seed_dfy, seed_dfz,
     &  seed_str, seed_stp, seed_sty, seed_cgr, seed_cgp, seed_cgy
      common / disturb2 / std_str, std_sct, std_cg, std_dfs, std_thr,
     &  lsb_str, lsb_sct, lsb_cgr, lsb_cgpy, lsb_dfs, lsb_thr,
     &  mean_cgr, mean_cgp, mean_cgy

      parameter (pi = 3.14159265358979323840d0)
      parameter (arcrad = pi / (180.0d0*3600.0d0))
      parameter (radarc = 1.0d0 / arcrad)

C  Initial control variables

      open (unit=14, file='gains.inp')
      open (unit=15, file='inputlog.out')

      write(15,*) 'Enter controller sampling period (sec)'
      read(14,*) dtcont
      write(15,*) dtcont

      write(15,*) 'Enter no. of dt"s / plot write for data.mat file'
      read(14,*) njunk !jrg no longer used
      write(15,*) njunk

      write(15,*) 'Enter no. of dt"s / plot write for control.mat file'
      read(14,*) njunk !jrg no longer used
      write(15,*) njunk

      write(15,*) 'Enter RV pitch/yaw gains (Kr, Kp, Ki, Kop, Koi)'
      read(14,*) Kpy_rv
      write(15,*) Kpy_rv

      write(15,*) 'Enter RV pitch/yaw limits (arcsec)'
      read(14,*) limpy_rv
      write(15,*) limpy_rv
      do i = 1,8
      limpy_rv(i) = limpy_rv(i)*arcrad
      enddo

      write(15,*) 'Enter pitch/yaw inertia (kg-m^2)'
      read(14,*) Ipy
      write(15,*) Ipy

      write(15,*) 'Enter roll gains (Kr, Kp, Ki, Kop, Koi)'
      read(14,*) Kroll
      write(15,*) Kroll

      write(15,*) 'Enter roll limits (arcsec)'
      read(14,*) limroll
      write(15,*) limroll
      do i = 1,8
      limroll(i) = limroll(i)*arcrad
      enddo

      write(15,*) 'Enter roll inertia (kg-m^2)'
      read(14,*) Iroll
      write(15,*) Iroll

      write(15,*) 'Enter translational gains (Kr, Kp, Ki)'
      read(14,*) K_trans
      write(15,*) K_trans

      write(15,*) 'Enter translational limits (m, N)'
      read(14,*) lim_trans
      write(15,*) lim_trans

      write(15,*) 'Enter mass for translational control (kg)'
      read(14,*) m_trans
      write(15,*) m_trans
```

```
write(15,*) 'Enter Thruster leakage, hysteresis & maximum (N)'
read(14,*) Tl, Th, Tmax
write(15,*) Tl, Th, Tmax

write(15,*) 'Enter Magnetic Torquer hysteresis & maximum (ATM^2)'
read(14,*) Mh, Mmax
write(15,*) Mh, Mmax

write(15,*) 'Enter mass flow rate command (kg/sec)'
read(14,*) mdot
write(15,*) mdot

write(15,*) 'Enter spacecraft inertia matrix'
read(14,*) (i_body(1,i),i=1,3)
read(14,*) (i_body(2,i),i=1,3)
read(14,*) (i_body(3,i),i=1,3)
write(15,*) (i_body(1,i),i=1,3)
write(15,*) (i_body(2,i),i=1,3)
write(15,*) (i_body(3,i),i=1,3)

write(15,*) 'Enter Earth orbit rate (rad/sec)'
read(14,*)  w_orbit
write(15,*)  w_orbit

write(15,*) 'Enter GPB commanded roll rate (deg/sec)'
read(14,*)  w_roll
write(15,*)  w_roll
w_roll = w_roll*pi/180.0d0

write(15,*) 'Gravity Gradient Force/Torque On (check .INT also)'
read(14,*)  GG_ON
write(15,*)  GG_ON

write(15,*) 'Cryoperm Shield Magnetic Torque On'
read(14,*)  CRYO_ON
write(15,*)  CRYO_ON

write(15,*) 'Velocity aberration feedforward On (check .INT also)'
read(14,*)  VAB_ON
write(15,*)  VAB_ON

write(15,*) 'Controller in Closed Loop Mode (thrusters enabled)'
read(14,*)  CLOSED_LOOP
write(15,*)  CLOSED_LOOP

close (14)

open (unit=14, file='errors.inp')

write(15,*) 'Enter roll Star Tracker noise seed'
read(14,*) seed_str
write(15,*) seed_str
write(15,*) 'Enter pitch & yaw Science Telescope noise seeds'
read(14,*) seed_stp, seed_sty
write(15,*) seed_stp, seed_sty
write(15,*) 'Enter Control Gyro (roll, pitch, yaw) noise seeds'
read(14,*) seed_cgr, seed_cgp, seed_cgy
write(15,*) seed_cgr, seed_cgp, seed_cgy
write(15,*) 'Enter Drag Free Sensor (x, y, z) noise seeds'
read(14,*) seed_dfx, seed_dfy, seed_dfz
write(15,*) seed_dfx, seed_dfy, seed_dfz
write(15,*) 'Enter 16 Thruster noise seeds'
read(14,*) seed_thr
write(15,*) seed_thr

write(15,*) 'Enter roll Star Tracker noise standard deviation'
write(15,*) '(in Arcseconds)'
read(14,*) std_str
write(15,*) std_str
std_str = std_str*arcrad
```

```
      write(15,*) 'Enter ST noise standard deviation'
      write(15,*) '(in milliArcseconds)'
      read(14,*) std_sct
      write(15,*) std_sct
      std_sct = std_sct*arcrad*1.0D-3
      write(15,*) 'Enter Control Gyro noise standard deviation'
      write(15,*) '(in Arcseconds/sec)'
      read(14,*) std_cg
      write(15,*) std_cg
      std_cg = std_cg*arcrad
      write(15,*) 'Enter Drag Free Sensor noise standard deviation'
      write(15,*) '(in nanometers)'
      read(14,*) std_dfs
      write(15,*) std_dfs
      std_dfs = std_dfs*1.0D-9
      write(15,*) 'Enter Thruster noise standard deviation'
      write(15,*) '(in milliNewtons)'
      read(14,*) std_thr
      write(15,*) std_thr
      std_thr = std_thr*1.0D-3

      write(15,*) 'Enter roll Star Tracker least significant bit'
      write(15,*) '(in Arcseconds)'
      read(14,*) lsb_str
      write(15,*) lsb_str
      lsb_str = lsb_str*arcrad
      write(15,*) 'Enter ST least significant bit'
      write(15,*) '(in milliArcseconds)'
      read(14,*) lsb_sct
      write(15,*) lsb_sct
      lsb_sct = lsb_sct*arcrad*1.0D-3
      write(15,*) 'Enter Roll Control Gyro least significant bit'
      write(15,*) '(in milliArcseconds)'
      read(14,*) lsb_cgr
      write(15,*) lsb_cgr
      lsb_cgr = lsb_cgr*arcrad*1.0D-3
      write(15,*) 'Enter Pitch/Yaw Control Gyro least significant bit'
      write(15,*) '(in milliArcseconds)'
      read(14,*) lsb_cgpy
      write(15,*) lsb_cgpy
      lsb_cgpy = lsb_cgpy*arcrad*1.0D-3
      write(15,*) 'Enter Drag Free Sensor least significant bit'
      write(15,*) '(in nanometers)'
      read(14,*) lsb_dfs
      write(15,*) lsb_dfs
      lsb_dfs = lsb_dfs*1.0D-9
      write(15,*) 'Enter Thruster least significant bit'
      write(15,*) '(in milliNewtons)'
      read(14,*) lsb_thr
      write(15,*) lsb_thr
      lsb_thr = lsb_thr*1.0D-3

      write(15,*) 'Enter Control Gyro drift (roll, pitch, yaw)'
      write(15,*) '(in Arcseconds/sec)'
      read(14,*) mean_cgr, mean_cgp, mean_cgy
      write(15,*) mean_cgr, mean_cgp, mean_cgy
      mean_cgr = mean_cgr*arcrad
      mean_cgp = mean_cgp*arcrad
      mean_cgy = mean_cgy*arcrad

      close(14)
      close(15)

      return
      end

C***********************************************************************
C  Discrete Proportional, Integral, Derivative Controller
C  for ATTITUDE control
C
C  Inputs: u(1)  attitude error input (rad)
```

```
C          u(2)  delta attitude error input (rad)
C          u(3)  second previous controller input
C          K(1)   Kr    rate gain
C          K(2)   Kp    position gain
C          K(3)   Ki    integral gain
C          T     sample period
C  Outputs:   Tcom    commanded torque
C             rf(1)   present filtered angular acceleration command
C             rf(2)   previous filtered angular acceleration command
C             rf(3)   second previous filtered angular acceleration command
C**********************************************************************
      subroutine pid_att (u, Tcom, uf, rf, T, K, lim, Inertia, w_roll)
      implicit none
      real*8 u(5), Tcom, uf(3), rf(3), T, K(5), lim(8), Inertia, w_roll
      real*8 yrate, ypos, yint
C     real*8 yop
      real*8 wa, wb, za, zb, c_rrf(6)

C Limit attitude error
      if (abs(u(1)).gt.lim(1)) u(1) = sign(lim(1),u(1))

C Observer
co    yop = K(4)*T*(u(1)-u(4))
co    u(5) = K(5)*T*T*(u(1)-u(4)) + u(5)
co    if (abs(u(5)).gt.lim(2)) u(5) = sign(lim(2),u(5))
co    u(4) = yop + u(5) + u(4) + u(2)
co    if (abs(u(4)).gt.lim(3)) u(4) = sign(lim(3),u(4))

C Rate loop
co    yrate = (u(2)+u(5))*K(1)/T
      yrate = u(2)*K(1)/T
      if (abs(yrate).gt.lim(6)) yrate = sign(lim(6),yrate)

C Proportional Loop
co    ypos = u(4)
      ypos = u(1)
      if (abs(ypos).gt.lim(4)) ypos = sign(lim(4),ypos)

C Integral loop
co    yint = K(3)*T*u(4) + u(3)
      yint = K(3)*T*u(1) + u(3)
      if (abs(yint).gt.lim(5)) yint = sign(lim(5),yint)
      u(3) = yint

C Sum PID loops to compute input to the roll rate filter
      uf(1) = yint + ypos + yrate

C Compute the coefficients of the roll rate filter
      if (wa .ne. dabs(w_roll)) then
c       print *, 'control gains ',k
        wa = dabs(w_roll)
        wb = wa
        za = 3.0d0
        zb = 0.003d0
        c_rrf(1) = (4.0d0 + 4.0d0*T*za*wa + wa**2*T**2) * wb**2 /wa**2
        c_rrf(2) = (2.0d0*wa**2*T**2 - 8.0d0) * wb**2 / wa**2
        c_rrf(3) = (wa**2*T**2 - 4.0d0*T*za*wa + 4.0d0) * wb**2 / wa**2
        c_rrf(4) = 4.0d0 + 4.0d0*T*zb*wb + wb**2*T**2
        c_rrf(5) = (2.0d0*wb**2*T**2 - 8.0d0)
        c_rrf(6) = (wb**2*T**2 - 4.0d0*T*zb*wb + 4.0d0)
      endif

      call discfil2 (uf,rf,c_rrf)
      if (abs(rf(1)).gt.lim(7)) rf(1) = sign(lim(7),rf(1))
      Tcom = K(2)*rf(1)*Inertia

      return
      end

C**********************************************************************
C  Discrete Proportional, Integral, Derivative Controller
```

```
C  for TRANSLATION control in Nadir frame
C
C  Inputs: u(1)  controller input
C          u(2)  previous rate loop input
C          u(3)  previous integral loop input
C          K(1)   Kr    rate gain
C          K(2)   Kp    position gain
C          K(3)   Ki    integral gain
C           T     sample period
C  Outputs:   rf(1)  filtered force command output
C**********************************************************************
      subroutine pid_trans (u, uf, rf, T, K, lim, mass, w_roll)
      implicit none
      real*8 u(3), uf(3), rf(3), T, K(3), lim(2), mass, w_roll
      real*8 yrate, ypos, yint
      real*8 wa, wb, za, zb, c_rrf(6)

C Rate loop
      yrate = u(1)*K(1)/T - u(2)
      u(2) = u(1)*K(1)/T

C Proportional Loop
      ypos = u(1)

C Integral loop
      yint = K(3)*T*u(1) + u(3)
      if (abs(yint).gt.lim(1)) yint = sign(lim(1),yint)
      u(3) = yint

C Sum PID loops to compute input to the roll rate filter
      uf(1) = (yint + ypos + yrate)*K(2)*mass

C Compute the coefficients of the roll rate filter
      if (wa .ne. dabs(w_roll)) then
      wa = dabs(w_roll)
      wb = wa
      za = 3.0d0
      zb = 0.003d0
      c_rrf(1) = (4.0d0 + 4.0d0*T*za*wa + wa**2*T**2) * wb**2 /wa**2
      c_rrf(2) = (2.0d0*wa**2*T**2 - 8.0d0) * wb**2 / wa**2
      c_rrf(3) = (wa**2*T**2 - 4.0d0*T*za*wa + 4.0d0) * wb**2 / wa**2
      c_rrf(4) = 4.0d0 + 4.0d0*T*zb*wb + wb**2*T**2
      c_rrf(5) = (2.0d0*wb**2*T**2 - 8.0d0)
      c_rrf(6) = (wb**2*T**2 - 4.0d0*T*zb*wb + 4.0d0)
      endif

      call discfil2 (uf,rf,c_rrf)

      return
      end
C**********************************************************************
C  Subroutine to convert from spacecraft inertial to spacecraft
C  body "NDZ" frame.  This transformation uses treetops body to inertial
C  transformation and is therefore exact.  It should be used only to compute
C  disturbances or outputs.
C**********************************************************************
      subroutine intobo (pi,pb,ndz)
      implicit none ! double precision (a-h,o-z)
      real*8 pi(3), pb(3)
      integer i,ndz
      include 'DBP.F'
      include 'DBB.F'

      do i = 1,3
      pb(i) = ctrans(1,i,ndz)*pi(1) + ctrans(2,i,ndz)*pi(2) +
     &        ctrans(3,i,ndz)*pi(3)
      enddo

      return
      end
C**********************************************************************
```

```
C  Subroutine to convert from spacecraft body "NDZ" to spacecraft
C  inertial frame.  This transformation uses treetops body to inertial
C  transformation and is therefore exact.  Should not be used for control,
C  but only to compute spacecraft disturbances.
C***********************************************************************
        subroutine botoin (pb,pi,ndz)
        implicit none ! double precision (a-h,o-z)
        real*8 pi(3), pb(3)
        integer i,ndz
        include 'DBP.F'
        include 'DBB.F'

        do i = 1,3
        pi(i) = ctrans(i,1,ndz)*pb(1) + ctrans(i,2,ndz)*pb(2) +
     &          ctrans(i,3,ndz)*pb(3)
        enddo

        return
        end

C***********************************************************************
C  Subroutine to apply hysteresis to the thruster command
C
C  T(1) = Thruster Command Input
C  T(2) = Thruster Command Output
C***********************************************************************
        subroutine thrhys(T)
        implicit none ! double precision (a-h,o-z)
        real*8 T(2)
        real*8 Th, Tl, Tmax
        common / thrhys1 / Th, Tl, Tmax

cc  NO HYSTERESIS
        if (Th .eq. 0.0d0) then
          t(2) = t(1)
          if (T(2) .gt. Tmax) T(2) = Tmax
          return
        endif


c       if (T(1).gt.T(2)-Tl .and. T(1).lt.T(2)+Th-Tl) then
c         T(2) = T(2)
c       elseif (T(1).ge.T(2)+Th-Tl) then
c         T(2) = T(1) - Th + Tl
c       elseif (T(1).le.T(2)-Tl) then
c         T(2) = T(1) + Tl
c       endif
c       if (T(2) .lt. Tl) T(2) = Tl

        if (T(1).lt.Tl-Th) T(1) = Tl-Th
        if (T(1).gt.T(2)-Th .and. T(1).lt.T(2)+Th) then
          T(2) = T(2)
        elseif (T(1).ge.T(2)+Th) then
          T(2) = T(1) - Th
        elseif (T(1).le.T(2)-Th) then
          T(2) = T(1) + Th
        endif

        if (T(2) .gt. Tmax) T(2) = Tmax

        return
        end

C***********************************************************************
C  Subroutine to apply Hysteresis to the Magnetic Torquer Command
C
C  M(1) = Magnetic Torquer Command Input
C  M(2) = Magnetic Torquer Command Output

        subroutine maghys(M)
        implicit none ! double precision (a-h,o-z)
```

```
      real*8 M(2)
      real*8 Mh, Mmax
      common / maghys1 / Mh, Mmax

      if (M(1).gt.M(2)-Mh .and. M(1).lt.M(2)+Mh) then
        M(2) = M(2)
      elseif (M(1).ge.M(2)+Mh) then
        M(2) = M(1) - Mh
      elseif (M(1).le.M(2)-Mh) then
        M(2) = M(1) + Mh
      endif

      if (abs(M(2)) .gt. Mmax) M(2) = sign(Mmax,M(2))
      return
      end

cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      subroutine vcross(u, v, w)
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
cc
cc  Function:  Computes the cross product of two vectors.
cc
cc  Source:  JC
cc
cc  Explicit Inputs:
cc            u(3) - first vector
cc            v(3) - second vector
cc
cc  Explicit Output:
cc            w(3) = u x v
cc
cc  Comments:  Real*8
cc
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc

      implicit none ! double precision (a-h,o-z)
      real*8  u(3), v(3), w(3)

      w(1)=u(2) * v(3) - u(3) * v(2)
      w(2)=u(3) * v(1) - u(1) * v(3)
      w(3)=u(1) * v(2) - u(2) * v(1)

      return
      end

cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
c     subroutine trace(a, tr, n)
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
cc
cc  Function:  Computes the trace of an nxn (square) matrix.
cc
cc  Source:  JC
cc
cc  Explicit Inputs:
cc            a - arbitrary nxn matrix
cc            n - dimension of square "a" matrix
cc
cc  Explicit Outputs:
cc            tr - trace; sum of diagonal elements.
cc
cc  Comments:  Real*8
cc
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
c
c     implicit none ! double precision (a-h,o-z)
c     integer i, n
c     real*8  a(n,n), tr
c
c     tr = 0.e0
c     do 20 i=1,n
c       tr = tr + a(i,i)
```

```
c 20   continue
c
c      return
c      end
c
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
c      subroutine d_rot(iaxis, ang, dcm)
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
cc
cc  Function:  Generate 3x3 rotation matrix based on inputs.
cc
cc  Source:  JC              Date:  12/90
cc
cc  Comments:  Real*8
cc             iaxis(+)    -->   Rotated to inertial trans
cc             iaxis(-)    -->   Inertial to rotated trans
cc
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
c
c      implicit none ! double precision (a-h,o-z)
c      integer  iaxis
c      real*8  dcm(3,3), ang
c      real*8  axis,ca,sa
c
c      axis = dble(iaxis)
c      ca = dcos(ang)
c      sa = dsin(ang)
c
cc  Build selected rotation matrix
c      goto(10,20,30), iabs(iaxis)
c
ccc  Rotation about axis 1 (x)
c   10 dcm(1,1) = 1.0e0
c      dcm(2,2) = ca
c      dcm(3,3) = ca
c      dcm(3,2) = sa*sign(1.0,axis)
c      dcm(2,3) = -dcm(3,2)
c      dcm(1,2) = 0.0e0
c      dcm(1,3) = 0.0e0
c      dcm(2,1) = 0.0e0
c      dcm(3,1) = 0.0e0
c      return
c
ccc  Rotation about axis 2 (y)
c   20 dcm(1,1) = ca
c      dcm(3,3) = ca
c      dcm(1,3) = sa*sign(1.0,axis)
c      dcm(3,1) = -dcm(1,3)
c      dcm(2,2) = 1.0e0
c      dcm(2,1) = 0.0e0
c      dcm(1,2) = 0.0e0
c      dcm(2,3) = 0.0e0
c      dcm(3,2) = 0.0e0
c      return
c
ccc  Rotation about axis 3 (z)
c   30 dcm(1,1) = ca
c      dcm(2,2) = ca
c      dcm(2,1) = sa*sign(1.0,axis)
c      dcm(1,2) = -dcm(2,1)
c      dcm(3,3) = 1.0e0
c      dcm(1,3) = 0.0e0
c      dcm(2,3) = 0.0e0
c      dcm(3,1) = 0.0e0
c      dcm(3,2) = 0.0e0
c      return
c
c      end
c
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
       subroutine dyad_xd(a, dyad, b, c)
```

```
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
cc
cc  Function:  Compute c = a x dyad . b
cc              where a, b, c are vectors
cc                     dyad is a "3x3 dyadic"
cc
cc  Source:  JC             Date:  12/19/90
cc
cc  Comments:  Real*8
cc             Uses other dutil subroutines/functions.
cc
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
        implicit none ! double precision (a-h,o-z)
        integer  i, j
        real*8  dyad(3,3), a(3), b(3), c(3)
        real*8  temp(3), ddb(3), d_dot

cc  Compute (dyad . b = ddb)
        do 20 i=1,3

          do 10 j=1,3
            temp(j) = dyad(i,j)
 10       continue

        ddb(i) = d_dot(temp, b)

 20   continue

cc  Compute (a x ddb = c)
        call vcross(a, ddb, c)

        return
        end

ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
        function d_dot(u, v)
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
cc
cc  Function:  Compute the dot product of two vectors (d_dot = u . v).
cc
cc  Source:  JC
cc
cc  Explicit Inputs:
cc             u(3) - first vector
cc             v(3) - second vector
cc
cc  Comments:  Real*8 version
cc
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc

        implicit none ! double precision (a-h,o-z)
        real*8  d_dot, u(3), v(3)

        d_dot = u(1) * v(1) + u(2) * v(2) + u(3) * v(3)

        return
        end

ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
        subroutine d_mxv(m, v, u)
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
cc
cc  Function:  To compute product of a matrix(3x3) and a vector(3x1).
cc
cc  Source:  JC
cc
cc  Explicit Inputs:
cc             m(3,3) - arbitrary 3x3 matrix
cc             v(3,1) - arbitrary vector
cc
cc  Explicit Output:
```

```
cc             u(3,1) - result of matrix times vector
cc
cc  Comments:  Real*8
cc
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc

      implicit none ! double precision (a-h,o-z)
      real*8  m(3,3), u(3), v(3)

      u(1) = m(1,1) * v(1) + m(1,2) * v(2) + m(1,3) * v(3)
      u(2) = m(2,1) * v(1) + m(2,2) * v(2) + m(2,3) * v(3)
      u(3) = m(3,1) * v(1) + m(3,2) * v(2) + m(3,3) * v(3)

      return
      end

cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      subroutine d_mtrans(A, AT, m, n)
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
cc
cc  Function:  Transpose mxn matrix.
cc
cc  Source:  JC
cc
cc  Explicit Input:
cc             A(m,n) - arbitrary mxn matrix
cc
cc  Explicit Output:
cc             AT(n,m) - transpose of matrix A
cc
cc  Comments:  Real*8
cc
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc

      implicit none
      integer i, j, m, n
      REAL*8  A(m,n), AT(n,m)

        do 20 i=1,m
          do 10 j=1,n
               AT(j,i) = A(i,j)
 10   continue
 20  continue

        return
        end

cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      subroutine d_mmul(A,B,C,L,M,N)
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
cc
cc  Function:  Multiply two matrices of arbitrary "outside"
cc             dimensions
cc
cc  Source:  JG via JC
cc
cc  Inputs:  A(L x M) - first matrix
cc           B(M x N) - second matrix
cc           L - row dimension of first matrix
cc           M - column dimension of first matrix and row dimension
cc               of second matrix
cc           N - column dimension of second matrix
cc
cc  Outputs:  C(L x N) - resultant matrix from A*B
cc
cc  Comments:  Real*8
cc             Vector arrays are (3x1) matrices
cc
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc

      implicit none ! double precision (a-h,o-z)
```

```
      INTEGER L,M,N,I,J,K
      REAL*8 A(L,M),B(M,N),C(L,N),T

      DO I=1,L
        DO J=1,N
          T=0.0
          DO K=1,M
            T=T+A(I,K)*B(K,J)
          ENDDO
          C(I,J)=T
        ENDDO
      ENDDO
      RETURN
      END

C*****************************************************************
      subroutine discfil2 (x,y,c)
C*****************************************************************
C
C     Function:  Second Order Discrete Filter
C
C     y      c1*z**2 + c2*z + c3
C     -  =  ---------------------
C     x      c4*z**2 + c5*z + c6
C
C     Inputs:
C            x(1)               present input
C            x(2)               previous input
C            x(3)               second previous input
C            c(1:6)             coefficients of filter
C     Outputs:
C            y(1)               present output
C            y(2)               previous output
C            y(3)               second previous output
C
C     Comments:  Real*8
C
C*****************************************************************
      implicit none ! double precision (a-h,o-z)
      real*8  x(3), y(3), c(6)
      y(1) = ( c(1)*x(1) + c(2)*x(2) + c(3)*x(3) -
     &       c(5)*y(2) - c(6)*y(3) ) / c(4)
      x(3) = x(2)
      x(2) = x(1)
      y(3) = y(2)
      y(2) = y(1)
      return
      end

C*****************************************************************************
C Subroutine to determine whether GPB is in the Rigel Valid (RV) or
C Rigel Invalid (RI) control mode and to determine when GPB is in the
C RI to RV or RV to RI transition phases.
      subroutine rigel(orbang, RV)

      implicit none ! double precision (a-h,o-z)
      real*8 lat, orbang, raddeg
      logical RV

      data raddeg / 57.2957795d0 /

c     lat = atan2(sin(orbang),cos(orbang))*raddeg
      lat = dmod(raddeg * orbang,360.d0);
      if (lat .gt.180.d0) lat = lat - 360.d0

c     if (lat .gt. -98.24 .and. lat .le. 81.76) then
      if (lat .gt. -115.24 .and. lat .le. 98.76) then
        RV = .true.
      else
        RV = .false.
      endif
```

```
      return
      end

ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
      SUBROUTINE THRSEL(time, f, r, r_mflow)
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
cc  Function:  Lockheed Pseudo Inverse Thruster Selection Logic
cc             for GPB 16 thruster configuration
cc
cc  Inputs: F(1-3)  Commanded Forces (x, y, z) from trans controller
cc          F(4-6)  Commanded Torques (roll, pitch, yaw) from attitude
cc                  controller after magnetic torque is subtracted.
cc          F(7)    Commanded Mass Flow
cc
cc  Outputs: R(1-16)  Thruster commands
ccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc

      implicit none
      integer  i, j, i2

      real*8 time, f(7), r(16), r_mflow
      real*8 A(6,8), AINV(8,6), AT(8,6), AAT(6,6), AATINV(6,6)
      real*8 ISP, fortorq(6), fpair(8),sumjets(6)
      real*8 flow, l_flow, flowc
      logical first_pass
      real*8 Th, Tl, Tmax

      common / thrhys1 / Th, Tl, Tmax

      DATA ISP / 130.0d0 /
      data first_pass / .true. /

c Read in thruster pair force/torque matrix
      if (first_pass) then
        first_pass = .false.
        open(unit=13,file='thruster.inp',status='old')
        do i = 1,6
          read(13,*) (A(i,j),j=1,8)
        enddo
        close(13)
      endif

C Compute the pseudo inverse of the thruster pair force/torque matrix
      call d_mtrans (A, AT, 6, 8)
      call d_mmul (A, AT, AAT, 6, 8, 6)
      call minv6x6 (AAT, AATINV)
      call d_mmul (AT, AATINV, AINV, 8, 6, 6)

C Compute the thruster pair forces
      do i = 1,6
        fortorq(i) = f(i)
        sumjets(i) = 0.d0
      enddo
      call d_mmul (AINV, fortorq, fpair, 8, 6, 1)

C Compute the force to each thruster
      do i = 1,8
        j = (i-1)*2 + 1
        if (fpair(i) .gt. 0.0d0) then
          r(j) = fpair(i)
          r(j+1) = 0.0d0
        else
          r(j) = 0.0d0
          r(j+1) = dabs(fpair(i))
        endif
      enddo

C Compute flow command less leakage
      flow = 0.0
c     l_flow = (16.0*Tl) / (ISP*9.81)
```

```
c      flowc = f(7) - l_flow
       flowc = f(7)

c  Sum mass flow due to current thrust commands
       do i=1,16
         flow = flow + r(i) / (ISP * 9.81)
       enddo

c  Compute total thrust error due to total mass flow error

c      if (flow .gt. flowc ) then
c      write(6,*) '***  Mass Flow from Thrusters > Com Mass Flow ***'
c      write(6,*) 'time = ',time, ' thruster mass flow (kg/s) = ',flow
c      endif

c  Compute and distribute residual thrust requirements evenly over body
c   (i.e., no resultant force/torque)
       r_mflow = (flowc - flow) * ISP * 9.81
       if (r_mflow .lt. 0.0d0) r_mflow = 0.0d0
       do i=1,16
         r(i) = r(i) + r_mflow / 16.0d0
       enddo
       do i=1,8
         i2 = 2*i
         do j=1,6
           sumjets(j) = sumjets(j) + a(j,i)*(r(i2-1)-r(i2))
         enddo
       enddo

c  Add leakage back in to each thruster
c      do i = 1,16
c        r(i) = r(i) + Tl
c      enddo

       RETURN
       END

C*********************************************************************
C 6X6 MATRIX INVERSE
       SUBROUTINE MINV6X6(A,AI)
       IMPLICIT NONE
       INTEGER i,j
       REAL*8 A(6,6),AI(6,6)
       REAL*8 B(3,3), C(3,3), D(3,3), E(3,3), BI(3,3), EI(3,3)
       REAL*8 X(3,3), Y(3,3), Z(3,3), U(3,3)
       REAL*8 CEI(3,3), CEID(3,3), DBI(3,3), DBIC(3,3), XI(3,3), UI(3,3)
       REAL*8 BIC(3,3), EID(3,3)

       DO i=1,3
         DO j=1,3
           B(i,j) = A(i,j)
         ENDDO
         DO j=1,3
           C(i,j) = A(i,j+3)
         ENDDO
       ENDDO
       DO i=1,3
         DO j=1,3
           D(i,j) = A(i+3,j)
         ENDDO
         DO j=1,3
           E(i,j) = A(i+3,j+3)
         ENDDO
       ENDDO
       CALL MINV3x3(B,BI)
       CALL MINV3x3(E,EI)
       CALL d_mmul (C,EI,CEI,3,3,3)
       CALL d_mmul (CEI,D,CEID,3,3,3)
       CALL d_mmul (D,BI,DBI,3,3,3)
       CALL d_mmul (DBI,C,DBIC,3,3,3)
       DO i=1,3
```

```
          DO j=1,3
            XI(i,j) = B(i,j) - CEID(i,j)
          ENDDO
        ENDDO
        DO i=1,3
          DO j=1,3
            UI(i,j) = E(i,j) - DBIC(i,j)
          ENDDO
        ENDDO
        CALL MINV3x3(XI,X)
        CALL MINV3x3(UI,U)
        CALL d_mmul (BI,C,BIC,3,3,3)
        CALL d_mmul (BIC,U,Y,3,3,3)
        CALL d_mmul (EI,D,EID,3,3,3)
        CALL d_mmul (EID,X,Z,3,3,3)
        DO i=1,3
          DO j=1,3
            AI(i,j) = X(i,j)
          ENDDO
          DO j=1,3
            AI(i,j+3) = -Y(i,j)
          ENDDO
        ENDDO
        DO i=1,3
          DO j=1,3
            AI(i+3,j) = -Z(i,j)
          ENDDO
          DO j=1,3
            AI(i+3,j+3) = U(i,j)
          ENDDO
        ENDDO
        RETURN
        END
C 3X3 MATRIX INVERSE
        SUBROUTINE MINV3X3(A,AI)
        IMPLICIT NONE
        REAL*8 A(3,3),AI(3,3),DET
        DET = A(1,1)*A(2,2)*A(3,3) + A(1,2)*A(2,3)*A(3,1) +
     &      A(1,3)*A(2,1)*A(3,2) - A(3,1)*A(2,2)*A(1,3) -
     &      A(3,2)*A(2,3)*A(1,1) - A(3,3)*A(2,1)*A(1,2)
        if (det .eq. 0.0d0) then
          write(6,*)'DETERMINANT = 0 in 3x3 MATRIX INVERSE'
          stop
        endif
        AI(1,1) =  (A(2,2)*A(3,3) - A(3,2)*A(2,3))/DET
        AI(2,1) = -(A(2,1)*A(3,3) - A(3,1)*A(2,3))/DET
        AI(3,1) =  (A(2,1)*A(3,2) - A(3,1)*A(2,2))/DET
        AI(1,2) = -(A(1,2)*A(3,3) - A(3,2)*A(1,3))/DET
        AI(2,2) =  (A(1,1)*A(3,3) - A(3,1)*A(1,3))/DET
        AI(3,2) = -(A(1,1)*A(3,2) - A(3,1)*A(1,2))/DET
        AI(1,3) =  (A(1,2)*A(2,3) - A(2,2)*A(1,3))/DET
        AI(2,3) = -(A(1,1)*A(2,3) - A(2,1)*A(1,3))/DET
        AI(3,3) =  (A(1,1)*A(2,2) - A(2,1)*A(1,2))/DET
        RETURN
        END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
        SUBROUTINE CAERR(DT,W_ERR,A_ERR,RV,VAB,VAB0,CSTAR_N)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CC  FUNCTION:  Compute pitch and yaw attitude angles,
CC   jrg revision, 11-22-97 and later
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

        IMPLICIT NONE

        include 'rstrt.f'

CC  Local declarations
        REAL*8 DT,W_ERR(3),WI_ERR(3),A_ERR(3),CSTAR_N(3,3)
        REAL*8 VAB(3),VAB0(3),DVABB(2),WSI(2)

        INTEGER I
```

```
      LOGICAL RV,RVP,VASET

      real*8 w_orbit,w_roll
      common / rates / w_orbit, w_roll
      equivalence (usdc_rs(6),wi_err(1))

      data rvp,vaset /.false., .false./

      IF (RV) THEN
        IF (.NOT. RVP) THEN
          print *, ' Start guide star valid'
          RVP = .TRUE.
        ENDIF
        IF (CSTAR_N(3,3) .GE. 0.D0 .AND. CSTAR_N(3,1) .LT. -0.9D0) THEN
          IF (.NOT. VASET)  THEN
            WI_ERR(1) = 0.D0
            WI_ERR(2) = 0.D0
            VAB0(1) = VAB(1)
            VAB0(2) = VAB(2)
            VAB0(3) = VAB(3)
            VASET = .TRUE.
          ENDIF
        ENDIF
      ELSEIF (RVP) THEN
        print *, ' Start guide star invalid'
        RVP = .FALSE.
        VASET = .FALSE.
      ENDIF

      A_ERR(1) = WI_ERR(1)
      A_ERR(2) = WI_ERR(2)
      wsi(1) = w_err(1)+w_err(3)*a_err(2)
      wsi(2) = w_err(2)-w_err(3)*a_err(1)
      WI_ERR(1) = WI_ERR(1) + WSI(1)*DT
      WI_ERR(2) = WI_ERR(2) + WSI(2)*DT
      A_ERR(1) = wi_err(1)
      A_ERR(2) = wi_err(2)

      RETURN
      END

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      REAL*8 FUNCTION UFMAG(A)
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CC
CC  FUNCTION:   Compute the magnitude of a vector.
CC
CC                            _______________________
CC               _        /      2        2        2
CC              |A| = \/ A(1)  + A(2)   + A(3)
CC
CC  ARGUMENT LIST INPUTS:
CC              A(3) - Vector
CC
CC  SUBROUTINES AND FUNCTIONS CALLED:
CC
CC  COMMENTS:   Real*8
CC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

      IMPLICIT NONE
      REAL*8 A(3)

      UFMAG = DSQRT( A(1)*A(1) + A(2)*A(2) + A(3)*A(3) )

      RETURN
      END
CC  John Glaese gyro quantization model, 11-25-97
CC    Models operation of pulse rebalanced, strapdown rate gyros
      real*8 function gyrquan(phrp,wdt,l)
      implicit none
```

```
      real*8 phr,phrp,wdt,l

      phr = phrp + wdt
      if (l .ne. 0.d0) then
        gyrquan = dint(phr / l) * l
      else
        gyrquan = phr
      endif
      phrp = phr - gyrquan
      return
      end
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
C  Ordinary quantization routine with protection for quantization at 0.
      real*8 function ordquan(phr,l)
      implicit none
      real*8 phr,l

      if (l .ne. 0.d0) then
        ordquan = dint(phr / l) * l
      else
        ordquan = phr
      endif

      return
      end
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
C  Subroutine to compute the Science Gyro drift angle
      subroutine sg_drift (dtcont, da_ns, da_ew, time, st_roll,st_pitch)
      implicit none ! double precision (a-h,o-z)
      include 'DBP.F'
      include 'DBSP.F'
      include 'DBB.F'
      include 'DBS.F'
      include 'rstrt.f'

c  Variables for suspension force vector on GP-B Science Gyro from SPRING.FOR
      real*8 F_sgi(3),ufmag
      common / sg / F_sgi
      real*8 Fsg_rotor(3,4),T_per(3),H(3,4),Hmag,H0,uh(3,4)
      real*8 xcm2cg(3), d, Fsg_rotorb(3),factb(3,4) !,tfacti(3,4)
      real*8 dtcont, da_ns(4), da_ew(4), st_roll,st_pitch
      real*8 Fsg_rotorp(3),ufix(3),ufiy(3),ufiz(3),rfix(3),rfiy(3)
      real*8 rfiz(3),c_gss(6)
      real*8 deltar,elect_half,preload_acc,t1i(3),t2i(3)
      integer i, kount, jgyro, kkf

c  Science gyro GG force calculation variables
      real*8 fsg_gg(3,4), fsg_ggi(3,4), fsg_j2_gg(3,4), fsg_j2_ggi(3,4)
      real*8 tsg_j2_gg(3,4), tsg_j2_ggi(3,4), tsg_gg(3,4), tsg_ggi(3,4)
      real*8 sg_1,sg_2,sg_3,sg_4,sg_1c,sg_2c,sg_3c,sg_4c
      real*8 squid_x,squid_y,tele_x,tele_y,thet1,thet2,thet3
      real*8 Hbody(3),tele_body(3),VABER(3),vab_x,vab_y
      common / sg_gg / fsg_gg, tsg_j2_gg, fsg_j2_gg, tsg_gg

      real*8 time,serr_p(2),serr_y(2),pi_loc,arcrad,radarc,dtkfil
      logical firstpass,ier
      parameter (pi_loc = 3.14159265358979323846d0)
      parameter (arcrad = pi_loc / (180.0d0*3600.0d0))
      parameter (radarc = 1.0d0 / arcrad)
      real*8 fp1i(3),fp2i(3), st_vec(3), ust_vec(3),perr
      COMMON /FP12I/ FP1I,FP2I,VABER

      equivalence (usdc_rs(71),h)
      data dtkfil,firstpass /8.6d0,.true. /

c  H=Iw where Inertia=9.2E-6 kg-m^2 and w = 2*pi*(130 Hz)
      data H0 / 0.0075147D0 /
c     data H /
c    1          0.0D0, 0.0D0, 0.0075147D0,
c    2          0.0D0, 0.0D0, 0.0075147D0,
c    3          0.0D0, 0.0D0, 0.0075147D0,
```

```
c     4          0.0D0, 0.0D0, 0.0075147D0 /
        data d / -5.08D-8/
        data deltar / -5.08D-8/
        data elect_half /  0.5061454830784d0 /
        data preload_acc / 1.962d-6 /
        data c_gss / 0.D0,
     1              2.714382128894188D-3,
     2              2.620082137667179D-3,
     3              1.D0,
     4             -1.894031723107232D0,
     5              8.993661873737933D-1 /

c  firstpass stuff
        if (firstpass) then
          firstpass=.false.
          kkf = int(.5d0+dmod(time,dtkfil)/dtcont)
          if (kkf .eq. 0) kkf=int(.5d0+dtkfil/dtcont)
c  Initialize the science gyros, if not restart run.
          if (.not. rs_flag) then
            do jgyro = 1,4
              h(1,jgyro) = 0.d0
              h(2,jgyro) = 0.d0
              h(3,jgyro) = h0
            enddo
          endif
c  Compute the drift angle
           do jgyro = 1,4
cash         da_ns(jgyro) = datan(H(1,jgyro)/H(3,jgyro))
             da_ns(jgyro) = datan(H(1,jgyro)/dsqrt(H(2,jgyro)**2
     &                                          +H(3,jgyro)**2))
             da_ew(jgyro) = datan(H(2,jgyro)/H(3,jgyro))
cash
           enddo
        endif

c  Cycle over all four SG's
        do jgyro = 1,4
c  Convert gravity gradient forces/torques from body to inertial frame vectors
           call botoin(fsg_gg(1,jgyro), fsg_ggi(1,jgyro),1)
           call botoin(fsg_j2_gg(1,jgyro), fsg_j2_ggi(1,jgyro),1)
           call botoin(tsg_gg(1,jgyro), tsg_ggi(1,jgyro),1)
           call botoin(tsg_j2_gg(1,jgyro), tsg_j2_ggi(1,jgyro),1)
           call intobo(facti(1,2+jgyro), factb(1,jgyro),1)

c  Compute the force vector on the SG rotor (GG + J2 term)
           Hmag = ufmag(H(1,jgyro))
           do i = 1,3
             uh(i,jgyro) = H(i,jgyro)/Hmag
             H(i,jgyro) = uh(i,jgyro)*H0
           enddo
c  Compute the drift angle
           da_ns(jgyro) = datan(H(1,jgyro)/
     &           dsqrt(H(2,jgyro)**2 + H(3,jgyro)**2))
           da_ew(jgyro) = datan(H(2,jgyro)/H(3,jgyro))
           do i = 1,3
             xcm2cg(i) = uh(i,jgyro)*d
             Fsg_rotor(i,jgyro) =  facti(i,2+jgyro)
             Fsg_rotorb(i)      =  factb(i,jgyro)
           enddo
           t1i(1) =-d*(Fsg_rotor(2,jgyro)+Fsg_rotor(3,jgyro)*da_ew(jgyro))
           t1i(2) = d*(Fsg_rotor(1,jgyro)-Fsg_rotor(3,jgyro)*da_ns(jgyro))
           t1i(3) = 0.d0

           t2i(1) = -deltar*dcos(elect_half)/preload_acc*
     &           ((Fsg_rotorb(2)**2 - (Fsg_rotorb(1)**2 +
     &            Fsg_rotorb(3)**2)/2.d0)
     &           *(da_ns(jgyro)*dsin(2.d0*st_roll)
     &           + da_ew(jgyro)*dcos(2.d0*st_roll) + da_ew(jgyro))
     &           - 2.d0*Fsg_rotorb(1)*Fsg_rotorb(3)
     &           *dsin(st_roll))
           t2i(2) = -deltar*dcos(elect_half)/preload_acc*
```

```
     &          ((Fsg_rotorb(2)**2 - (Fsg_rotorb(1)**2 +
     &           Fsg_rotorb(3)**2)/2.d0)
     &           *(da_ew(jgyro)*dsin(2.d0*st_roll)
     &           - da_ns(jgyro)*dcos(2.d0*st_roll) + da_ns(jgyro))
     &           + 2.d0*Fsg_rotorb(1)*Fsg_rotorb(3)
     &           *dcos(st_roll))
          t2i(3) = 0.d0

          do i = 1,3
             T_per(i) = t1i(i) + t2i(i)
          enddo

c  Compute the torque perpendicular to the Momentum vector total

c  Compute the new momentum vector and normalize to the original magnitude
          do i = 1,3
c  this is odd H(i,jgyro) = H(i,jgyro) + (T_per(i))*dtcont
c  this is direct         H(i,jgyro) = H(i,jgyro)
c     &           + (tsg_ggi(i,jgyro)+tsg_j2_ggi(i,jgyro))*dtcont
c  this is direct and odd         H(i,jgyro) = H(i,jgyro) + (T_per(i)
c     &                 +tsg_ggi(i,jgyro)+tsg_j2_ggi(i,jgyro))*dtcont
             H(i,jgyro) = H(i,jgyro) + (T_per(i)
     &                 +tsg_ggi(i,jgyro)+tsg_j2_ggi(i,jgyro))*dtcont
          enddo

        enddo

c  Compute SQUID noise in pitch and yaw
        do i = 1,2
           serr_p(i) = 0.d0
           serr_y(i) = 0.d0
        enddo

c  Compute Science Gyro Output angles
        sg_1 =-da_ew(1)*dsin(st_roll) + da_ns(1)*dcos(st_roll) - serr_p(1)
        sg_2 =-da_ew(2)*dsin(st_roll) + da_ns(2)*dcos(st_roll) - serr_p(2)
        sg_3 = da_ew(3)*dcos(st_roll) + da_ns(3)*dsin(st_roll) - serr_y(1)
        sg_4 = da_ew(4)*dcos(st_roll) + da_ns(4)*dsin(st_roll) - serr_y(2)

C Convert Science Gyro outputs from radians to counts
cash  Output Kalman filter data to kalfil.out every 8.60sec
        if (kkf .eq. 86) then
cash
cash  Calculate pointing vector of star tracker
           call vcross(fp1i,fp2i,st_vec)
           call unit(st_vec,ust_vec,ier)
cash
cash  Calculate pointing error (star tracker only)
cash          perr=atan2(ust_vec(1),ust_vec(3))-atan2(uh(1,4),uh(3,4))
           perr=atan2(dsin(st_pitch)*dcos(st_roll),dcos(st_pitch))
cash
cash  Calculate the body attitude wrt inertial (312 rotation)
cash          thet1= dasin( ctrans(2,3,1))
cash          thet2=datan2(-ctrans(1,3,1),ctrans(3,3,1))
cash          thet3=datan2(-ctrans(2,1,1),ctrans(2,2,1))
           thet1= dasin( ctrans(3,2,1))
           thet2=datan2(-ctrans(3,1,1),ctrans(3,3,1))
           thet3=datan2(-ctrans(1,2,1),ctrans(2,2,1))
cash
cash  Convert Angular Momentum vector to body and define squid outputs
           call intobo(UH(1,4),Hbody,1)
           squid_x = -Hbody(2)
           squid_y =  Hbody(1)
cash
cash  Convert Science Telescope Measurement to body and define tel. outputs
cash  (science telescope is sensor #4)
           call intobo(USI(1,4),tele_body,1)
           tele_x = -tele_body(2)
           tele_y =  tele_body(1)
cash
cash  Output the current velocity aberration angles in inertial frame (star frame)
```

```
cjrg  Z along GS, X in plane, south, Y completes RHS.
          vab_x = -VABER(2)
          vab_y =  VABER(1)
          kkf = 1
       else
          kkf = kkf + 1
       endif

       return
       end
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
       subroutine  gg_body(time,t_sp_gg, t_j2_gg, f_sp_gg, f_j2_gg,bona)
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
cc
cc  Function:  Compute gravity gradient torques due to
cc              spherical earth and J2 oblateness term.
cc
cc  Source:  JC; JG notes            Date:  12/18/90
cc
cc  Output:  t_sp_gg - grav grad body torque vector due
cc                     to sperical earth model.
cc           t_j2_gg - grav grad body torque vector due
cc                     to J2 term only (Nt-m).
cc
cc  Comments:  Real*8
cc             Requires data available in common declarations
cc              from initialization subroutine.
cc
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc

       implicit none ! double precision (a-h,o-z)
cc  Include transformation data
       save
       include 'DBP.F'
       include 'DBB.F'

       real*8 time, omeglvsq    !sim time; angles
       real*8 body_ti(3,3)       !TREETOPS inertial to body trans
       real*8 ti_prime(3,3), body_prime(3,3)
       real*8 t_sp_gg(3)         !spherical earth grav grad torques
       real*8 s(3,3)             !dyadic
       real*8 t_j2_gg(3)         !J2 gravity gradient torques
       real*8 gme                !grav constant x earth's mass
       real*8 re                 !earth's equatorial radius
       real*8 j2                 !J2 oblate earth term
c      real*8 rig_dec            !Rigel declination angle (deg)
       real*8 ti_eci(3,3)        !orbit plane eci to TREETOPS i frame
       real*8 body_eci(3,3)      !ECI to BODY trans
       real*8 ur_prime(3)         !unit vector from veh CM to earth CM
       real*8 ur_body(3)
       real*8 ua_eci(3)          !unit vector from earth CM to N pole
       real*8 ua_body(3)
       real*8 temp1(3), temp2(3), t1, t2
       real*8 temp3(3)
       real*8 bona(3,3)           !TT body from nadir transform
       real*8 d_dot
       real*8 pi,ro,traci,ufmag
       integer  i, j, jgyro
       logical  pass_flag

       parameter( pi = 3.1415926535897932384d0 )
       parameter( gme = 3.986032d5 )        !Km^3 sec^-2
       parameter( re = 6.378165d3 )         !Km
       parameter( j2 = 1.08263d-3 )
c      parameter( rig_dec = -8.21666667d0*pi/180.d0 )
       parameter( ro = re + 650.0 )         !Km; 650 Km orbit alt
       parameter(omeglvsq = gme / ro**3)     !gg force and torque constant

       INCLUDE 'XFRM.F'
C      common / CSCI2ECI / CLE
```

```
        real*8 w_orbit, w_roll    !orbit rate; roll rate (rad/sec)
        common / rates / w_orbit, w_roll

        real*8 i_body(3,3)        !body inertia dyadic
        common / ggfeedf / i_body

        real*8 uec2sc_b(3), ucm2pm_b(3), cm2pm_b(3), t3
        real*8 f_sp_gg(3), f_j2_gg(3)
cash
cash      real*8 alf,g_alpha,h_alpha,rpvec(3),d_ov_rp(3),dsg2pm,rpd(3),rpdm
cash

c  Science gyro GG force calculation variables
        real*8 fsg_gg(3,4), sg2pm_b(3,4), tsg_j2_gg(3,4), i_sg(3,3)
        real*8 usg2pm_b(3,4), fsg_j2_gg(3,4), tsg_gg(3,4), s_sg(3,3)
        common / sg_gg / fsg_gg, tsg_j2_gg, fsg_j2_gg, tsg_gg
        data sg2pm_b /
     1              0.0d0, 0.0d0, 0.00000d0,
     2              0.0d0, 0.0d0, 0.08250d0,
     3              0.0d0, 0.0d0, 0.16500d0,
     4              0.0d0, 0.0d0, 0.24750d0 /
        data usg2pm_b /
     1              0.0d0, 0.0d0, 1.0d0,
     2              0.0d0, 0.0d0, 1.0d0,
     3              0.0d0, 0.0d0, 1.0d0,
     4              0.0d0, 0.0d0, 1.0d0 /
        data i_sg / 9*0.0d0 /

C  Worse case center of mass to proof mass vector (meters)
        data cm2pm_b / 0.0d0, 0.0d0, -0.1816d0 /
        data ucm2pm_b / 0.0d0, 0.0d0, -1.d0 /

        data ua_eci / 0., 1., 0. /
        data ur_prime / 0., 0., 1. /
        data pass_flag / .true. /

cjrg  This calculation uses control system estimated value of orbit rate
cjrg  This is incorrect and becomes significantly so over long times.  Replaced
cjrg  by correct value, csi_l transformation.  jrg 12-29-97
cc  Compute trans from PRIME to TI based on nominal orbit
cc   rate and simulation time.
c      orb = w_orbit * time
c      call d_rot(2, -orb, ti_prime)

cc  Use trans TI to BODY from TREETOPS code
cjrg  Also use csi_l from treetops.  Use local vertical sensor to define csi_l.
cjrg  bona is body from nadir.

cjrg      do i=1,3
cjrg        do j=1,3
cjrg        ti_prime(i,j) = csi_l(i,j)
cjrg        ti_prime(i,j) = bona(j,i)
cjrg          body_ti(i,j) = ctrans(j,i,1)
cjrg        enddo
cjrg      enddo

cc  Compute unit vector from body CM to earth CM expressed in body
cjrg  Prime frame is local vertical frame.
cjrg      call d_mmul(body_ti, ti_prime, body_prime, 3, 3, 3)
        body_prime(1,1) = bona(1,1)
        body_prime(1,2) = bona(1,2)
        body_prime(1,3) = bona(1,3)
        body_prime(2,1) = bona(2,1)
        body_prime(2,2) = bona(2,2)
        body_prime(2,3) = bona(2,3)
        body_prime(3,1) = bona(3,1)
        body_prime(3,2) = bona(3,2)
        body_prime(3,3) = bona(3,3)
        call d_mxv(body_prime, ur_prime, ur_body)

        if(pass_flag) then
```

```
         pass_flag = .false.
cc  Transformation from TREETOPS ECI frame to the on-orbit
cc   spacecraft inertial frame (SI); computed at time=0 in TT code
         do i=1,3
           do j=1,3
c            ti_eci(i,j) = cle(i,j)
             ti_eci(i,j) = csi_eci(i,j)
           enddo
         enddo

cc  Compute S = dyadic defined by (1/2 trace II) I - II)  where II
cc   is the moment of inertia dyadic and I is the identity matrix.

c       call trace(i_body, traci, 3)
         traci = i_body(1,1) + i_body(2,2) + i_body(3,3)

         do i=1,3
           do j=1,3
             if(i .eq. j) then
               s(i,j) = 0.5d0*traci - i_body(i,j)
             else
               s(i,j) = - i_body(i,j)
             endif
           enddo
         enddo

c ****** for SG ******
cash    i_sg(1,1) = 9.1999324D-6
cash    i_sg(2,2) = 9.1999540D-6
          i_sg(1,1) = 9.1999432D-6
          i_sg(2,2) = 9.1999432D-6
          i_sg(3,3) = 9.2000000D-6
c       call trace(i_sg, traci, 3)
          traci = i_sg(1,1) + i_sg(2,2) + i_sg(3,3)

          do i=1,3
            do j=1,3
              if(i .eq. j) then
                s_sg(i,j) = 0.5*traci - i_sg(i,j)
              else
                s_sg(i,j) = - i_sg(i,j)
              endif
            enddo
          enddo
c ****** for SG ******

        endif

cc  Compute gravity grad torque terms; several
cc   ( a x S . b ) terms in expansion; a,b = unit vectors,
cc   S = dyadic defined by (1/2 trace II) I - II)  where II is the
cc   moment of inerita dyadic and I is the identity matrix.

        call d_mmul(body_ti, ti_eci, body_eci, 3, 3, 3)
        call d_mxv(body_eci, ua_eci, ua_body)
        t1 = d_dot(ua_body, ur_body)

        call dyad_xd(ur_body, s, ua_body, temp1)
        call dyad_xd(ua_body, s, ur_body, temp2)
cash
cash  addition from Kasdin paper page 8
        call dyad_xd(ua_body, s, ua_body, temp3)

        do i=1,3
          temp1(i) = temp1(i) + temp2(i)
        enddo

        t2 = d_dot(ua_body, ur_body)
c       t2 = 0.5d0 * ( 7.d0 * (t2**2) - 1.d0)
        t2 = 3.5d0 * (t2**2) - 0.5d0
```

```
        call dyad_xd(ur_body, s, ur_body, temp2)

        do i=1,3

cc  Compute grav grad torque vector due to J2 term
          t_j2_gg(i) = ( gme * 15. * j2 * (re**2) / (ro**5) ) *
     &                 ( -t1 * temp1(i) + t2 * temp2(i)
     &                   +0.2d0 * temp3(i) )

cc  Compute grav grad torque vector for spherical earth model
          t_sp_gg(i) = -3. * omeglvsq * temp2(i)

        enddo

cc  Compute the gravity gradient force on the main body
        uec2sc_b(1) = -ur_body(1)
        uec2sc_b(2) = -ur_body(2)
        uec2sc_b(3) = -ur_body(3)
        t3 = d_dot(uec2sc_b, cm2pm_b)
        do i = 1,3
          f_sp_gg(i) = omeglvsq*BMASS(1) * (cm2pm_b(i)-3.0d0*t3*uec2sc_b(i))
        enddo
cc  Compute the gravity gradient J2 force on the vehicle (body 1)
        t1 = d_dot(ur_body, ucm2pm_b)
        t2 = d_dot(ur_body, ua_body)
        t3 = d_dot(ucm2pm_b, ua_body)
      do i=1,3
          f_j2_gg(i) = 1.5D0 * omeglvsq * BMASS(1) *j2 * (re/ro)**2 *
     &     ufmag(cm2pm_b) * ( ucm2pm_b(i) - 5.0d0*t1*ur_body(i) -
     &     5.0d0*t2**2*ucm2pm_b(i) - (10.0d0*t2*t3 - 35.0d0*t1*t2**2)
     &     *ur_body(i) + (2.0d0*t3 - 10.0d0*t2*t1)*ua_body(i) )
        enddo

cc  Compute the gravity gradient spherical and J2 torque on the SG (body 3)
        call dyad_xd(ur_body, s_sg, ua_body, temp1)
        call dyad_xd(ua_body, s_sg, ur_body, temp2)
cash
cash  addition from Kasdin paper page 8
        call dyad_xd(ua_body, s_sg, ua_body, temp3)
cash

        do i=1,3
          temp1(i) = temp1(i) + temp2(i)
        enddo

        t2 = d_dot(ua_body, ur_body)
c       t2 = 0.5 * ( 7.e0 * (t2**2) - 1.e0)
        t2 = 3.5d0 * (t2**2) - 0.5d0

        call dyad_xd(ur_body, s_sg, ur_body, temp2)
      t1 = d_dot(ua_body, ur_body)
        do jgyro=1,4
          do i=1,3
            tsg_j2_gg(i,jgyro) = (15.d0 * omeglvsq * j2*(re / ro)**2)*
     &                         ( -t1 * temp1(i) + t2 * temp2(i)
     &                           +0.2d0 * temp3(i) )
cc  Compute grav grad torque vector for spherical earth model
            tsg_gg(i,jgyro) =  -3. * omeglvsq * temp2(i)
          enddo
        enddo

cc  Compute the gravity gradient force on the science gyro (body 3)
        do jgyro = 1,4
          t3 = d_dot(uec2sc_b, sg2pm_b(1,jgyro))
          do i = 1,3
            fsg_gg(i,jgyro) = omeglvsq*BMASS(2+jgyro) *
     &          (sg2pm_b(i,jgyro) - 3.0d0*t3*uec2sc_b(i))
          enddo
        enddo

cc  Compute the gravity gradient J2 force on the science gyro (body 3)
```

```
      do jgyro = 1,4
        t1 = d_dot(ur_body, usg2pm_b(1,jgyro))
        t2 = d_dot(ur_body, ua_body)
        t3 = d_dot(usg2pm_b(1,jgyro), ua_body)
       do i=1,3
         fsg_j2_gg(i,jgyro) = 1.5D0 * omeglvsq * BMASS(2+jgyro)
     &         • j2 * (re/ro)**2 * ufmag(sg2pm_b(1,jgyro)) *
     &         ( usg2pm_b(i,jgyro) - 5.0d0*t1*ur_body(i)
     &          - 5.0d0*t2**2*usg2pm_b(i,jgyro) - (10.0d0*t2*t3
     &          - 35.0d0*t1*t2**2) • ur_body(i) +
     &          (2.0d0*t3 - 10.0d0*t2*t1)*ua_body(i) )
        enddo
      enddo

      return
      end
```

Appendix C

INPUT FILE DEFINING CONTROL GAINS FOR THE TREETOPS GP-B SIMULATION GAINS.INP

```
.1                              ! dt (s) for plotting
10                              ! No. of dt's / plot write (data.mat)
50                              ! No. of dt's / plot write (control.mat)
1.98,0.482,0.25,0.030,0.00093 ! RV p/y gains kr, kp, ki, kop, koi (.15 Hz BW)
18000.0,0.1,100.0,25.0,5.0,25.0,25.0,0.0           ! RV p/y limits (arcsec)
5188.9                          ! pitch/yaw Inertia (kg-m^2)
14.9227,0.0083371,0.0335059,0.00408,0.0041,  ! Roll gains  kr, kp, ki, kop, koi (.06 Hz BW)
18000.0,0.1,100.0,25.0,5.0,25.0,25.0,0.0           ! Roll limits (arcsec)
3693.4                          ! Roll Inertia (kg-m^2)
1.2435,2.44,0.605               ! translational gains kr, kp, ki (.5 Hz BW)
5.0D-6, 5.D-2,  5.0D-6, 0.005               ! translational limits (m, N)
3182.8                          ! translational mass (kg)
0.0d0,0.0d0,0.01024d12          ! thruster leakage, hysteresis & maximum (N)
1.4,150.0                       ! Magnetic command hysteresis & maximum (ATM^2)
0.0E0                           ! Mass flow rate command (kg/sec)
5230.2, -19.3, 6.0          ! body inertia matrix
-19.3, 5147.5, 0.
6.0, 0., 3693.4
1.068387D-3                     ! orbit rate (rad/sec)
1.80D0                          ! roll rate (deg/sec)
.false.                         ! Gravity Gradient feed forwardON (check .INT file also)
.false.                         ! Cryo feed forward torque ON (check .INT file also)
.true.                          ! Velocity aberration feed forward ON (check .INT also)
.true.                          ! Closed loop controller (thrusters enabled)


   5.6443950e+03   1.5239867e+03   1.3715880e+02   4.1147640e+00
   5.5775970e+03   1.5059512e+03   1.3553561e+02   4.0660682e+00
   1.9016563e+03   3.5845377e+02   2.2522314e+01   4.7170625e-01
```

Appendix D

INPUT FILE DEFINING HELIUM THRUSTER MOUNTING LOCATIONS AND FORCE DIRECTIONS FOR THE TREETOPS GP-B SIMULATION THRUSTERS.INP

```
1.00, 1.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.00
0.00, 0.00, 1.00, 1.00, 1.00, 1.00, 0.00, 0.00
0.00, 0.00, 0.00, 0.00, 0.00, 0.00, 1.00, 1.00
0.00, 0.00, 1.90,-2.51, 1.90,-2.51, 0.00, 0.00
2.51,-1.90, 0.00, 0.00, 0.00, 0.00, 1.19,-1.19
0.00, 0.00, 1.19,-1.19,-1.19, 1.19, 0.00, 0.00
```

Appendix E

INPUT FILE DEFINING SENSOR AND ACTUATOR NOISE, QUANTIZATION VALUES, FOR THE TREETOPS GP-B SIMULATION ERRORS.INP

```
21               ! roll Star Tracker noise seed
22, 23           ! pitch & yaw Science Telescope noise seeds
24, 25, 26       ! Control Gyro (roll, pitch, yaw) noise seeds
27, 28, 29       ! Drag Free Sensor (x, y, z) noise seeds
1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16          ! 16 Thruster noise seeds
5.0d0            ! roll Star Tracker noise standard deviation (Arcsec)
22.36d0          ! ST noise standard deviation (milliArcsec)
0.002236d0       ! Control Gyro noise standard deviation (Arcsec/sec)
3.354d0          ! Drag Free Sensor noise standard deviation (nanometers)
0.0559d0         ! Thruster noise standard deviation (milliNewtons)
0.5d0            ! roll Star Tracker least significant bit (Arcsec)
0.25d0           ! ST least significant bit (milliArcsec)
375.0d-1         ! Roll Control Gyro least significant bit (milliArcsec)
1.3d0            ! Pitch/Yaw Control Gyro least significant bit (milliArcsec)
1.0d0            ! Drag Free Sensor least significant bit (nanometers)
0.0025d0         ! Thruster least significant bit (milliNewtons)
0.000d0, 0.000d0, 0.000d0       ! Control Gyro drift (r, p, y) (Arcsec/sec)
```

Appendix F

INPUT FILE DEFINING MODEL FOR THE TRANSFER FUNCTION APPROACH TO SLOSH DYNAMICS ANALYSIS
IMPEG_GPB_TF.INT

```
        TREETOPS REV 10X   1/10/02

        SIM CONTROL

SI   0 Title                                                     GPB MODEL FOR 2002
SI   0 Simulation stop time                                      20000
SI   0 Plot data interval                                        5
SI   0 Integration type (R,S or U)                               R
SI   0 Step size (sec)                                           0.10
SI   0 Sandia integration absolute and relative error
SI   0 RK78 ODE solver absolute error and first step size
SI   0 Linearization option  (L,Z or N)                          N
SI   0 Restart option         (Y/N)                              N
SI   0 Contact force computation option     (Y/N)                N
SI   0 Constraint force computation option  (Y/N)                N
SI   0 Small angle speedup option (All,Bypass,First,Nth)         A
SI   0 Mass matrix speedup option (All,Bypass,First,Nth)         A
SI   0 Non-Linear  speedup option (All,Bypass,First,Nth)         A
SI   0 Constraint  speedup option (All,Bypass,First,Nth)         A
SI   0 Constraint stabilization option  (Y/N)                    N
SI   0 Stabilization epsilon


        GENGRAV

GG   2 Gravity, earth sphere/nonsphere/user (S/N/U)?             N
GG   1 Input gravity constants:  GME, ERAD, EMASS
GG   1 Spherical or Nonspherical (S/N)?
GG   1 Gravity Potential Harmonics J2,J3,J4
GG   2 English (ft-slug-s) or metric (m-kg-s)    (E/M)?          M
GG   2 Day, Month, Year,                                         21 6 2003
GG   2 GMT @ sim time 0 (minutes past midnight,                  720
GG   2 Solar Pressure forces Y/N?                                N
GG   2 Input new data for aero model? (Y/N)                      Y
GG   2   Solar flux F10 for aero model                           230
GG   2   Solar flux, 81 day average F10B                         230
GG   2   Geomagnetic index, GEAP                                 400

        BODY

BO   1 Body ID number                                            1
BO   1 Type (Rigid,Flexible,NASTRAN)                             R
BO   1 Number of modes
BO   1 Modal calculation option (0, 1 or 2)
BO   1 Foreshortening Option (Y/N)
BO   1 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   1 NASTRAN data file FORTRAN unit number (40 - 60)
BO   1 Number of augmented nodes (0 if none)
BO   1 Damping matrix option (NS,CD,HL,SD)
BO   1 Constant damping ratio
BO   1 Low frequency, High frequency ratios
BO   1 Mode ID number, damping ratio
BO   1 Conversion factors: Length,Mass,Force
BO   1 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)        1
BO   1 Moments of inertia (kg-m2) Ixx,Iyy,Izz                    5230.2 5147.5 3693.4
BO   1 Products of inertia (kg-m2) Ixy,Ixz,Iyz                   19.3 -6 0
```

```
BO   1 Mass (kg)                                                  3182.8
BO   1 Number of Nodes                                            13
BO   1 Node ID, Node coord. (meters) x,y,z                        1 0 -0.0002 0.8647
BO   1 Node ID, Node coord. (meters) x,y,z                        2 0 -0.0002 0.8647
BO   1 Node ID, Node coord. (meters) x,y,z                        3 0 1.0467 0.6380
BO   1 Node ID, Node coord. (meters) x,y,z                        4 0 0 0.10033
BO   1 Node ID, Node coord. (meters) x,y,z                        5 -1.19 0 2.51
BO   1 Node ID, Node coord. (meters) x,y,z                        6 1.19 0 2.51
BO   1 Node ID, Node coord. (meters) x,y,z                        7 -1.19 0 -1.9
BO   1 Node ID, Node coord. (meters) x,y,z                        8 1.19 0 -1.9
BO   1 Node ID, Node coord. (meters) x,y,z                        9 0 0 -.10033
BO   1 Node ID, Node coord. (meters) x,y,z                        10 0 0 -.18283
BO   1 Node ID, Node coord. (meters) x,y,z                        11 0 0 -.26533
BO   1 Node ID, Node coord. (meters) x,y,z                        12 0 0 -.34783
BO   1 Node ID, Node coord. (meters) x,y,z                        13 0 0 0.10937
BO   1 Node ID, Node structural joint ID

BO   2 Body ID number                                             2
BO   2 Type (Rigid,Flexible,NASTRAN)                              R
BO   2 Number of modes
BO   2 Modal calculation option (0, 1 or 2)
BO   2 Foreshortening Option (Y/N)
BO   2 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   2 NASTRAN data file FORTRAN unit number (40 - 60)
BO   2 Number of augmented nodes (0 if none)
BO   2 Damping matrix option (NS,CD,HL,SD)
BO   2 Constant damping ratio
BO   2 Low frequency, High frequency ratios
BO   2 Mode ID number, damping ratio
BO   2 Conversion factors: Length,Mass,Force
BO   2 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)         1
BO   2 Moments of inertia (kg-m2) Ixx,Iyy,Izz                     .00001 .00001 .00001
BO   2 Products of inertia (kg-m2) Ixy,Ixz,Iyz                    0 0 0
BO   2 Mass (kg)                                                  .076
BO   2 Number of Nodes                                            1
BO   2 Node ID, Node coord. (meters) x,y,z                        1 0 0 0
BO   2 Node ID, Node structural joint ID

BO   3 Body ID number                                             3
BO   3 Type (Rigid,Flexible,NASTRAN)                              R
BO   3 Number of modes
BO   3 Modal calculation option (0, 1 or 2)
BO   3 Foreshortening option (Y/N)
BO   3 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   3 NASTRAN data file FORTRAN unit number (40 - 60)
BO   3 Number of augmented nodes (0 if none)
BO   3 Damping matrix option (NS,CD,HL,SD)
BO   3 Constant damping ratio
BO   3 Low frequency, High frequency ratios
BO   3 Mode ID number, damping ratio
BO   3 Conversion factors: Length,Mass,Force
BO   3 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)         1
BO   3 Moments of inertia (kg-m2) Ixx,Iyy,Izz                     9.1999324E-6 9.199954E-6 9.2E-6
BO   3 Products of inertia (kg-m2) Ixy,Ixz,Iyz                    0 0 0
BO   3 Mass (kg)                                                  0.06335
BO   3 Number of Nodes                                            2
BO   3 Node ID, Node coord. (meters) x,y,z                        1 0 0 0
BO   3 Node ID, Node coord. (meters) x,y,z                        2 0 0 -5.08E-8
BO   3 Node ID, Node structural joint ID

BO   4 Body ID number                                             4
BO   4 Type (Rigid,Flexible,NASTRAN)                              R
BO   4 Number of modes
BO   4 Modal calculation option (0, 1 or 2)
BO   4 Foreshortening option (Y/N)
BO   4 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   4 NASTRAN data file FORTRAN unit number (40 - 60)
BO   4 Number of augmented nodes (0 if none)
BO   4 Damping matrix option (NS,CD,HL,SD)
BO   4 Constant damping ratio
BO   4 Low frequency, High frequency ratios
```

```
BO   4 Mode ID number, damping ratio
BO   4 Conversion factors: Length,Mass,Force
BO   4 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)       1
BO   4 Moments of inertia (kg-m2) Ixx,Iyy,Izz                   9.1999324E-6 9.199954E-6 9.2E-6
BO   4 Products of inertia (kg-m2) Ixy,Ixz,Iyz                  0 0 0
BO   4 Mass (kg)                                                .06335
BO   4 Number of Nodes                                          2
BO   4 Node ID, Node coord. (meters) x,y,z                      1 0 0 0
BO   4 Node ID, Node coord. (meters) x,y,z                      2 0 0 -5.08E-8
BO   4 Node ID, Node structual joint ID

BO   5 Body ID number                                           5
BO   5 Type (Rigid,Flexible,NASTRAN)                            R
BO   5 Number of modes
BO   5 Modal calculation option (0, 1 or 2)
BO   5 Foreshortening option (Y/N)
BO   5 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   5 NASTRAN data file FORTRAN unit number (40 - 60)
BO   5 Number of augmented nodes (0 if none)
BO   5 Damping matrix option (NS,CD,HL,SD)
BO   5 Constant damping ratio
BO   5 Low frequency, High frequency ratios
BO   5 Mode ID number, damping ratio
BO   5 Conversion factors: Length,Mass,Force
BO   5 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)       1
BO   5 Moments of inertia (kg-m2) Ixx,Iyy,Izz                   9.1999324E-6 9.199954E-6 9.2E-6
BO   5 Products of inertia (kg-m2) Ixy,Ixz,Iyz                  0 0 0
BO   5 Mass (kg)                                                .06335
BO   5 Number of Nodes                                          2
BO   5 Node ID, Node coord. (meters) x,y,z                      1 0 0 0
BO   5 Node ID, Node coord. (meters) x,y,z                      2 0 0 -5.08E-8
BO   5 Node ID, Node structual joint ID

BO   6 Body ID number                                           6
BO   6 Type (Rigid,Flexible,NASTRAN)                            R
BO   6 Number of modes
BO   6 Modal calculation option (0, 1 or 2)
BO   6 Foreshortening option (Y/N)
BO   6 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   6 NASTRAN data file FORTRAN unit number (40 - 60)
BO   6 Number of augmented nodes (0 if none)
BO   6 Damping matrix option (NS,CD,HL,SD)
BO   6 Constant damping ratio
BO   6 Low frequency, High frequency ratios
BO   6 Mode ID number, damping ratio
BO   6 Conversion factors: Length,Mass,Force
BO   6 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)       1
BO   6 Moments of inertia (kg-m2) Ixx,Iyy,Izz                   9.1999324E-6 9.199954E-6 9.2E-6
BO   6 Products of inertia (kg-m2) Ixy,Ixz,Iyz                  0 0 0
BO   6 Mass (kg)                                                .06335
BO   6 Number of Nodes                                          2
BO   6 Node ID, Node coord. (meters) x,y,z                      1 0 0 0
BO   6 Node ID, Node coord. (meters) x,y,z                      2 0 0 -5.08E-8
BO   6 Node ID, Node structual joint ID

       HINGE


HI   1 Hinge ID number                                          1
HI   1 Inboard body ID, Outboard body ID                        0 1
HI   1 "p" node ID, "q" node ID                                 0 4
HI   1 Number of rotation DOFs, Rotation option (F or G)        3 F
HI   1 L1 unit vector in inboard body coord. x,y,z              0 1 0
HI   1 L1 unit vector in outboard body coord. x,y,z             0 1 0
HI   1 L2 unit vector in inboard body coord. x,y,z
HI   1 L2 unit vector in outboard body coord. x,y,z
HI   1 L3 unit vector in inboard body coord. x,y,z              0 0 1
HI   1 L3 unit vector in outboard body coord. x,y,z             0 0 1
HI   1 Initial rotation angles (deg)        -16.7408 16.8411 -90   -16.739107675801 16.838172287528
-90.0
HI   1 Initial rotation rates (deg/sec)                         0 0 1.8
```

```
HI   1 Rotation stiffness (newton-meters/rad)                   0 0 0
HI   1 Rotation damping (newton-meters/rad/sec)                 0 0 0
HI   1 Null torque angles (deg)                                 0 0 0
HI   1 Number of translation DOFs                               3
HI   1 First translation unit vector   g1                       1 0 0
HI   1 Second translation unit vector  g2                       0 1 0
HI   1 Third translation unit vector   g3                       0 0 1
HI   1 Initial translation (meters)                             2021331.3322 0 -6720778.19992
HI   1 Initial translation velocity (meters/sec)                0 -7533.0 0
HI   1 Translation stiffness (newtons/meters)                   0 0 0
HI   1 Translation damping (newtons/meter/sec)                  0 0 0
HI   1 Null force translations                                  0 0 0

HI   2 Hinge ID number                                          2
HI   2 Inboard body ID, Outboard body ID                        1 2
HI   2 "p" node ID, "q" node ID                                 4 1
HI   2 Number of rotation DOFs, Rotation option (F or G)        0
HI   2 L1 unit vector in inboard body coord. x,y,z              1 0 0
HI   2 L1 unit vector in outboard body coord. x,y,z             1 0 0
HI   2 L2 unit vector in inboard body coord. x,y,z
HI   2 L2 unit vector in outboard body coord. x,y,z
HI   2 L3 unit vector in inboard body coord. x,y,z              0 0 1
HI   2 L3 unit vector in outboard body coord. x,y,z             0 0 1
HI   2 Initial rotation angles (deg)                            0 0 0
HI   2 Initial rotation rates (deg/sec)
HI   2 Rotation stiffness (newton-meters/rad)
HI   2 Rotation damping (newton-meters/rad/sec)
HI   2 Null torque angles (deg)
HI   2 Number of translation DOFs                               3
HI   2 First translation unit vector   g1                       1 0 0
HI   2 Second translation unit vector  g2                       0 1 0
HI   2 Third translation unit vector   g3                       0 0 1
HI   2 Initial translation (meters)                             0 0 0
HI   2 Initial translation velocity (meters/sec)                0 0 0
HI   2 Translation stiffness (newtons/meters)                   0 0 0
HI   2 Translation damping (newtons/meter/sec)                  0 0 0
HI   2 Null force translations                                  0 0 0

HI   3 Hinge ID number                                          3
HI   3 Inboard body ID, Outboard body ID                        1 3
HI   3 "p" node ID, "q" node ID                                 9 2
HI   3  No of rotation DOFs, Hinge 1 rotation option(F/G)       0
HI   3 L1 unit vector in inboard body coord. x,y,z              1 0 0
HI   3 L1 unit vector in outboard body coord. x,y,z             1 0 0
HI   3 L2 unit vector in inboard body coord. x,y,z
HI   3 L2 unit vector in outboard body coord. x,y,z
HI   3 L3 unit vector in inboard body coord. x,y,z              0 0 1
HI   3 L3 unit vector in outboard body coord. x,y,z             0 0 1
HI   3 Initial rotation angles (deg)                            0 0 0
HI   3 Initial rotation rates (deg/sec)
HI   3 Rotation stiffness (newton-meters/rad)
HI   3 Rotation damping (newton-meters/rad/sec)
HI   3 Null torque angles (deg)
HI   3 Number of translation DOFs                               3
HI   3 First translation unit vector   g1                       1 0 0
HI   3 Second translation unit vector  g2                       0 1 0
HI   3 Third translation unit vector   g3                       0 0 1
HI   3 Initial translation (meters)                             0 0 0
HI   3 Initial translation velocity (meters/sec)                0 0 0
HI   3 Translation stiffness (newtons/meters)                   10. 10. 10.
HI   3 Translation damping (newtons/meter/sec)                  1.125 1.125 1.125
HI   3 Null force translations                                  0 0 0

HI   4 Hinge ID number                                          4
HI   4 Inboard body ID, Outboard body ID                        1 4
HI   4 "p" node ID, "q" node ID                                 10 2
HI   4 Number of rotation DOFs, Rotation option (F or G)        0
HI   4 L1 unit vector in inboard body coord. x,y,z              1 0 0
HI   4 L1 unit vector in outboard body coord. x,y,z             1 0 0
HI   4 L2 unit vector in inboard body coord. x,y,z
HI   4 L2 unit vector in outboard body coord. x,y,z
```

```
HI   4 L3 unit vector in inboard body coord. x,y,z          0 0 1
HI   4 L3 unit vector in outboard body coord. x,y,z         0 0 1
HI   4 Initial rotation angles (deg)                        0 0 0
HI   4 Initial rotation rates (deg/sec)
HI   4 Rotation stiffness (newton-meters/rad)
HI   4 Rotation damping (newton-meters/rad/sec)
HI   4 Null torque angles (deg)
HI   4 Number of translation DOFs                           3
HI   4 First translation unit vector   g1                   1 0 0
HI   4 Second translation unit vector  g2                   0 1 0
HI   4 Third translation unit vector   g3                   0 0 1
HI   4 Initial translation (meters)                         0 0 0
HI   4 Initial translation velocity (meters/sec)            0 0 0
HI   4 Translation stiffness (newtons/meters)               10 10 10
HI   4 Translation damping (newtons/meter/sec)              1.125 1.125 1.125
HI   4 Null force translations                              0 0 0

HI   5 Hinge ID number                                      5
HI   5 Inboard body ID, Outboard body ID                    1 5
HI   5 "p" node ID, "q" node ID                             11 2
HI   5  Number of rotation DOFs                             0
HI   5 L1 unit vector in inboard body coord. x,y,z          1 0 0
HI   5 L1 unit vector in outboard body coord. x,y,z         1 0 0
HI   5 L2 unit vector in inboard body coord. x,y,z
HI   5 L2 unit vector in outboard body coord. x,y,z
HI   5 L3 unit vector in inboard body coord. x,y,z          0 0 1
HI   5 L3 unit vector in outboard body coord. x,y,z         0 0 1
HI   5 Initial rotation angles (deg)                        0 0 0
HI   5 Initial rotation rates (deg/sec)
HI   5 Rotation stiffness (newton-meters/rad)
HI   5 Rotation damping (newton-meters/rad/sec)
HI   5 Null torque angles (deg)
HI   5 Number of translation DOFs                           3
HI   5 First translation unit vector   g1                   1 0 0
HI   5 Second translation unit vector  g2                   0 1 0
HI   5 Third translation unit vector   g3                   0 0 1
HI   5 Initial translation (meters)                         0 0 0
HI   5 Initial translation velocity (meters/sec)            0 0 0
HI   5 Translation stiffness (newtons/meters)               10 10 10
HI   5 Translation damping (newtons/meter/sec)              1.125 1.125 1.125
HI   5 Null force translations                              0 0 0

HI   6 Hinge ID number                                      6
HI   6 Inboard body ID, Outboard body ID                    1 6
HI   6 "p" node ID, "q" node ID                             12 2
HI   6  Number of rotation DOFs                             0
HI   6 L1 unit vector in inboard body coord. x,y,z          1 0 0
HI   6 L1 unit vector in outboard body coord. x,y,z         1 0 0
HI   6 L2 unit vector in inboard body coord. x,y,z
HI   6 L2 unit vector in outboard body coord. x,y,z
HI   6 L3 unit vector in inboard body coord. x,y,z          0 0 1
HI   6 L3 unit vector in outboard body coord. x,y,z         0 0 1
HI   6 Initial rotation angles (deg)                        0 0 0
HI   6 Initial rotation rates (deg/sec)
HI   6 Rotation stiffness (newton-meters/rad)
HI   6 Rotation damping (newton-meters/rad/sec)
HI   6 Null torque angles (deg)
HI   6 Number of translation DOFs                           3
HI   6 First translation unit vector   g1                   1 0 0
HI   6 Second translation unit vector  g2                   0 1 0
HI   6 Third translation unit vector   g3                   0 0 1
HI   6 Initial translation (meters)                         0 0 0
HI   6 Initial translation velocity (meters/sec)            0 0 0
HI   6 Translation stiffness (newtons/meters)               10 10 10
HI   6 Translation damping (newtons/meter/sec)              1.125 1.125 1.125
HI   6 Null force translations                              0 0 0
```

SENSOR

```
SE   1 Sensor ID number                                     1
```

```
SE   1 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)   G
SE   1 Mounting point body ID, Mounting point node ID              1 3
SE   1 Second mounting point body ID, Second node ID
SE   1 Input axis unit vector (IA) x,y,z                           0 0 1
SE   1 Mounting point Hinge index, Axis index
SE   1 First focal plane unit vector  (Fp1) x,y,z
SE   1 Second focal plane unit vector (Fp2) x,y,z
SE   1 Sun/Star unit vector (Us) x,y,z
SE   1 Velocity Aberration Option (Y/N)
SE   1 Euler Angle Sequence (1-6)
SE   1 CMG ID number and Gimbal number
SE   1 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   2 Sensor ID number                                            2
SE   2 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)   G
SE   2 Mounting point body ID, Mounting point node ID              1 3
SE   2 Second mounting point body ID, Second node ID
SE   2 Input axis unit vector (IA) x,y,z                           0 1 0
SE   2 Mounting point Hinge index, Axis index
SE   2 First focal plane unit vector  (Fp1) x,y,z
SE   2 Second focal plane unit vector (Fp2) x,y,z
SE   2 Sun/Star unit vector (Us) x,y,z
SE   2 Velocity Aberration Option (Y/N)
SE   2 Euler Angle Sequence (1-6)
SE   2 CMG ID number and Gimbal number
SE   2 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   3 Sensor ID number                                            3
SE   3 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)   G
SE   3 Mounting point body ID, Mounting point node ID              1 3
SE   3 Second mounting point body ID, Second node ID
SE   3 Input axis unit vector (IA) x,y,z                           1 0 0
SE   3 Mounting point Hinge index, Axis index
SE   3 First focal plane unit vector  (Fp1) x,y,z
SE   3 Second focal plane unit vector (Fp2) x,y,z
SE   3 Sun/Star unit vector (Us) x,y,z
SE   3 Velocity Aberration Option (Y/N)
SE   3 Euler Angle Sequence (1-6)
SE   3 CMG ID number and Gimbal number
SE   3 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   4 Sensor ID number                                            4
SE   4 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)   ST
SE   4 Mounting point body ID, Mounting point node ID              1 2
SE   4 Second mounting point body ID, Second node ID
SE   4 Input axis unit vector (IA) x,y,z
SE   4 Mounting point Hinge index, Axis index
SE   4 First focal plane unit vector  (Fp1) x,y,z                  1 0 0
SE   4 Second focal plane unit vector (Fp2) x,y,z                  0 1 0
SE   4 Sun/Star unit vector (Us) x,y,z                             -0.2756889168 0.2897184368
0.9165472429
SE   4 Velocity Aberration Option (Y/N)                            Y
SE   4 Euler Angle Sequence (1-6)
SE   4 CMG ID number and Gimbal number
SE   4 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   5 Sensor ID number                                            5
SE   5 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)   P3
SE   5 Mounting point body ID, Mounting point node ID              1 4
SE   5 Second mounting point body ID, Second node ID               2 1
SE   5 Input axis unit vector (IA) x,y,z
SE   5 Mounting point Hinge index, Axis index
SE   5 First focal plane unit vector  (Fp1) x,y,z
SE   5 Second focal plane unit vector (Fp2) x,y,z
SE   5 Sun/Star unit vector (Us) x,y,z
SE   5 Velocity Aberration Option (Y/N)
SE   5 Euler Angle Sequence (1-6)
SE   5 CMG ID number and Gimbal number
SE   5 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   6 Sensor ID number                                            6
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SE    6 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)    AC
SE    6 Mounting point body ID, Mounting point node ID                2 1
SE    6 Second mounting point body ID, Second node ID
SE    6 Input axis unit vector (IA) x,y,z                             1 0 0
SE    6 Mounting point Hinge index, Axis index
SE    6 First focal plane unit vector  (Fp1) x,y,z
SE    6 Second focal plane unit vector (Fp2) x,y,z
SE    6 Sun/Star unit vector (Us) x,y,z
SE    6 Velocity Aberration Option (Y/N)
SE    6 Euler Angle Sequence (1-6)
SE    6 CMG ID number and Gimbal number
SE    6 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE    7 Sensor ID number                                              7
SE    7 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)    AC
SE    7 Mounting point body ID, Mounting point node ID                2 1
SE    7 Second mounting point body ID, Second node ID
SE    7 Input axis unit vector (IA) x,y,z                             0 1 0
SE    7 Mounting point Hinge index, Axis index
SE    7 First focal plane unit vector  (Fp1) x,y,z
SE    7 Second focal plane unit vector (Fp2) x,y,z
SE    7 Sun/Star unit vector (Us) x,y,z
SE    7 Velocity Aberration Option (Y/N)
SE    7 Euler Angle Sequence (1-6)
SE    7 CMG ID number and Gimbal number
SE    7 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE    8 Sensor ID number                                              8
SE    8 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)    AC
SE    8 Mounting point body ID, Mounting point node ID                2 1
SE    8 Second mounting point body ID, Second node ID
SE    8 Input axis unit vector (IA) x,y,z                             0 0 1
SE    8 Mounting point Hinge index, Axis index
SE    8 First focal plane unit vector  (Fp1) x,y,z
SE    8 Second focal plane unit vector (Fp2) x,y,z
SE    8 Sun/Star unit vector (Us) x,y,z
SE    8 Velocity Aberration Option (Y/N)
SE    8 Euler Angle Sequence (1-6)
SE    8 CMG ID number and Gimbal number
SE    8 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE    9 Sensor ID number                                              9
SE    9 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)    I
SE    9 Mounting point body ID, Mounting point node ID                1 3
SE    9 Second mounting point body ID, Second node ID
SE    9 Input axis unit vector (IA) x,y,z                             0 0 1
SE    9 Mounting point Hinge index, Axis index
SE    9 First focal plane unit vector  (Fp1) x,y,z
SE    9 Second focal plane unit vector (Fp2) x,y,z
SE    9 Sun/Star unit vector (Us) x,y,z
SE    9 Velocity Aberration Option (Y/N)
SE    9 Euler Angle Sequence (1-6)
SE    9 CMG ID number and Gimbal number
SE    9 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   10 Sensor ID number                                              10
SE   10 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)    P3
SE   10 Mounting point body ID, Mounting point node ID                1 9
SE   10 Second mounting point body ID, Second node ID                 3 1
SE   10 Input axis unit vector (IA) x,y,z
SE   10 Mounting point Hinge index, Axis index
SE   10 First focal plane unit vector  (Fp1) x,y,z
SE   10 Second focal plane unit vector (Fp2) x,y,z
SE   10 Sun/Star unit vector (Us) x,y,z
SE   10 Velocity Aberration Option (Y/N)
SE   10 Euler Angle Sequence (1-6)
SE   10 CMG ID number and Gimbal number
SE   10 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   11 Sensor ID number                                              11
SE   11 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)    V3
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SE  11 Mounting point body ID, Mounting point node ID                     1 9
SE  11 Second mounting point body ID, Second node ID                      3 1
SE  11 Input axis unit vector (IA) x,y,z
SE  11 Mounting point Hinge index, Axis index
SE  11 First focal plane unit vector  (Fp1) x,y,z
SE  11 Second focal plane unit vector (Fp2) x,y,z
SE  11 Sun/Star unit vector (Us) x,y,z
SE  11 Velocity Aberration Option (Y/N)
SE  11 Euler Angle Sequence (1-6)
SE  11 CMG ID number and Gimbal number
SE  11 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  12 Sensor ID number                                                   12
SE  12 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)          FM
SE  12 Mounting point body ID, Mounting point node ID                     1 1
SE  12 Second mounting point body ID, Second node ID
SE  12 Input axis unit vector (IA) x,y,z
SE  12 Mounting point Hinge index, Axis index
SE  12 First focal plane unit vector  (Fp1) x,y,z
SE  12 Second focal plane unit vector (Fp2) x,y,z
SE  12 Sun/Star unit vector (Us) x,y,z
SE  12 Velocity Aberration Option (Y/N)
SE  12 Euler Angle Sequence (1-6)
SE  12 CMG ID number and Gimbal number
SE  12 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  13 Sensor ID number                                                   13
SE  13 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)          FM
SE  13 Mounting point body ID, Mounting point node ID                     1 2
SE  13 Second mounting point body ID, Second node ID
SE  13 Input axis unit vector (IA) x,y,z
SE  13 Mounting point Hinge index, Axis index
SE  13 First focal plane unit vector  (Fp1) x,y,z
SE  13 Second focal plane unit vector (Fp2) x,y,z
SE  13 Sun/Star unit vector (Us) x,y,z
SE  13 Velocity Aberration Option (Y/N)
SE  13 Euler Angle Sequence (1-6)
SE  13 CMG ID number and Gimbal number
SE  13 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  14 Sensor ID number                                                   14
SE  14 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)          FM
SE  14 Mounting point body ID, Mounting point node ID                     1 13
SE  14 Second mounting point body ID, Second node ID
SE  14 Input axis unit vector (IA) x,y,z
SE  14 Mounting point Hinge index, Axis index
SE  14 First focal plane unit vector  (Fp1) x,y,z
SE  14 Second focal plane unit vector (Fp2) x,y,z
SE  14 Sun/Star unit vector (Us) x,y,z
SE  14 Velocity Aberration Option (Y/N)
SE  14 Euler Angle Sequence (1-6)
SE  14 CMG ID number and Gimbal number
SE  14 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  15 Sensor ID number                                                   15
SE  15 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)          DN
SE  15 Mounting point body ID, Mounting point node ID                     1 1
SE  15 Second mounting point body ID, Second node ID
SE  15 Input axis unit vector (IA) x,y,z                                  1 0 0
SE  15 Mounting point Hinge index, Axis index
SE  15 First focal plane unit vector  (Fp1) x,y,z
SE  15 Second focal plane unit vector (Fp2) x,y,z
SE  15 Sun/Star unit vector (Us) x,y,z
SE  15 Velocity Aberration Option (Y/N)
SE  15 Euler Angle Sequence (1-6)
SE  15 CMG ID number and Gimbal number
SE  15 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  16 Sensor ID number                                                   16
SE  16 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)          MG
SE  16 Mounting point body ID, Mounting point node ID                     1 1
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SE  16 Second mounting point body ID, Second node ID
SE  16 Input axis unit vector (IA) x,y,z                              1 0 0
SE  16 Mounting point Hinge index, Axis index
SE  16 First focal plane unit vector  (Fp1) x,y,z
SE  16 Second focal plane unit vector (Fp2) x,y,z
SE  16 Sun/Star unit vector (Us) x,y,z
SE  16 Velocity Aberration Option (Y/N)
SE  16 Euler Angle Sequence (1-6)
SE  16 CMG ID number and Gimbal number
SE  16 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  17 Sensor ID number                                               17
SE  17 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      LV
SE  17 Mounting point body ID, Mounting point node ID                 1,1
SE  17 Second mounting point body ID, Second node ID
SE  17 Input axis unit vector (IA) x,y,z
SE  17 Mounting point Hinge index, Axis index
SE  17 First focal plane unit vector  (Fp1) x,y,z
SE  17 Second focal plane unit vector (Fp2) x,y,z
SE  17 Sun/Star unit vector (Us) x,y,z
SE  17 Velocity Aberration Option (Y/N)
SE  17 Euler Angle Sequence (1-6)
SE  17 CMG ID number and Gimbal number
SE  17 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  18 Sensor ID number                                               18
SE  18 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      FM
SE  18 Mounting point body ID, Mounting point node ID                 2 1
SE  18 Second mounting point body ID, Second node ID
SE  18 Input axis unit vector (IA) x,y,z
SE  18 Mounting point Hinge index, Axis index
SE  18 First focal plane unit vector  (Fp1) x,y,z
SE  18 Second focal plane unit vector (Fp2) x,y,z
SE  18 Sun/Star unit vector (Us) x,y,z
SE  18 Velocity Aberration Option (Y/N)
SE  18 Euler Angle Sequence (1-6)
SE  18 CMG ID number and Gimbal number
SE  18 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  19 Sensor ID number                                               19
SE  19 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      AN
SE  19 Mounting point body ID, Mounting point node ID                 1 2
SE  19 Second mounting point body ID, Second node ID
SE  19 Input axis unit vector (IA) x,y,z                              1 0 0
SE  19 Mounting point Hinge index, Axis index
SE  19 First focal plane unit vector  (Fp1) x,y,z
SE  19 Second focal plane unit vector (Fp2) x,y,z
SE  19 Sun/Star unit vector (Us) x,y,z
SE  19 Velocity Aberration Option (Y/N)
SE  19 Euler Angle Sequence (1-6)
SE  19 CMG ID number and Gimbal number
SE  19 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  20 Sensor ID number                                               20
SE  20 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      AN
SE  20 Mounting point body ID, Mounting point node ID                 1 2
SE  20 Second mounting point body ID, Second node ID
SE  20 Input axis unit vector (IA) x,y,z                              0 1 0
SE  20 Mounting point Hinge index, Axis index
SE  20 First focal plane unit vector  (Fp1) x,y,z
SE  20 Second focal plane unit vector (Fp2) x,y,z
SE  20 Sun/Star unit vector (Us) x,y,z
SE  20 Velocity Aberration Option (Y/N)
SE  20 Euler Angle Sequence (1-6)
SE  20 CMG ID number and Gimbal number
SE  20 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

        ACTR

AC   1 Actuator ID number                                             1
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```
AC   1 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                      J
AC   1 Actuator location; Node or Hinge (N or H)
AC   1 Mounting point body ID number, node ID number            1 5
AC   1 Second mounting point body ID, second node ID
AC   1 Output axis unit vector x,y,z                            1 0 0
AC   1 Mounting point Hinge index, Axis index
AC   1 Rotor spin axis unit vector x,y,z
AC   1 Initial rotor momentum, H
AC   1 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   1 Outer gimbal axis unit vector x,y,z
AC   1 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   1 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   1 Inner gimbal axis unit vector x,y,z
AC   1 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   1 Initial length and rate, y(to) and ydot(to)
AC   1 Constants; K1 or wo, n or zeta, Kg, Jm
AC   1 Non-linearities; TLim, Tco, Dz

AC   2 Actuator ID number                                       2
AC   2 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                      J
AC   2 Actuator location; Node or Hinge (N or H)
AC   2 Mounting point body ID number, node ID number            1 6
AC   2 Second mounting point body ID, second node ID
AC   2 Output axis unit vector x,y,z                            -1 0 0
AC   2 Mounting point Hinge index, Axis index
AC   2 Rotor spin axis unit vector x,y,z
AC   2 Initial rotor momentum, H
AC   2 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   2 Outer gimbal axis unit vector x,y,z
AC   2 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   2 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   2 Inner gimbal axis unit vector x,y,z
AC   2 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   2 Initial length and rate, y(to) and ydot(to)
AC   2 Constants; K1 or wo, n or zeta, Kg, Jm
AC   2 Non-linearities; TLim, Tco, Dz

AC   3 Actuator ID number                                       3
AC   3 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                      J
AC   3 Actuator location; Node or Hinge (N or H)
AC   3 Mounting point body ID number, node ID number            1 7
AC   3 Second mounting point body ID, second node ID
AC   3 Output axis unit vector x,y,z                            1 0 0
AC   3 Mounting point Hinge index, Axis index
AC   3 Rotor spin axis unit vector x,y,z
AC   3 Initial rotor momentum, H
AC   3 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   3 Outer gimbal axis unit vector x,y,z
AC   3 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   3 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   3 Inner gimbal axis unit vector x,y,z
AC   3 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   3 Initial length and rate, y(to) and ydot(to)
AC   3 Constants; K1 or wo, n or zeta, Kg, Jm
AC   3 Non-linearities; TLim, Tco, Dz

AC   4 Actuator ID number                                       4
AC   4 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                      J
AC   4 Actuator location; Node or Hinge (N or H)
AC   4 Mounting point body ID number, node ID number            1 8
AC   4 Second mounting point body ID, second node ID
AC   4 Output axis unit vector x,y,z                            -1 0 0
AC   4 Mounting point Hinge index, Axis index
AC   4 Rotor spin axis unit vector x,y,z
AC   4 Initial rotor momentum, H
AC   4 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   4 Outer gimbal axis unit vector x,y,z
AC   4 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   4 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   4 Inner gimbal axis unit vector x,y,z
AC   4 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
```

```
AC   4 Initial length and rate, y(to) and ydot(to)
AC   4 Constants; K1 or wo, n or zeta, Kg, Jm
AC   4 Non-linearities; TLim, Tco, Dz

AC   5 Actuator ID number                                        5
AC   5 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       J
AC   5 Actuator location; Node or Hinge (N or H)
AC   5 Mounting point body ID number, node ID number             1 8
AC   5 Second mounting point body ID, second node ID
AC   5 Output axis unit vector x,y,z                             0 1 0
AC   5 Mounting point Hinge index, Axis index
AC   5 Rotor spin axis unit vector x,y,z
AC   5 Initial rotor momentum, H
AC   5 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   5 Outer gimbal axis unit vector x,y,z
AC   5 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   5 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   5 Inner gimbal axis unit vector x,y,z
AC   5 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   5 Initial length and rate, y(to) and ydot(to)
AC   5 Constants; K1 or wo, n or zeta, Kg, Jm
AC   5 Non-linearities; TLim, Tco, Dz

AC   6 Actuator ID number                                        6
AC   6 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       J
AC   6 Actuator location; Node or Hinge (N or H)
AC   6 Mounting point body ID number, node ID number             1 8
AC   6 Second mounting point body ID, second node ID
AC   6 Output axis unit vector x,y,z                             0 -1 0
AC   6 Mounting point Hinge index, Axis index
AC   6 Rotor spin axis unit vector x,y,z
AC   6 Initial rotor momentum, H
AC   6 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   6 Outer gimbal axis unit vector x,y,z
AC   6 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   6 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   6 Inner gimbal axis unit vector x,y,z
AC   6 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   6 Initial length and rate, y(to) and ydot(to)
AC   6 Constants; K1 or wo, n or zeta, Kg, Jm
AC   6 Non-linearities; TLim, Tco, Dz

AC   7 Actuator ID number                                        7
AC   7 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       J
AC   7 Actuator location; Node or Hinge (N or H)
AC   7 Mounting point body ID number, node ID number             1 5
AC   7 Second mounting point body ID, second node ID
AC   7 Output axis unit vector x,y,z                             0 1 0
AC   7 Mounting point Hinge index, Axis index
AC   7 Rotor spin axis unit vector x,y,z
AC   7 Initial rotor momentum, H
AC   7 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   7 Outer gimbal axis unit vector x,y,z
AC   7 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   7 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   7 Inner gimbal axis unit vector x,y,z
AC   7 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   7 Initial length and rate, y(to) and ydot(to)
AC   7 Constants; K1 or wo, n or zeta, Kg, Jm
AC   7 Non-linearities; TLim, Tco, Dz

AC   8 Actuator ID number                                        8
AC   8 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       J
AC   8 Actuator location; Node or Hinge (N or H)
AC   8 Mounting point body ID number, node ID number             1 5
AC   8 Second mounting point body ID, second node ID
AC   8 Output axis unit vector x,y,z                             0 -1 0
AC   8 Mounting point Hinge index, Axis index
AC   8 Rotor spin axis unit vector x,y,z
AC   8 Initial rotor momentum, H
AC   8 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
```

```
AC    8 Outer gimbal axis unit vector x,y,z
AC    8 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC    8 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC    8 Inner gimbal axis unit vector x,y,z
AC    8 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC    8 Initial length and rate, y(to) and ydot(to)
AC    8 Constants; K1 or wo, n or zeta, Kg, Jm
AC    8 Non-linearities; TLim, Tco, Dz

AC    9 Actuator ID number                                   9
AC    9 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
AC    9 Actuator location; Node or Hinge (N or H)
AC    9 Mounting point body ID number, node ID number        1 7
AC    9 Second mounting point body ID, second node ID
AC    9 Output axis unit vector x,y,z                        0 1 0
AC    9 Mounting point Hinge index, Axis index
AC    9 Rotor spin axis unit vector x,y,z
AC    9 Initial rotor momentum, H
AC    9 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC    9 Outer gimbal axis unit vector x,y,z
AC    9 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC    9 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC    9 Inner gimbal axis unit vector x,y,z
AC    9 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC    9 Initial length and rate, y(to) and ydot(to)
AC    9 Constants; K1 or wo, n or zeta, Kg, Jm
AC    9 Non-linearities; TLim, Tco, Dz

AC   10 Actuator ID number                                   10
AC   10 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
AC   10 Actuator location; Node or Hinge (N or H)
AC   10 Mounting point body ID number, node ID number        1 7
AC   10 Second mounting point body ID, second node ID
AC   10 Output axis unit vector x,y,z                        0 -1 0
AC   10 Mounting point Hinge index, Axis index
AC   10 Rotor spin axis unit vector x,y,z
AC   10 Initial rotor momentum, H
AC   10 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   10 Outer gimbal axis unit vector x,y,z
AC   10 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   10 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   10 Inner gimbal axis unit vector x,y,z
AC   10 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   10 Initial length and rate, y(to) and ydot(to)
AC   10 Constants; K1 or wo, n or zeta, Kg, Jm
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AC   11 Actuator ID number                                   11
AC   11 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
AC   11 Actuator location; Node or Hinge (N or H)
AC   11 Mounting point body ID number, node ID number        1 6
AC   11 Second mounting point body ID, second node ID
AC   11 Output axis unit vector x,y,z                        0 1 0
AC   11 Mounting point Hinge index, Axis index
AC   11 Rotor spin axis unit vector x,y,z
AC   11 Initial rotor momentum, H
AC   11 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   11 Outer gimbal axis unit vector x,y,z
AC   11 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   11 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   11 Inner gimbal axis unit vector x,y,z
AC   11 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   11 Initial length and rate, y(to) and ydot(to)
AC   11 Constants; K1 or wo, n or zeta, Kg, Jm
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AC   12 Actuator ID number                                   12
AC   12 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
AC   12 Actuator location; Node or Hinge (N or H)
AC   12 Mounting point body ID number, node ID number        1 6
AC   12 Second mounting point body ID, second node ID
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AC  12 Output axis unit vector x,y,z                                0 -1 0
AC  12 Mounting point Hinge index, Axis index
AC  12 Rotor spin axis unit vector x,y,z
AC  12 Initial rotor momentum, H
AC  12 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
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AC  12 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  13 Actuator ID number                                           13
AC  13 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                          J
AC  13 Actuator location; Node or Hinge (N or H)
AC  13 Mounting point body ID number, node ID number                1 7
AC  13 Second mounting point body ID, second node ID
AC  13 Output axis unit vector x,y,z                                0 0 1
AC  13 Mounting point Hinge index, Axis index
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AC  13 Initial rotor momentum, H
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AC  13 Constants; K1 or wo, n or zeta, Kg, Jm
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AC  14 Actuator ID number                                           14
AC  14 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                          J
AC  14 Actuator location; Node or Hinge (N or H)
AC  14 Mounting point body ID number, node ID number                1 5
AC  14 Second mounting point body ID, second node ID
AC  14 Output axis unit vector x,y,z                                0 0 -1
AC  14 Mounting point Hinge index, Axis index
AC  14 Rotor spin axis unit vector x,y,z
AC  14 Initial rotor momentum, H
AC  14 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  14 Outer gimbal axis unit vector x,y,z
AC  14 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  14 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  14 Inner gimbal axis unit vector x,y,z
AC  14 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  15 Actuator ID number                                           15
AC  15 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                          J
AC  15 Actuator location; Node or Hinge (N or H)
AC  15 Mounting point body ID number, node ID number                1 8
AC  15 Second mounting point body ID, second node ID
AC  15 Output axis unit vector x,y,z                                0 0 1
AC  15 Mounting point Hinge index, Axis index
AC  15 Rotor spin axis unit vector x,y,z
AC  15 Initial rotor momentum, H
AC  15 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  15 Outer gimbal axis unit vector x,y,z
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AC  16 Actuator ID number                                            16
AC  16 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                           J
AC  16 Actuator location; Node or Hinge (N or H)
AC  16 Mounting point body ID number, node ID number                 1 6
AC  16 Second mounting point body ID, second node ID
AC  16 Output axis unit vector x,y,z                                 0 0 -1
AC  16 Mounting point Hinge index, Axis index
AC  16 Rotor spin axis unit vector x,y,z
AC  16 Initial rotor momentum, H
AC  16 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  16 Outer gimbal axis unit vector x,y,z
AC  16 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  16 Inner gimbal axis unit vector x,y,z
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AC  17 Actuator ID number                                            17
AC  17 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                           J
AC  17 Actuator location; Node or Hinge (N or H)
AC  17 Mounting point body ID number, node ID number                 1 2
AC  17 Second mounting point body ID, second node ID
AC  17 Output axis unit vector x,y,z                                 1 0 0
AC  17 Mounting point Hinge index, Axis index
AC  17 Rotor spin axis unit vector x,y,z
AC  17 Initial rotor momentum, H
AC  17 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
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AC  17 Constants; K1 or wo, n or zeta, Kg, Jm
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AC  18 Actuator ID number                                            18
AC  18 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                           J
AC  18 Actuator location; Node or Hinge (N or H)
AC  18 Mounting point body ID number, node ID number                 1 2
AC  18 Second mounting point body ID, second node ID
AC  18 Output axis unit vector x,y,z                                 0 1 0
AC  18 Mounting point Hinge index, Axis index
AC  18 Rotor spin axis unit vector x,y,z
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AC  18 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
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AC  19 Actuator ID number                                            19
AC  19 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                           J
AC  19 Actuator location; Node or Hinge (N or H)
AC  19 Mounting point body ID number, node ID number                 1 2
AC  19 Second mounting point body ID, second node ID
AC  19 Output axis unit vector x,y,z                                 0 0 1
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AC  19 Rotor spin axis unit vector x,y,z
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AC  19 Outer gimbal axis unit vector x,y,z
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AC  19 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  19 Inner gimbal axis unit vector x,y,z
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AC  19 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  19 Initial length and rate, y(to) and ydot(to)
AC  19 Constants; K1 or wo, n or zeta, Kg, Jm
AC  19 Non-linearities; TLim, Tco, Dz

AC  20 Actuator ID number                                        20
AC  20 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       MO
AC  20 Actuator location; Node or Hinge (N or H)
AC  20 Mounting point body ID number, node ID number             1 2
AC  20 Second mounting point body ID, second node ID
AC  20 Output axis unit vector x,y,z                             1 0 0
AC  20 Mounting point Hinge index, Axis index
AC  20 Rotor spin axis unit vector x,y,z
AC  20 Initial rotor momentum, H
AC  20 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  20 Outer gimbal axis unit vector x,y,z
AC  20 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  22 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       MO
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AC  22 Second mounting point body ID, second node ID
AC  22 Output axis unit vector x,y,z                             0 0 1
AC  22 Mounting point Hinge index, Axis index
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AC  23 Actuator ID number                                        23
AC  23 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       MA
AC  23 Actuator location; Node or Hinge (N or H)
AC  23 Mounting point body ID number, node ID number             1 2
AC  23 Second mounting point body ID, second node ID
AC  23 Output axis unit vector x,y,z                             1 0 0
AC  23 Mounting point Hinge index, Axis index
AC  23 Rotor spin axis unit vector x,y,z
AC  23 Initial rotor momentum, H
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AC  23 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  23 Outer gimbal axis unit vector x,y,z
AC  23 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  24 Actuator ID number                                 24
AC  24 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                MA
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AC  26 Actuator ID number                                 26
AC  26 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                J
AC  26 Actuator location; Node or Hinge (N or H)
AC  26 Mounting point body ID number, node ID number      3 2
AC  26 Second mounting point body ID, second node ID
AC  26 Output axis unit vector x,y,z                      1 0 0
AC  26 Mounting point Hinge index, Axis index
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AC  27 Actuator ID number                                 27
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AC  27 Actuator location; Node or Hinge (N or H)
AC  27 Mounting point body ID number, node ID number      3 2
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AC  27 Second mounting point body ID, second node ID
AC  27 Output axis unit vector x,y,z                           0 1 0
AC  27 Mounting point Hinge index, Axis index
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AC  28 Initial length and rate, y(to) and ydot(to)
AC  28 Constants; K1 or wo, n or zeta, Kg, Jm
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AC  29 Actuator ID number                                      29
AC  29 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7,US)                  MO
AC  29 Actuator location; Node or Hinge (N or H)
AC  29 Mounting point body ID number, node ID number           1 2
AC  29 Second mounting point body ID, second node ID
AC  29 Output axis unit vector x,y,z                           1 0 0
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AC  29 Initial rotor momentum, H
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AC  30 Mounting point body ID number, node ID number           1 2
AC  30 Second mounting point body ID, second node ID
AC  30 Output axis unit vector x,y,z                           0 1 0
AC  30 Mounting point Hinge index, Axis index
AC  30 Rotor spin axis unit vector x,y,z
AC  30 Initial rotor momentum, H
AC  30 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  30 Outer gimbal axis unit vector x,y,z
AC  30 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  30 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  30 Inner gimbal axis unit vector x,y,z
AC  30 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  30 Initial length and rate, y(to) and ydot(to)
AC  30 Constants; K1 or wo, n or zeta, Kg, Jm
AC  30 Non-linearities; TLim, Tco, Dz
```

```
          CONTROLLER

CO   1 Controller ID number                                       1
CO   1 Controller type (CB,CM,DB,DM,UC,UD)                        UD
CO   1 Sample time (sec)                                          0.10
CO   1 Number of inputs, Number of outputs                        21 16
CO   1 Number of states
CO   1 Output No., Input type (I,S,T), Input ID, Gain

CO   2 Controller ID number                                       2
CO   2 Controller type (CB,CM,DB,DM,UC,UD)                        UC
CO   2 Sample time (sec)
CO   2 Number of inputs, Number of outputs                        6,6
CO   2 Number of states                                           0
CO   2 Output No., Input type (I,S,T), Input ID, Gain

CO   3 Controller ID number                                       3
CO   3 Controller type (CB,CM,DB,DM,UC,UD)                        CB
CO   3 Sample time (sec)
CO   3 Number of inputs, Number of outputs                        2 2
CO   3 Number of states
CO   3 Output No., Input type (I,S,T), Input ID, Gain             1 T 1 1
CO   3 Output No., Input type (I,S,T), Input ID, Gain             2 T 2 1

          TRANSFER FUN

TR   1 Transfer function ID number                                1
TR   1 Controller ID number                                       3
TR   1 Input type (I,S or T), Input ID number                     I 1
TR   1 Order of numerator                                         12
TR   1 Numerator coefficients (4 per line max)                    0 0 0 0
TR   1 Numerator coefficients (4 per line max)                    0 0 0 0
TR   1 Numerator coefficients (4 per line max)                    0 0 0 0
TR   1 Numerator coefficients (4 per line max)                    0.9794
TR   1 Order of denominator                                       14
TR   1 Denominator coefficients (4 per line max)                  0 0 0 0
TR   1 Denominator coefficients (4 per line max)                  0 0 0 0
TR   1 Denominator coefficients (4 per line max)                  0 0 0 0
TR   1 Denominator coefficients (4 per line max)                  0 0 0
TR   1 Transfer function gain                                     1

TR   2 Transfer function ID number                                2
TR   2 Controller ID number                                       3
TR   2 Input type (I,S or T), Input ID number                     I 2
TR   2 Order of numerator                                         12
TR   2 Numerator coefficients (4 per line max)                    0 0 0 0
TR   2 Numerator coefficients (4 per line max)                    0 0 0 0
TR   2 Numerator coefficients (4 per line max)                    0 0 0 0
TR   2 Numerator coefficients (4 per line max)                    0
TR   2 Order of denominator                                       14
TR   2 Denominator coefficients (4 per line max)                  0 0 0 0
TR   2 Denominator coefficients (4 per line max)                  0 0 0 0
TR   2 Denominator coefficients (4 per line max)                  0 0 0 0
TR   2 Denominator coefficients (4 per line max)                  0 0 0
TR   2 Transfer function gain                                     1

          INTERCONNECT

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

IN   2 Interconnect ID number                                     2
IN   2 Source type(S,C, or F),Source ID,Source row #              C 1 2
IN   2 Destination type(A or C),Dest ID,Dest row #                A 2 1
IN   2 Gain                                                       1
```

```
IN   3 Interconnect ID number                                3
IN   3 Source type(S,C, or F),Source ID,Source row #         C 1 3
IN   3 Destination type(A or C),Dest ID,Dest row #           A 3 1
IN   3 Gain                                                  1

IN   4 Interconnect ID number                                4
IN   4 Source type(S,C, or F),Source ID,Source row #         C 1 4
IN   4 Destination type(A or C),Dest ID,Dest row #           A 4 1
IN   4 Gain                                                  1

IN   5 Interconnect ID number                                5
IN   5 Source type(S,C, or F),Source ID,Source row #         C 1 5
IN   5 Destination type(A or C),Dest ID,Dest row #           A 5 1
IN   5 Gain                                                  1

IN   6 Interconnect ID number                                6
IN   6 Source type(S,C, or F),Source ID,Source row #         C 1 6
IN   6 Destination type(A or C),Dest ID,Dest row #           A 6 1
IN   6 Gain                                                  1

IN   7 Interconnect ID number                                7
IN   7 Source type(S,C, or F),Source ID,Source row #         C 1 7
IN   7 Destination type(A or C),Dest ID,Dest row #           A 7 1
IN   7 Gain                                                  1

IN   8 Interconnect ID number                                8
IN   8 Source type(S,C, or F),Source ID,Source row #         C 1 8
IN   8 Destination type(A or C),Dest ID,Dest row #           A 8 1
IN   8 Gain                                                  1

IN   9 Interconnect ID number                                9
IN   9 Source type(S,C, or F),Source ID,Source row #         C 1 9
IN   9 Destination type(A or C),Dest ID,Dest row #           A 9 1
IN   9 Gain                                                  1

IN  10 Interconnect ID number                                10
IN  10 Source type(S,C, or F),Source ID,Source row #         C 1 10
IN  10 Destination type(A or C),Dest ID,Dest row #           A 10 1
IN  10 Gain                                                  1

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

IN  12 Interconnect ID number                                12
IN  12 Source type(S,C, or F),Source ID,Source row #         C 1 12
IN  12 Destination type(A or C),Dest ID,Dest row #           A 12 1
IN  12 Gain                                                  1

IN  13 Interconnect ID number                                13
IN  13 Source type(S,C, or F),Source ID,Source row #         C 1 13
IN  13 Destination type(A or C),Dest ID,Dest row #           A 13 1
IN  13 Gain                                                  1

IN  14 Interconnect ID number                                14
IN  14 Source type(S,C, or F),Source ID,Source row #         C 1 14
IN  14 Destination type(A or C),Dest ID,Dest row #           A 14 1
IN  14 Gain                                                  1

IN  15 Interconnect ID number                                15
IN  15 Source type(S,C, or F),Source ID,Source row #         C 1 15
IN  15 Destination type(A or C),Dest ID,Dest row #           A 15 1
IN  15 Gain                                                  1

IN  16 Interconnect ID number                                16
IN  16 Source type(S,C, or F),Source ID,Source row #         C 1 16
IN  16 Destination type(A or C),Dest ID,Dest row #           A 16 1
IN  16 Gain                                                  1
```

```
IN  26 Interconnect ID number                                  26
IN  26 Source type(S,C, or F),Source ID,Source row #           S 1 1
IN  26 Destination type(A or C),Dest ID,Dest row #             C 1 1
IN  26 Gain                                                    1

IN  27 Interconnect ID number                                  27
IN  27 Source type(S,C, or F),Source ID,Source row #           S 2 1
IN  27 Destination type(A or C),Dest ID,Dest row #             C 1 2
IN  27 Gain                                                    1

IN  28 Interconnect ID number                                  28
IN  28 Source type(S,C, or F),Source ID,Source row #           S 3 1
IN  28 Destination type(A or C),Dest ID,Dest row #             C 1 3
IN  28 Gain                                                    1

IN  29 Interconnect ID number                                  29
IN  29 Source type(S,C, or F),Source ID,Source row #           S 4 1
IN  29 Destination type(A or C),Dest ID,Dest row #             C 1 4
IN  29 Gain                                                    1

IN  30 Interconnect ID number                                  30
IN  30 Source type(S,C, or F),Source ID,Source row #           S 4 2
IN  30 Destination type(A or C),Dest ID,Dest row #             C 1 5
IN  30 Gain                                                    1

IN  31 Interconnect ID number                                  31
IN  31 Source type(S,C, or F),Source ID,Source row #           S 5 1
IN  31 Destination type(A or C),Dest ID,Dest row #             C 1 6
IN  31 Gain                                                    1

IN  32 Interconnect ID number                                  32
IN  32 Source type(S,C, or F),Source ID,Source row #           S 5 2
IN  32 Destination type(A or C),Dest ID,Dest row #             C 1 7
IN  32 Gain                                                    1

IN  33 Interconnect ID number                                  33
IN  33 Source type(S,C, or F),Source ID,Source row #           S 5 3
IN  33 Destination type(A or C),Dest ID,Dest row #             C 1 8
IN  33 Gain                                                    1

IN  34 Interconnect ID number                                  34
IN  34 Source type(S,C, or F),Source ID,Source row #           S 6 1
IN  34 Destination type(A or C),Dest ID,Dest row #             C 1 9
IN  34 Gain                                                    1

IN  35 Interconnect ID number                                  35
IN  35 Source type(S,C, or F),Source ID,Source row #           S 7 1
IN  35 Destination type(A or C),Dest ID,Dest row #             C 1 10
IN  35 Gain                                                    1

IN  36 Interconnect ID number                                  36
IN  36 Source type(S,C, or F),Source ID,Source row #           S 8 1
IN  36 Destination type(A or C),Dest ID,Dest row #             C 1 11
IN  36 Gain                                                    1

IN  37 Interconnect ID number                                  37
IN  37 Source type(S,C, or F),Source ID,Source row #           S 9 1
IN  37 Destination type(A or C),Dest ID,Dest row #             C 1 12
IN  37 Gain                                                    1

IN  38 Interconnect ID number                                  38
IN  38 Source type(S,C, or F),Source ID,Source row #           S 10 1
IN  38 Destination type(A or C),Dest ID,Dest row #             C 2 1
IN  38 Gain                                                    1

IN  39 Interconnect ID number                                  39
IN  39 Source type(S,C, or F),Source ID,Source row #           S 10 2
IN  39 Destination type(A or C),Dest ID,Dest row #             C 2 2
IN  39 Gain                                                    1

IN  40 Interconnect ID number                                  40
```

```
IN  40 Source type(S,C, or F),Source ID,Source row #          S 10 3
IN  40 Destination type(A or C),Dest ID,Dest row #            C 2 3
IN  40 Gain                                                   1

IN  41 Interconnect ID number                                 41
IN  41 Source type(S,C, or F),Source ID,Source row #          S 11 1
IN  41 Destination type(A or C),Dest ID,Dest row #            C 2 4
IN  41 Gain                                                   1

IN  42 Interconnect ID number                                 42
IN  42 Source type(S,C, or F),Source ID,Source row #          S 11 2
IN  42 Destination type(A or C),Dest ID,Dest row #            C 2 5
IN  42 Gain                                                   1

IN  43 Interconnect ID number                                 43
IN  43 Source type(S,C, or F),Source ID,Source row #          S 11 3
IN  43 Destination type(A or C),Dest ID,Dest row #            C 2 6
IN  43 Gain                                                   1

IN  17 Interconnect ID number                                 17
IN  17 Source type(S,C, or F),Source ID,Source row #          C 2 1
IN  17 Destination type(A or C),Dest ID,Dest row #            A 26 1
IN  17 Gain                                                   0

IN  18 Interconnect ID number                                 18
IN  18 Source type(S,C, or F),Source ID,Source row #          C 2 2
IN  18 Destination type(A or C),Dest ID,Dest row #            A 27 1
IN  18 Gain                                                   0

IN  19 Interconnect ID number                                 19
IN  19 Source type(S,C, or F),Source ID,Source row #          C 2 3
IN  19 Destination type(A or C),Dest ID,Dest row #            A 28 1
IN  19 Gain                                                   0

IN  20 Interconnect ID number                                 20
IN  20 Source type(S,C, or F),Source ID,Source row #          C 2 4
IN  20 Destination type(A or C),Dest ID,Dest row #            A 23 1
IN  20 Gain                                                   1

IN  21 Interconnect ID number                                 21
IN  21 Source type(S,C, or F),Source ID,Source row #          C 2 5
IN  21 Destination type(A or C),Dest ID,Dest row #            A 24 1
IN  21 Gain                                                   1

IN  22 Interconnect ID number                                 22
IN  22 Source type(S,C, or F),Source ID,Source row #          C 2 6
IN  22 Destination type(A or C),Dest ID,Dest row #            A 25 1
IN  22 Gain                                                   1

IN  23 Interconnect ID number                                 23
IN  23 Source type(S,C, or F),Source ID,Source row #          S 17 1
IN  23 Destination type(A or C),Dest ID,Dest row #            C 1 13
IN  23 Gain                                                   1

IN  24 Interconnect ID number                                 24
IN  24 Source type(S,C, or F),Source ID,Source row #          S 17 2
IN  24 Destination type(A or C),Dest ID,Dest row #            C 1 14
IN  24 Gain                                                   1

IN  25 Interconnect ID number                                 25
IN  25 Source type(S,C, or F),Source ID,Source row #          S 17 3
IN  25 Destination type(A or C),Dest ID,Dest row #            C 1 15
IN  25 Gain                                                   1

IN  44 Interconnect ID number                                 44
IN  44 Source type(S,C, or F),Source ID,Source row #          S 17 4
IN  44 Destination type(A or C),Dest ID,Dest row #            C 1 16
IN  44 Gain                                                   1

IN  45 Interconnect ID number                                 45
IN  45 Source type(S,C, or F),Source ID,Source row #          S 17 5
```

```
IN  45 Destination type(A or C),Dest ID,Dest row #          C 1 17
IN  45 Gain                                                  1

IN  46 Interconnect ID number                                46
IN  46 Source type(S,C, or F),Source ID,Source row #         S 17 6
IN  46 Destination type(A or C),Dest ID,Dest row #           C 1 18
IN  46 Gain                                                  1

IN  47 Interconnect ID number                                47
IN  47 Source type(S,C, or F),Source ID,Source row #         S 17 7
IN  47 Destination type(A or C),Dest ID,Dest row #           C 1 19
IN  47 Gain                                                  1

IN  48 Interconnect ID number                                48
IN  48 Source type(S,C, or F),Source ID,Source row #         S 17 8
IN  48 Destination type(A or C),Dest ID,Dest row #           C 1 20
IN  48 Gain                                                  1

IN  49 Interconnect ID number                                49
IN  49 Source type(S,C, or F),Source ID,Source row #         S 17 9
IN  49 Destination type(A or C),Dest ID,Dest row #           C 1 21
IN  49 Gain                                                  1

IN  50 Interconnect ID number                                50
IN  50 Source type(S,C, or F),Source ID,Source row #         S 19 1
IN  50 Destination type(A or C),Dest ID,Dest row #           C 3 1
IN  50 Gain                                                  1

IN  51 Interconnect ID number                                51
IN  51 Source type(S,C, or F),Source ID,Source row #         S 20 1
IN  51 Destination type(A or C),Dest ID,Dest row #           C 3 2
IN  51 Gain                                                  1

IN  52 Interconnect ID number                                52
IN  52 Source type(S,C, or F),Source ID,Source row #         C 3 1
IN  52 Destination type(A or C),Dest ID,Dest row #           A 29 1
IN  52 Gain                                                  1

IN  53 Interconnect ID number                                53
IN  53 Source type(S,C, or F),Source ID,Source row #         C 3 2
IN  53 Destination type(A or C),Dest ID,Dest row #           A 30 1
IN  53 Gain                                                  1
```

AEROD

```
AE   1 Aerodynamic Model ID #                                1
AE   1 Body ID, Center of Pressure Node ID                   1 13
AE   1 Atmosphere Type (C,J,M)                               J
AE   1 Constant Density for Atmosphere Type=C
AE   1 Model Type (P,C,T,B)                                  T
AE   1 Dimensions D,L (meters)
AE   1 Unit Normal Vector x,y,z
AE   1 Aero Ref Area, Ref Length (meters)                    16.6051 2.2990
AE   1 Name of Aero Coefficient Table Input File             .\newttae.dat
AE   1 Axial unit vector in body (alpha=0,phi=0)             0. 0. 1.
AE   1 Vert  unit vector in body (alpha=90,phi=0)            .7071 -.7071 0.
AE   1 Horiz unit vector in body (alpha=90,phi=90)           .7071 .7071 0.
```

Appendix G

XFERFN.DAT

```
2
1, 12, 14,
1.172e-015,1.791e-013,1.689e-011,9.742e-010,
3.67e-008,9.875e-007,2.021e-005,0.0003199,
0.003825,0.03284,0.1885,0.6426,0.9794
1.172e-015,8.378e-015,1.073e-011,6.83e-011,
1.945e-008,1.199e-007,1.294e-005,7.784e-005
0.003281,0.019,0.2916,1.54,
3.265,3.001,1.0,
2, 12, 14,
1.172e-015,1.791e-013,1.689e-011,9.742e-010,
3.67e-008,9.875e-007,2.021e-005,0.0003199,
0.003825,0.03284,0.1885,0.6426,0.9794
1.172e-015,8.378e-015,1.073e-011,6.83e-011,
1.945e-008,1.199e-007,1.294e-005,7.784e-005,
0.003281,0.019,0.2916,1.54,
3.265,3.001,1.0,
```

Appendix H

INPUT FILE DEFINING MODEL FOR THE FLEXIBLE BODY MODEL APPROACH TO SLOSH DYNAMICS ANALYSIS
IMPEG_GPB_MS.INT

```
        TREETOPS REV 10X   1/10/02

        SIM CONTROL

SI   0 Title                                                    GPB MODEL FOR 2002
SI   0 Simulation stop time                                     20000
SI   0 Plot data interval                                       5
SI   0 Integration type (R,S or U)                              R
SI   0 Step size (sec)                                          0.1
SI   0 Sandia integration absolute and relative error
SI   0 RK78 ODE solver absolute error and first step size
SI   0 Linearization option  (L,Z or N)                         N
SI   0 Restart option        (Y/N)                              N
SI   0 Contact force computation option     (Y/N)               Y
SI   0 Constraint force computation option  (Y/N)               N
SI   0 Small angle speedup option (All,Bypass,First,Nth)        A
SI   0 Mass matrix speedup option (All,Bypass,First,Nth)        A
SI   0 Non-Linear  speedup option (All,Bypass,First,Nth)        A
SI   0 Constraint  speedup option (All,Bypass,First,Nth)        A
SI   0 Constraint stabilization option  (Y/N)                   N
SI   0 Stabilization epsilon



        GENGRAV

GG   0 Gravity, earth sphere/nonsphere/user (S/N/U)?            N
GG   1 Input gravity constants:  GME, ERAD, EMASS
GG   1 Spherical or Nonspherical (S/N)?
GG   1 Gravity Potential Harmonics J2,J3,J4
GG   0 English (ft-slug-s) or metric (m-kg-s)    (E/M)?         M
GG   0 Day, Month, Year,                                        21 6 2003
GG   0 GMT @ sim time 0 (minutes past midnight,                 720
GG   0 Solar Pressure forces Y/N?                               N
GG   0 Input new data for aero model? (Y/N)                     Y
GG   0   Solar flux F10 for aero model                          230
GG   0   Solar flux, 81 day average F10B                        230
GG   0   Geomagnetic index, GEAP                                400


        BODY

BO   1 Body ID number                                           1
BO   1 Type (Rigid,Flexible,NASTRAN)                            R
BO   1 Number of modes
BO   1 Modal calculation option (0, 1 or 2)
BO   1 Foreshortening Option (Y/N)
BO   1 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   1 NASTRAN data file FORTRAN unit number (40 - 60)
BO   1 Number of augmented nodes (0 if none)
BO   1 Damping matrix option (NS,CD,HL,SD)
BO   1 Constant damping ratio
BO   1 Low frequency, High frequency ratios
BO   1 Mode ID number, damping ratio
BO   1 Conversion factors: Length,Mass,Force
BO   1 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)       1
```

```
BO   1 Moments of inertia (kg-m2) Ixx,Iyy,Izz                 5230.2 5147.5 3693.4
BO   1 Products of inertia (kg-m2) Ixy,Ixz,Iyz                19.3 -6 0
BO   1 Mass (kg)                                              3182.8
BO   1 Number of Nodes                                        13
BO   1 Node ID, Node coord. (meters) x,y,z                    1 0 -0.0002 0.8647
BO   1 Node ID, Node coord. (meters) x,y,z                    2 0 -0.0002 0.8647
BO   1 Node ID, Node coord. (meters) x,y,z                    3 0 1.0467 0.6380
BO   1 Node ID, Node coord. (meters) x,y,z                    4 0 0 0.10033
BO   1 Node ID, Node coord. (meters) x,y,z                    5 -1.19 0 2.51
BO   1 Node ID, Node coord. (meters) x,y,z                    6 1.19 0 2.51
BO   1 Node ID, Node coord. (meters) x,y,z                    7 -1.19 0 -1.9
BO   1 Node ID, Node coord. (meters) x,y,z                    8 1.19 0 -1.9
BO   1 Node ID, Node coord. (meters) x,y,z                    9 0 0 -.10033
BO   1 Node ID, Node coord. (meters) x,y,z                    10 0 0 -.18283
BO   1 Node ID, Node coord. (meters) x,y,z                    11 0 0 -.26533
BO   1 Node ID, Node coord. (meters) x,y,z                    12 0 0 -.34783
BO   1 Node ID, Node coord. (meters) x,y,z                    13 0 0 0.10937
BO   1 Node ID, Node structual joint ID

BO   2 Body ID number                                         2
BO   2 Type (Rigid,Flexible,NASTRAN)                          R
BO   2 Number of modes
BO   2 Modal calculation option (0, 1 or 2)
BO   2 Foreshortening Option (Y/N)
BO   2 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   2 NASTRAN data file FORTRAN unit number (40 - 60)
BO   2 Number of augmented nodes (0 if none)
BO   2 Damping matrix option (NS,CD,HL,SD)
BO   2 Constant damping ratio
BO   2 Low frequency, High frequency ratios
BO   2 Mode ID number, damping ratio
BO   2 Conversion factors: Length,Mass,Force
BO   2 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)     1
BO   2 Moments of inertia (kg-m2) Ixx,Iyy,Izz                 .00001 .00001 .00001
BO   2 Products of inertia (kg-m2) Ixy,Ixz,Iyz                0 0 0
BO   2 Mass (kg)                                              .076
BO   2 Number of Nodes                                        1
BO   2 Node ID, Node coord. (meters) x,y,z                    1 0 0 0
BO   2 Node ID, Node structual joint ID

BO   3 Body ID number                                         3
BO   3 Type (Rigid,Flexible,NASTRAN)                          R
BO   3 Number of modes
BO   3 Modal calculation option (0, 1 or 2)
BO   3 Foreshortening option (Y/N)
BO   3 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   3 NASTRAN data file FORTRAN unit number (40 - 60)
BO   3 Number of augmented nodes (0 if none)
BO   3 Damping matrix option (NS,CD,HL,SD)
BO   3 Constant damping ratio
BO   3 Low frequency, High frequency ratios
BO   3 Mode ID number, damping ratio
BO   3 Conversion factors: Length,Mass,Force
BO   3 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)     1
BO   3 Moments of inertia (kg-m2) Ixx,Iyy,Izz                 9.1999324E-6 9.199954E-6 9.2E-6
BO   3 Products of inertia (kg-m2) Ixy,Ixz,Iyz                0 0 0
BO   3 Mass (kg)                                              0.06335
BO   3 Number of Nodes                                        2
BO   3 Node ID, Node coord. (meters) x,y,z                    1 0 0 0
BO   3 Node ID, Node coord. (meters) x,y,z                    2 0 0 -5.08E-8
BO   3 Node ID, Node structual joint ID

BO   4 Body ID number                                         4
BO   4 Type (Rigid,Flexible,NASTRAN)                          R
BO   4 Number of modes
BO   4 Modal calculation option (0, 1 or 2)
BO   4 Foreshortening option (Y/N)
BO   4 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   4 NASTRAN data file FORTRAN unit number (40 - 60)
BO   4 Number of augmented nodes (0 if none)
BO   4 Damping matrix option (NS,CD,HL,SD)
```

```
BO   4 Constant damping ratio
BO   4 Low frequency, High frequency ratios
BO   4 Mode ID number, damping ratio
BO   4 Conversion factors: Length,Mass,Force
BO   4 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)      1
BO   4 Moments of inertia (kg-m2) Ixx,Iyy,Izz                  9.1999324E-6 9.199954E-6 9.2E-6
BO   4 Products of inertia (kg-m2) Ixy,Ixz,Iyz                 0 0 0
BO   4 Mass (kg)                                               .06335
BO   4 Number of Nodes                                         2
BO   4 Node ID, Node coord. (meters) x,y,z                     1 0 0 0
BO   4 Node ID, Node coord. (meters) x,y,z                     2 0 0 -5.08E-8
BO   4 Node ID, Node structual joint ID

BO   5 Body ID number                                          5
BO   5 Type (Rigid,Flexible,NASTRAN)                           R
BO   5 Number of modes
BO   5 Modal calculation option (0, 1 or 2)
BO   5 Foreshortening option (Y/N)
BO   5 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   5 NASTRAN data file FORTRAN unit number (40 - 60)
BO   5 Number of augmented nodes (0 if none)
BO   5 Damping matrix option (NS,CD,HL,SD)
BO   5 Constant damping ratio
BO   5 Low frequency, High frequency ratios
BO   5 Mode ID number, damping ratio
BO   5 Conversion factors: Length,Mass,Force
BO   5 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)      1
BO   5 Moments of inertia (kg-m2) Ixx,Iyy,Izz                  9.1999324E-6 9.199954E-6 9.2E-6
BO   5 Products of inertia (kg-m2) Ixy,Ixz,Iyz                 0 0 0
BO   5 Mass (kg)                                               .06335
BO   5 Number of Nodes                                         2
BO   5 Node ID, Node coord. (meters) x,y,z                     1 0 0 0
BO   5 Node ID, Node coord. (meters) x,y,z                     2 0 0 -5.08E-8
BO   5 Node ID, Node structual joint ID

BO   6 Body ID number                                          6
BO   6 Type (Rigid,Flexible,NASTRAN)                           R
BO   6 Number of modes
BO   6 Modal calculation option (0, 1 or 2)
BO   6 Foreshortening option (Y/N)
BO   6 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   6 NASTRAN data file FORTRAN unit number (40 - 60)
BO   6 Number of augmented nodes (0 if none)
BO   6 Damping matrix option (NS,CD,HL,SD)
BO   6 Constant damping ratio
BO   6 Low frequency, High frequency ratios
BO   6 Mode ID number, damping ratio
BO   6 Conversion factors: Length,Mass,Force
BO   6 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)      1
BO   6 Moments of inertia (kg-m2) Ixx,Iyy,Izz                  9.1999324E-6 9.199954E-6 9.2E-6
BO   6 Products of inertia (kg-m2) Ixy,Ixz,Iyz                 0 0 0
BO   6 Mass (kg)                                               .06335
BO   6 Number of Nodes                                         2
BO   6 Node ID, Node coord. (meters) x,y,z                     1 0 0 0
BO   6 Node ID, Node coord. (meters) x,y,z                     2 0 0 -5.08E-8
BO   6 Node ID, Node structual joint ID

BO   7 Body ID number                                          7
BO   7 Type (Rigid,Flexible,NASTRAN)                           F
BO   7 Number of modes                                         33
BO   7 Modal calculation option (0, 1 or 2)                    0
BO   7 Foreshortening option (Y/N)
BO   7 Model reduction method (NO,MS,MC,CC,QM,CV)
BO   7 NASTRAN data file FORTRAN unit number (40 - 60)
BO   7 Number of augmented nodes (0 if none)
BO   7 Damping matrix option (NS,CD,HL,SD)
BO   7 Constant damping ratio
BO   7 Low frequency, High frequency ratios
BO   7 Mode ID number, damping ratio
BO   7 Conversion factors: Length,Mass,Force
BO   7 Inertia reference node (0=Bdy Ref Frm; 1=mass cen)      1
```

```
BO   7 Moments of inertia (kg-m2) Ixx,Iyy,Izz                        0 0 0
BO   7 Products of inertia (kg-m2) Ixy,Ixz,Iyz                       0 0 0
BO   7 Mass (kg)                                                     0
BO   7 Number of Nodes                                               2
BO   7 Node ID, Node coord. (meters) x,y,z                           1 0 0 0
BO   7 Node ID, Node coord. (meters) x,y,z                           2 0 0 0
BO   7 Node ID, Node structual joint ID

       HINGE


HI   1 Hinge ID number                                               1
HI   1 Inboard body ID, Outboard body ID                             0 1
HI   1 "p" node ID, "q" node ID                                      0 4
HI   1 Number of rotation DOFs, Rotation option (F or G)             3 F
HI   1 L1 unit vector in inboard body coord. x,y,z                   0 1 0
HI   1 L1 unit vector in outboard body coord. x,y,z                  0 1 0
HI   1 L2 unit vector in inboard body coord. x,y,z
HI   1 L2 unit vector in outboard body coord. x,y,z
HI   1 L3 unit vector in inboard body coord. x,y,z                   0 0 1
HI   1 L3 unit vector in outboard body coord. x,y,z                  0 0 1
HI   1 Initial rotation angles (deg)        -16.7408 16.8411 -90  -16.739107675801 16.838172287528
-90.0
HI   1 Initial rotation rates (deg/sec)                              0 0 1.8
HI   1 Rotation stiffness (newton-meters/rad)                        0 0 0
HI   1 Rotation damping (newton-meters/rad/sec)                      0 0 0
HI   1 Null torque angles (deg)                                      0 0 0
HI   1 Number of translation DOFs                                    3
HI   1 First translation unit vector   g1                            1 0 0
HI   1 Second translation unit vector  g2                            0 1 0
HI   1 Third translation unit vector   g3                            0 0 1
HI   1 Initial translation (meters)                                  2021331.3322 0 -6720778.19992
HI   1 Initial translation velocity (meters/sec)                     0 -7533.0 0
HI   1 Translation stiffness (newtons/meters)                        0 0 0
HI   1 Translation damping (newtons/meter/sec)                       0 0 0
HI   1 Null force translations                                       0 0 0

HI   2 Hinge ID number                                               2
HI   2 Inboard body ID, Outboard body ID                             1 2
HI   2 "p" node ID, "q" node ID                                      4 1
HI   2 Number of rotation DOFs, Rotation option (F or G)             0
HI   2 L1 unit vector in inboard body coord. x,y,z                   1 0 0
HI   2 L1 unit vector in outboard body coord. x,y,z                  1 0 0
HI   2 L2 unit vector in inboard body coord. x,y,z
HI   2 L2 unit vector in outboard body coord. x,y,z
HI   2 L3 unit vector in inboard body coord. x,y,z                   0 0 1
HI   2 L3 unit vector in outboard body coord. x,y,z                  0 0 1
HI   2 Initial rotation angles (deg)                                 0 0 0
HI   2 Initial rotation rates (deg/sec)
HI   2 Rotation stiffness (newton-meters/rad)
HI   2 Rotation damping (newton-meters/rad/sec)
HI   2 Null torque angles (deg)
HI   2 Number of translation DOFs                                    3
HI   2 First translation unit vector   g1                            1 0 0
HI   2 Second translation unit vector  g2                            0 1 0
HI   2 Third translation unit vector   g3                            0 0 1
HI   2 Initial translation (meters)                                  0 0 0
HI   2 Initial translation velocity (meters/sec)                     0 0 0
HI   2 Translation stiffness (newtons/meters)                        0 0 0
HI   2 Translation damping (newtons/meter/sec)                       0 0 0
HI   2 Null force translations                                       0 0 0

HI   3 Hinge ID number                                               3
HI   3 Inboard body ID, Outboard body ID                             1 3
HI   3 "p" node ID, "q" node ID                                      9 2
HI   3  No of rotation DOFs, Hinge 1 rotation option(F/G)            0
HI   3 L1 unit vector in inboard body coord. x,y,z                   1 0 0
HI   3 L1 unit vector in outboard body coord. x,y,z                  1 0 0
HI   3 L2 unit vector in inboard body coord. x,y,z
HI   3 L2 unit vector in outboard body coord. x,y,z
HI   3 L3 unit vector in inboard body coord. x,y,z                   0 0 1
```

```
HI   3 L3 unit vector in outboard body coord. x,y,z           0 0 1
HI   3 Initial rotation angles (deg)                          0 0 0
HI   3 Initial rotation rates (deg/sec)
HI   3 Rotation stiffness (newton-meters/rad)
HI   3 Rotation damping (newton-meters/rad/sec)
HI   3 Null torque angles (deg)
HI   3 Number of translation DOFs                             3
HI   3 First translation unit vector   g1                     1 0 0
HI   3 Second translation unit vector  g2                     0 1 0
HI   3 Third translation unit vector   g3                     0 0 1
HI   3 Initial translation (meters)                           0 0 0
HI   3 Initial translation velocity (meters/sec)              0 0 0
HI   3 Translation stiffness (newtons/meters)                 10. 10. 10.
HI   3 Translation damping (newtons/meter/sec)                1.125 1.125 1.125
HI   3 Null force translations                                0 0 0

HI   4 Hinge ID number                                        4
HI   4 Inboard body ID, Outboard body ID                      1 4
HI   4 "p" node ID, "q" node ID                               10 2
HI   4 Number of rotation DOFs, Rotation option (F or G)      0
HI   4 L1 unit vector in inboard body coord. x,y,z            1 0 0
HI   4 L1 unit vector in outboard body coord. x,y,z           1 0 0
HI   4 L2 unit vector in inboard body coord. x,y,z
HI   4 L2 unit vector in outboard body coord. x,y,z
HI   4 L3 unit vector in inboard body coord. x,y,z            0 0 1
HI   4 L3 unit vector in outboard body coord. x,y,z           0 0 1
HI   4 Initial rotation angles (deg)                          0 0 0
HI   4 Initial rotation rates (deg/sec)
HI   4 Rotation stiffness (newton-meters/rad)
HI   4 Rotation damping (newton-meters/rad/sec)
HI   4 Null torque angles (deg)
HI   4 Number of translation DOFs                             3
HI   4 First translation unit vector   g1                     1 0 0
HI   4 Second translation unit vector  g2                     0 1 0
HI   4 Third translation unit vector   g3                     0 0 1
HI   4 Initial translation (meters)                           0 0 0
HI   4 Initial translation velocity (meters/sec)              0 0 0
HI   4 Translation stiffness (newtons/meters)                 10 10 10
HI   4 Translation damping (newtons/meter/sec)                1.125 1.125 1.125
HI   4 Null force translations                                0 0 0

HI   5 Hinge ID number                                        5
HI   5 Inboard body ID, Outboard body ID                      1 5
HI   5 "p" node ID, "q" node ID                               11 2
HI   5  Number of rotation DOFs                               0
HI   5 L1 unit vector in inboard body coord. x,y,z            1 0 0
HI   5 L1 unit vector in outboard body coord. x,y,z           1 0 0
HI   5 L2 unit vector in inboard body coord. x,y,z
HI   5 L2 unit vector in outboard body coord. x,y,z
HI   5 L3 unit vector in inboard body coord. x,y,z            0 0 1
HI   5 L3 unit vector in outboard body coord. x,y,z           0 0 1
HI   5 Initial rotation angles (deg)                          0 0 0
HI   5 Initial rotation rates (deg/sec)
HI   5 Rotation stiffness (newton-meters/rad)
HI   5 Rotation damping (newton-meters/rad/sec)
HI   5 Null torque angles (deg)
HI   5 Number of translation DOFs                             3
HI   5 First translation unit vector   g1                     1 0 0
HI   5 Second translation unit vector  g2                     0 1 0
HI   5 Third translation unit vector   g3                     0 0 1
HI   5 Initial translation (meters)                           0 0 0
HI   5 Initial translation velocity (meters/sec)              0 0 0
HI   5 Translation stiffness (newtons/meters)                 10 10 10
HI   5 Translation damping (newtons/meter/sec)                1.125 1.125 1.125
HI   5 Null force translations                                0 0 0

HI   6 Hinge ID number                                        6
HI   6 Inboard body ID, Outboard body ID                      1 6
HI   6 "p" node ID, "q" node ID                               12 2
HI   6  Number of rotation DOFs                               0
HI   6 L1 unit vector in inboard body coord. x,y,z            1 0 0
```

```
HI   6 L1 unit vector in outboard body coord. x,y,z          1 0 0
HI   6 L2 unit vector in inboard body coord. x,y,z
HI   6 L2 unit vector in outboard body coord. x,y,z
HI   6 L3 unit vector in inboard body coord. x,y,z           0 0 1
HI   6 L3 unit vector in outboard body coord. x,y,z          0 0 1
HI   6 Initial rotation angles (deg)                         0 0 0
HI   6 Initial rotation rates (deg/sec)
HI   6 Rotation stiffness (newton-meters/rad)
HI   6 Rotation damping (newton-meters/rad/sec)
HI   6 Null torque angles (deg)
HI   6 Number of translation DOFs                            3
HI   6 First translation unit vector   g1                    1 0 0
HI   6 Second translation unit vector  g2                    0 1 0
HI   6 Third translation unit vector   g3                    0 0 1
HI   6 Initial translation (meters)                          0 0 0
HI   6 Initial translation velocity (meters/sec)             0 0 0
HI   6 Translation stiffness (newtons/meters)                10 10 10
HI   6 Translation damping (newtons/meter/sec)               1.125 1.125 1.125
HI   6 Null force translations                               0 0 0

HI   7 Hinge ID number                                       7
HI   7 Inboard body ID, Outboard body ID                     1 7
HI   7 "p" node ID, "q" node ID                              2 2
HI   7 Number of rotation DOFs, Rotation option (F or G)     0
HI   7 L1 unit vector in inboard body coord. x,y,z           1 0 0
HI   7 L1 unit vector in outboard body coord. x,y,z          1 0 0
HI   7 L2 unit vector in inboard body coord. x,y,z
HI   7 L2 unit vector in outboard body coord. x,y,z
HI   7 L3 unit vector in inboard body coord. x,y,z           0 0 1
HI   7 L3 unit vector in outboard body coord. x,y,z          0 0 1
HI   7 Initial rotation angles (deg)                         0 0 0
HI   7 Initial rotation rates (deg/sec)
HI   7 Rotation stiffness (newton-meters/rad)
HI   7 Rotation damping (newton-meters/rad/sec)
HI   7 Null torque angles (deg)
HI   7 Number of translation DOFs                            0
HI   7 First translation unit vector   g1                    1 0 0
HI   7 Second translation unit vector  g2                    0 1 0
HI   7 Third translation unit vector   g3                    0 0 1
HI   7 Initial translation (meters)                          0 0 0
HI   7 Initial translation velocity (meters/sec)
HI   7 Translation stiffness (newtons/meters)
HI   7 Translation damping (newtons/meter/sec)
HI   7 Null force translations
```

SENSOR

```
SE   1 Sensor ID number                                                  1
SE   1 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)        G
SE   1 Mounting point body ID, Mounting point node ID                    1 3
SE   1 Second mounting point body ID, Second node ID
SE   1 Input axis unit vector (IA) x,y,z                                 0 0 1
SE   1 Mounting point Hinge index, Axis index
SE   1 First focal plane unit vector  (Fp1) x,y,z
SE   1 Second focal plane unit vector (Fp2) x,y,z
SE   1 Sun/Star unit vector (Us) x,y,z
SE   1 Velocity Aberration Option (Y/N)
SE   1 Euler Angle Sequence (1-6)
SE   1 CMG ID number and Gimbal number
SE   1 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   2 Sensor ID number                                                  2
SE   2 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)        G
SE   2 Mounting point body ID, Mounting point node ID                    1 3
SE   2 Second mounting point body ID, Second node ID
SE   2 Input axis unit vector (IA) x,y,z                                 0 1 0
SE   2 Mounting point Hinge index, Axis index
SE   2 First focal plane unit vector  (Fp1) x,y,z
SE   2 Second focal plane unit vector (Fp2) x,y,z
SE   2 Sun/Star unit vector (Us) x,y,z
```

```
SE   2 Velocity Aberration Option (Y/N)
SE   2 Euler Angle Sequence (1-6)
SE   2 CMG ID number and Gimbal number
SE   2 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   3 Sensor ID number                                          3
SE   3 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  G
SE   3 Mounting point body ID, Mounting point node ID            1 3
SE   3 Second mounting point body ID, Second node ID
SE   3 Input axis unit vector (IA) x,y,z                         1 0 0
SE   3 Mounting point Hinge index, Axis index
SE   3 First focal plane unit vector  (Fp1) x,y,z
SE   3 Second focal plane unit vector (Fp2) x,y,z
SE   3 Sun/Star unit vector (Us) x,y,z
SE   3 Velocity Aberration Option (Y/N)
SE   3 Euler Angle Sequence (1-6)
SE   3 CMG ID number and Gimbal number
SE   3 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   4 Sensor ID number                                          4
SE   4 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  ST
SE   4 Mounting point body ID, Mounting point node ID            1 2
SE   4 Second mounting point body ID, Second node ID
SE   4 Input axis unit vector (IA) x,y,z
SE   4 Mounting point Hinge index, Axis index
SE   4 First focal plane unit vector  (Fp1) x,y,z                1 0 0
SE   4 Second focal plane unit vector (Fp2) x,y,z                0 1 0
SE   4 Sun/Star unit vector (Us) x,y,z                           -0.2756889168 0.2897184368
0.9165472429
SE   4 Velocity Aberration Option (Y/N)                          Y
SE   4 Euler Angle Sequence (1-6)
SE   4 CMG ID number and Gimbal number
SE   4 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   5 Sensor ID number                                          5
SE   5 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  P3
SE   5 Mounting point body ID, Mounting point node ID            1 4
SE   5 Second mounting point body ID, Second node ID             2 1
SE   5 Input axis unit vector (IA) x,y,z
SE   5 Mounting point Hinge index, Axis index
SE   5 First focal plane unit vector  (Fp1) x,y,z
SE   5 Second focal plane unit vector (Fp2) x,y,z
SE   5 Sun/Star unit vector (Us) x,y,z
SE   5 Velocity Aberration Option (Y/N)
SE   5 Euler Angle Sequence (1-6)
SE   5 CMG ID number and Gimbal number
SE   5 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   6 Sensor ID number                                          6
SE   6 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  AC
SE   6 Mounting point body ID, Mounting point node ID            2 1
SE   6 Second mounting point body ID, Second node ID
SE   6 Input axis unit vector (IA) x,y,z                         1 0 0
SE   6 Mounting point Hinge index, Axis index
SE   6 First focal plane unit vector  (Fp1) x,y,z
SE   6 Second focal plane unit vector (Fp2) x,y,z
SE   6 Sun/Star unit vector (Us) x,y,z
SE   6 Velocity Aberration Option (Y/N)
SE   6 Euler Angle Sequence (1-6)
SE   6 CMG ID number and Gimbal number
SE   6 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   7 Sensor ID number                                          7
SE   7 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  AC
SE   7 Mounting point body ID, Mounting point node ID            2 1
SE   7 Second mounting point body ID, Second node ID
SE   7 Input axis unit vector (IA) x,y,z                         0 1 0
SE   7 Mounting point Hinge index, Axis index
SE   7 First focal plane unit vector  (Fp1) x,y,z
SE   7 Second focal plane unit vector (Fp2) x,y,z
SE   7 Sun/Star unit vector (Us) x,y,z
```

```
SE   7 Velocity Aberration Option (Y/N)
SE   7 Euler Angle Sequence (1-6)
SE   7 CMG ID number and Gimbal number
SE   7 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   8 Sensor ID number                                                8
SE   8 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      AC
SE   8 Mounting point body ID, Mounting point node ID                  2 1
SE   8 Second mounting point body ID, Second node ID
SE   8 Input axis unit vector (IA) x,y,z                               0 0 1
SE   8 Mounting point Hinge index, Axis index
SE   8 First focal plane unit vector  (Fp1) x,y,z
SE   8 Second focal plane unit vector (Fp2) x,y,z
SE   8 Sun/Star unit vector (Us) x,y,z
SE   8 Velocity Aberration Option (Y/N)
SE   8 Euler Angle Sequence (1-6)
SE   8 CMG ID number and Gimbal number
SE   8 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE   9 Sensor ID number                                                9
SE   9 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      I
SE   9 Mounting point body ID, Mounting point node ID                  1 3
SE   9 Second mounting point body ID, Second node ID
SE   9 Input axis unit vector (IA) x,y,z                               0 0 1
SE   9 Mounting point Hinge index, Axis index
SE   9 First focal plane unit vector  (Fp1) x,y,z
SE   9 Second focal plane unit vector (Fp2) x,y,z
SE   9 Sun/Star unit vector (Us) x,y,z
SE   9 Velocity Aberration Option (Y/N)
SE   9 Euler Angle Sequence (1-6)
SE   9 CMG ID number and Gimbal number
SE   9 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  10 Sensor ID number                                                10
SE  10 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      P3
SE  10 Mounting point body ID, Mounting point node ID                  1 9
SE  10 Second mounting point body ID, Second node ID                   3 1
SE  10 Input axis unit vector (IA) x,y,z
SE  10 Mounting point Hinge index, Axis index
SE  10 First focal plane unit vector  (Fp1) x,y,z
SE  10 Second focal plane unit vector (Fp2) x,y,z
SE  10 Sun/Star unit vector (Us) x,y,z
SE  10 Velocity Aberration Option (Y/N)
SE  10 Euler Angle Sequence (1-6)
SE  10 CMG ID number and Gimbal number
SE  10 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  11 Sensor ID number                                                11
SE  11 Type(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)      V3
SE  11 Mounting point body ID, Mounting point node ID                  1 9
SE  11 Second mounting point body ID, Second node ID                   3 1
SE  11 Input axis unit vector (IA) x,y,z
SE  11 Mounting point Hinge index, Axis index
SE  11 First focal plane unit vector  (Fp1) x,y,z
SE  11 Second focal plane unit vector (Fp2) x,y,z
SE  11 Sun/Star unit vector (Us) x,y,z
SE  11 Velocity Aberration Option (Y/N)
SE  11 Euler Angle Sequence (1-6)
SE  11 CMG ID number and Gimbal number
SE  11 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  12 Sensor ID number                                                12
SE  12 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)       FM
SE  12 Mounting point body ID, Mounting point node ID                  1 1
SE  12 Second mounting point body ID, Second node ID
SE  12 Input axis unit vector (IA) x,y,z
SE  12 Mounting point Hinge index, Axis index
SE  12 First focal plane unit vector  (Fp1) x,y,z
SE  12 Second focal plane unit vector (Fp2) x,y,z
SE  12 Sun/Star unit vector (Us) x,y,z
SE  12 Velocity Aberration Option (Y/N)
```

```
SE  12 Euler Angle Sequence (1-6)
SE  12 CMG ID number and Gimbal number
SE  12 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  13 Sensor ID number                                              13
SE  13 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)     FM
SE  13 Mounting point body ID, Mounting point node ID                1 2
SE  13 Second mounting point body ID, Second node ID
SE  13 Input axis unit vector (IA) x,y,z
SE  13 Mounting point Hinge index, Axis index
SE  13 First focal plane unit vector  (Fp1) x,y,z
SE  13 Second focal plane unit vector (Fp2) x,y,z
SE  13 Sun/Star unit vector (Us) x,y,z
SE  13 Velocity Aberration Option (Y/N)
SE  13 Euler Angle Sequence (1-6)
SE  13 CMG ID number and Gimbal number
SE  13 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  14 Sensor ID number                                              14
SE  14 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)     FM
SE  14 Mounting point body ID, Mounting point node ID                1 13
SE  14 Second mounting point body ID, Second node ID
SE  14 Input axis unit vector (IA) x,y,z
SE  14 Mounting point Hinge index, Axis index
SE  14 First focal plane unit vector  (Fp1) x,y,z
SE  14 Second focal plane unit vector (Fp2) x,y,z
SE  14 Sun/Star unit vector (Us) x,y,z
SE  14 Velocity Aberration Option (Y/N)
SE  14 Euler Angle Sequence (1-6)
SE  14 CMG ID number and Gimbal number
SE  14 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  15 Sensor ID number                                              15
SE  15 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)     DN
SE  15 Mounting point body ID, Mounting point node ID                1 1
SE  15 Second mounting point body ID, Second node ID
SE  15 Input axis unit vector (IA) x,y,z                             1 0 0
SE  15 Mounting point Hinge index, Axis index
SE  15 First focal plane unit vector  (Fp1) x,y,z
SE  15 Second focal plane unit vector (Fp2) x,y,z
SE  15 Sun/Star unit vector (Us) x,y,z
SE  15 Velocity Aberration Option (Y/N)
SE  15 Euler Angle Sequence (1-6)
SE  15 CMG ID number and Gimbal number
SE  15 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  16 Sensor ID number                                              16
SE  16 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)     MG
SE  16 Mounting point body ID, Mounting point node ID                1 1
SE  16 Second mounting point body ID, Second node ID
SE  16 Input axis unit vector (IA) x,y,z                             1 0 0
SE  16 Mounting point Hinge index, Axis index
SE  16 First focal plane unit vector  (Fp1) x,y,z
SE  16 Second focal plane unit vector (Fp2) x,y,z
SE  16 Sun/Star unit vector (Us) x,y,z
SE  16 Velocity Aberration Option (Y/N)
SE  16 Euler Angle Sequence (1-6)
SE  16 CMG ID number and Gimbal number
SE  16 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  17 Sensor ID number                                              17
SE  17 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)     LV
SE  17 Mounting point body ID, Mounting point node ID                1,1
SE  17 Second mounting point body ID, Second node ID
SE  17 Input axis unit vector (IA) x,y,z
SE  17 Mounting point Hinge index, Axis index
SE  17 First focal plane unit vector  (Fp1) x,y,z
SE  17 Second focal plane unit vector (Fp2) x,y,z
SE  17 Sun/Star unit vector (Us) x,y,z
SE  17 Velocity Aberration Option (Y/N)
SE  17 Euler Angle Sequence (1-6)
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SE  17 CMG ID number and Gimbal number
SE  17 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

SE  18 Sensor ID number                                        18
SE  18 Typ(G,R,AN,V,P,AC,T,I,SU,ST,L,IM,P3,V3,CR,CT,ET,LV,A3,FM)  FM
SE  18 Mounting point body ID, Mounting point node ID          2 1
SE  18 Second mounting point body ID, Second node ID
SE  18 Input axis unit vector (IA) x,y,z
SE  18 Mounting point Hinge index, Axis index
SE  18 First focal plane unit vector  (Fp1) x,y,z
SE  18 Second focal plane unit vector (Fp2) x,y,z
SE  18 Sun/Star unit vector (Us) x,y,z
SE  18 Velocity Aberration Option (Y/N)
SE  18 Euler Angle Sequence (1-6)
SE  18 CMG ID number and Gimbal number
SE  18 Earth pt (rad,lat,lon,ang.rate [m/e, d, d, d/s])

       ACTR

AC   1 Actuator ID number                                      1
AC   1 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                     J
AC   1 Actuator location; Node or Hinge (N or H)
AC   1 Mounting point body ID number, node ID number           1 5
AC   1 Second mounting point body ID, second node ID
AC   1 Output axis unit vector x,y,z                           1 0 0
AC   1 Mounting point Hinge index, Axis index
AC   1 Rotor spin axis unit vector x,y,z
AC   1 Initial rotor momentum, H
AC   1 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   1 Outer gimbal axis unit vector x,y,z
AC   1 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   1 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   1 Inner gimbal axis unit vector x,y,z
AC   1 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   1 Initial length and rate, y(to) and ydot(to)
AC   1 Constants; K1 or wo, n or zeta, Kg, Jm
AC   1 Non-linearities; TLim, Tco, Dz

AC   2 Actuator ID number                                      2
AC   2 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                     J
AC   2 Actuator location; Node or Hinge (N or H)
AC   2 Mounting point body ID number, node ID number           1 6
AC   2 Second mounting point body ID, second node ID
AC   2 Output axis unit vector x,y,z                           -1 0 0
AC   2 Mounting point Hinge index, Axis index
AC   2 Rotor spin axis unit vector x,y,z
AC   2 Initial rotor momentum, H
AC   2 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   2 Outer gimbal axis unit vector x,y,z
AC   2 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   2 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   2 Inner gimbal axis unit vector x,y,z
AC   2 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   2 Initial length and rate, y(to) and ydot(to)
AC   2 Constants; K1 or wo, n or zeta, Kg, Jm
AC   2 Non-linearities; TLim, Tco, Dz

AC   3 Actuator ID number                                      3
AC   3 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                     J
AC   3 Actuator location; Node or Hinge (N or H)
AC   3 Mounting point body ID number, node ID number           1 7
AC   3 Second mounting point body ID, second node ID
AC   3 Output axis unit vector x,y,z                           1 0 0
AC   3 Mounting point Hinge index, Axis index
AC   3 Rotor spin axis unit vector x,y,z
AC   3 Initial rotor momentum, H
AC   3 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   3 Outer gimbal axis unit vector x,y,z
AC   3 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   3 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
```

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AC   3 Inner gimbal axis unit vector x,y,z
AC   3 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   3 Initial length and rate, y(to) and ydot(to)
AC   3 Constants; K1 or wo, n or zeta, Kg, Jm
AC   3 Non-linearities; TLim, Tco, Dz

AC   4 Actuator ID number                                   4
AC   4 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                   J
AC   4 Actuator location; Node or Hinge (N or H)
AC   4 Mounting point body ID number, node ID number        1 8
AC   4 Second mounting point body ID, second node ID
AC   4 Output axis unit vector x,y,z                        -1 0 0
AC   4 Mounting point Hinge index, Axis index
AC   4 Rotor spin axis unit vector x,y,z
AC   4 Initial rotor momentum, H
AC   4 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   4 Outer gimbal axis unit vector x,y,z
AC   4 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   4 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   4 Inner gimbal axis unit vector x,y,z
AC   4 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   4 Initial length and rate, y(to) and ydot(to)
AC   4 Constants; K1 or wo, n or zeta, Kg, Jm
AC   4 Non-linearities; TLim, Tco, Dz

AC   5 Actuator ID number                                   5
AC   5 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                   J
AC   5 Actuator location; Node or Hinge (N or H)
AC   5 Mounting point body ID number, node ID number        1 8
AC   5 Second mounting point body ID, second node ID
AC   5 Output axis unit vector x,y,z                        0 1 0
AC   5 Mounting point Hinge index, Axis index
AC   5 Rotor spin axis unit vector x,y,z
AC   5 Initial rotor momentum, H
AC   5 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   5 Outer gimbal axis unit vector x,y,z
AC   5 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   5 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   5 Inner gimbal axis unit vector x,y,z
AC   5 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   5 Initial length and rate, y(to) and ydot(to)
AC   5 Constants; K1 or wo, n or zeta, Kg, Jm
AC   5 Non-linearities; TLim, Tco, Dz

AC   6 Actuator ID number                                   6
AC   6 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                   J
AC   6 Actuator location; Node or Hinge (N or H)
AC   6 Mounting point body ID number, node ID number        1 8
AC   6 Second mounting point body ID, second node ID
AC   6 Output axis unit vector x,y,z                        0 -1 0
AC   6 Mounting point Hinge index, Axis index
AC   6 Rotor spin axis unit vector x,y,z
AC   6 Initial rotor momentum, H
AC   6 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   6 Outer gimbal axis unit vector x,y,z
AC   6 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   6 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   6 Inner gimbal axis unit vector x,y,z
AC   6 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   6 Initial length and rate, y(to) and ydot(to)
AC   6 Constants; K1 or wo, n or zeta, Kg, Jm
AC   6 Non-linearities; TLim, Tco, Dz

AC   7 Actuator ID number                                   7
AC   7 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                   J
AC   7 Actuator location; Node or Hinge (N or H)
AC   7 Mounting point body ID number, node ID number        1 5
AC   7 Second mounting point body ID, second node ID
AC   7 Output axis unit vector x,y,z                        0 1 0
AC   7 Mounting point Hinge index, Axis index
AC   7 Rotor spin axis unit vector x,y,z
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AC    7 Initial rotor momentum, H
AC    7 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC    7 Outer gimbal axis unit vector x,y,z
AC    7 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC    7 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC    7 Inner gimbal axis unit vector x,y,z
AC    7 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC    7 Initial length and rate, y(to) and ydot(to)
AC    7 Constants; K1 or wo, n or zeta, Kg, Jm
AC    7 Non-linearities; TLim, Tco, Dz

AC    8 Actuator ID number                                8
AC    8 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)               J
AC    8 Actuator location; Node or Hinge (N or H)
AC    8 Mounting point body ID number, node ID number     1 5
AC    8 Second mounting point body ID, second node ID
AC    8 Output axis unit vector x,y,z                     0 -1 0
AC    8 Mounting point Hinge index, Axis index
AC    8 Rotor spin axis unit vector x,y,z
AC    8 Initial rotor momentum, H
AC    8 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC    8 Outer gimbal axis unit vector x,y,z
AC    8 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC    8 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC    8 Inner gimbal axis unit vector x,y,z
AC    8 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC    8 Initial length and rate, y(to) and ydot(to)
AC    8 Constants; K1 or wo, n or zeta, Kg, Jm
AC    8 Non-linearities; TLim, Tco, Dz

AC    9 Actuator ID number                                9
AC    9 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)               J
AC    9 Actuator location; Node or Hinge (N or H)
AC    9 Mounting point body ID number, node ID number     1 7
AC    9 Second mounting point body ID, second node ID
AC    9 Output axis unit vector x,y,z                     0 1 0
AC    9 Mounting point Hinge index, Axis index
AC    9 Rotor spin axis unit vector x,y,z
AC    9 Initial rotor momentum, H
AC    9 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC    9 Outer gimbal axis unit vector x,y,z
AC    9 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC    9 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC    9 Inner gimbal axis unit vector x,y,z
AC    9 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC    9 Initial length and rate, y(to) and ydot(to)
AC    9 Constants; K1 or wo, n or zeta, Kg, Jm
AC    9 Non-linearities; TLim, Tco, Dz

AC   10 Actuator ID number                                10
AC   10 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)               J
AC   10 Actuator location; Node or Hinge (N or H)
AC   10 Mounting point body ID number, node ID number     1 7
AC   10 Second mounting point body ID, second node ID
AC   10 Output axis unit vector x,y,z                     0 -1 0
AC   10 Mounting point Hinge index, Axis index
AC   10 Rotor spin axis unit vector x,y,z
AC   10 Initial rotor momentum, H
AC   10 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   10 Outer gimbal axis unit vector x,y,z
AC   10 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   10 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC   10 Inner gimbal axis unit vector x,y,z
AC   10 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC   10 Initial length and rate, y(to) and ydot(to)
AC   10 Constants; K1 or wo, n or zeta, Kg, Jm
AC   10 Non-linearities; TLim, Tco, Dz

AC   11 Actuator ID number                                11
AC   11 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)               J
AC   11 Actuator location; Node or Hinge (N or H)
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AC  11 Mounting point body ID number, node ID number             1 6
AC  11 Second mounting point body ID, second node ID
AC  11 Output axis unit vector x,y,z                             0 1 0
AC  11 Mounting point Hinge index, Axis index
AC  11 Rotor spin axis unit vector x,y,z
AC  11 Initial rotor momentum, H
AC  11 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  11 Outer gimbal axis unit vector x,y,z
AC  11 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  11 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  11 Inner gimbal axis unit vector x,y,z
AC  11 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  11 Initial length and rate, y(to) and ydot(to)
AC  11 Constants; K1 or wo, n or zeta, Kg, Jm
AC  11 Non-linearities; TLim, Tco, Dz

AC  12 Actuator ID number                                        12
AC  12 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       J
AC  12 Actuator location; Node or Hinge (N or H)
AC  12 Mounting point body ID number, node ID number             1 6
AC  12 Second mounting point body ID, second node ID
AC  12 Output axis unit vector x,y,z                             0 -1 0
AC  12 Mounting point Hinge index, Axis index
AC  12 Rotor spin axis unit vector x,y,z
AC  12 Initial rotor momentum, H
AC  12 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  12 Outer gimbal axis unit vector x,y,z
AC  12 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  12 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  12 Inner gimbal axis unit vector x,y,z
AC  12 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  12 Initial length and rate, y(to) and ydot(to)
AC  12 Constants; K1 or wo, n or zeta, Kg, Jm
AC  12 Non-linearities; TLim, Tco, Dz

AC  13 Actuator ID number                                        13
AC  13 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       J
AC  13 Actuator location; Node or Hinge (N or H)
AC  13 Mounting point body ID number, node ID number             1 7
AC  13 Second mounting point body ID, second node ID
AC  13 Output axis unit vector x,y,z                             0 0 1
AC  13 Mounting point Hinge index, Axis index
AC  13 Rotor spin axis unit vector x,y,z
AC  13 Initial rotor momentum, H
AC  13 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  13 Outer gimbal axis unit vector x,y,z
AC  13 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  13 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  13 Inner gimbal axis unit vector x,y,z
AC  13 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  13 Initial length and rate, y(to) and ydot(to)
AC  13 Constants; K1 or wo, n or zeta, Kg, Jm
AC  13 Non-linearities; TLim, Tco, Dz

AC  14 Actuator ID number                                        14
AC  14 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                       J
AC  14 Actuator location; Node or Hinge (N or H)
AC  14 Mounting point body ID number, node ID number             1 5
AC  14 Second mounting point body ID, second node ID
AC  14 Output axis unit vector x,y,z                             0 0 -1
AC  14 Mounting point Hinge index, Axis index
AC  14 Rotor spin axis unit vector x,y,z
AC  14 Initial rotor momentum, H
AC  14 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  14 Outer gimbal axis unit vector x,y,z
AC  14 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  14 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  14 Inner gimbal axis unit vector x,y,z
AC  14 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  14 Initial length and rate, y(to) and ydot(to)
AC  14 Constants; K1 or wo, n or zeta, Kg, Jm
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AC  14 Non-linearities; TLim, Tco, Dz

AC  15 Actuator ID number                                 15
AC  15 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                J
AC  15 Actuator location; Node or Hinge (N or H)
AC  15 Mounting point body ID number, node ID number      1 8
AC  15 Second mounting point body ID, second node ID
AC  15 Output axis unit vector x,y,z                      0 0 1
AC  15 Mounting point Hinge index, Axis index
AC  15 Rotor spin axis unit vector x,y,z
AC  15 Initial rotor momentum, H
AC  15 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  15 Outer gimbal axis unit vector x,y,z
AC  15 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  15 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  15 Inner gimbal axis unit vector x,y,z
AC  15 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  15 Initial length and rate, y(to) and ydot(to)
AC  15 Constants; K1 or wo, n or zeta, Kg, Jm
AC  15 Non-linearities; TLim, Tco, Dz

AC  16 Actuator ID number                                 16
AC  16 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                J
AC  16 Actuator location; Node or Hinge (N or H)
AC  16 Mounting point body ID number, node ID number      1 6
AC  16 Second mounting point body ID, second node ID
AC  16 Output axis unit vector x,y,z                      0 0 -1
AC  16 Mounting point Hinge index, Axis index
AC  16 Rotor spin axis unit vector x,y,z
AC  16 Initial rotor momentum, H
AC  16 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  16 Outer gimbal axis unit vector x,y,z
AC  16 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  16 Inner gimbal axis unit vector x,y,z
AC  16 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  16 Initial length and rate, y(to) and ydot(to)
AC  16 Constants; K1 or wo, n or zeta, Kg, Jm
AC  16 Non-linearities; TLim, Tco, Dz

AC  17 Actuator ID number                                 17
AC  17 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                J
AC  17 Actuator location; Node or Hinge (N or H)
AC  17 Mounting point body ID number, node ID number      1 2
AC  17 Second mounting point body ID, second node ID
AC  17 Output axis unit vector x,y,z                      1 0 0
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AC  17 Initial rotor momentum, H
AC  17 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  17 Outer gimbal axis unit vector x,y,z
AC  17 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  17 Inner gimbal axis unit vector x,y,z
AC  17 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  17 Initial length and rate, y(to) and ydot(to)
AC  17 Constants; K1 or wo, n or zeta, Kg, Jm
AC  17 Non-linearities; TLim, Tco, Dz

AC  18 Actuator ID number                                 18
AC  18 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                J
AC  18 Actuator location; Node or Hinge (N or H)
AC  18 Mounting point body ID number, node ID number      1 2
AC  18 Second mounting point body ID, second node ID
AC  18 Output axis unit vector x,y,z                      0 1 0
AC  18 Mounting point Hinge index, Axis index
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AC  18 Initial rotor momentum, H
AC  18 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  18 Outer gimbal axis unit vector x,y,z
AC  18 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  18 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  18 Inner gimbal axis unit vector x,y,z
AC  18 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  18 Initial length and rate, y(to) and ydot(to)
AC  18 Constants; K1 or wo, n or zeta, Kg, Jm
AC  18 Non-linearities; TLim, Tco, Dz

AC  19 Actuator ID number                                   19
AC  19 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  J
AC  19 Actuator location; Node or Hinge (N or H)
AC  19 Mounting point body ID number, node ID number        1 2
AC  19 Second mounting point body ID, second node ID
AC  19 Output axis unit vector x,y,z                        0 0 1
AC  19 Mounting point Hinge index, Axis index
AC  19 Rotor spin axis unit vector x,y,z
AC  19 Initial rotor momentum, H
AC  19 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
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AC  19 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  19 Inner gimbal axis unit vector x,y,z
AC  19 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  19 Initial length and rate, y(to) and ydot(to)
AC  19 Constants; K1 or wo, n or zeta, Kg, Jm
AC  19 Non-linearities; TLim, Tco, Dz

AC  20 Actuator ID number                                   20
AC  20 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  MO
AC  20 Actuator location; Node or Hinge (N or H)
AC  20 Mounting point body ID number, node ID number        1 2
AC  20 Second mounting point body ID, second node ID
AC  20 Output axis unit vector x,y,z                        1 0 0
AC  20 Mounting point Hinge index, Axis index
AC  20 Rotor spin axis unit vector x,y,z
AC  20 Initial rotor momentum, H
AC  20 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  20 Outer gimbal axis unit vector x,y,z
AC  20 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  20 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  20 Inner gimbal axis unit vector x,y,z
AC  20 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  20 Initial length and rate, y(to) and ydot(to)
AC  20 Constants; K1 or wo, n or zeta, Kg, Jm
AC  20 Non-linearities; TLim, Tco, Dz

AC  21 Actuator ID number                                   21
AC  21 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  MO
AC  21 Actuator location; Node or Hinge (N or H)
AC  21 Mounting point body ID number, node ID number        1 2
AC  21 Second mounting point body ID, second node ID
AC  21 Output axis unit vector x,y,z                        0 1 0
AC  21 Mounting point Hinge index, Axis index
AC  21 Rotor spin axis unit vector x,y,z
AC  21 Initial rotor momentum, H
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AC  21 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  21 Initial length and rate, y(to) and ydot(to)
AC  21 Constants; K1 or wo, n or zeta, Kg, Jm
AC  21 Non-linearities; TLim, Tco, Dz

AC  22 Actuator ID number                                   22
AC  22 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                  MO
AC  22 Actuator location; Node or Hinge (N or H)
AC  22 Mounting point body ID number, node ID number        1 2
AC  22 Second mounting point body ID, second node ID
AC  22 Output axis unit vector x,y,z                        0 0 1
AC  22 Mounting point Hinge index, Axis index
```

```
AC  22 Rotor spin axis unit vector x,y,z
AC  22 Initial rotor momentum, H
AC  22 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  22 Outer gimbal axis unit vector x,y,z
AC  22 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  22 Inner gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  22 Inner gimbal axis unit vector x,y,z
AC  22 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  22 Initial length and rate, y(to) and ydot(to)
AC  22 Constants; K1 or wo, n or zeta, Kg, Jm
AC  22 Non-linearities; TLim, Tco, Dz

AC  23 Actuator ID number                                    23
AC  23 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                   MA
AC  23 Actuator location; Node or Hinge (N or H)
AC  23 Mounting point body ID number, node ID number         1 2
AC  23 Second mounting point body ID, second node ID
AC  23 Output axis unit vector x,y,z                         1 0 0
AC  23 Mounting point Hinge index, Axis index
AC  23 Rotor spin axis unit vector x,y,z
AC  23 Initial rotor momentum, H
AC  23 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  23 Outer gimbal axis unit vector x,y,z
AC  23 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  23 Constants; K1 or wo, n or zeta, Kg, Jm
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AC  24 Actuator ID number                                    24
AC  24 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                   MA
AC  24 Actuator location; Node or Hinge (N or H)
AC  24 Mounting point body ID number, node ID number         1 2
AC  24 Second mounting point body ID, second node ID
AC  24 Output axis unit vector x,y,z                         0 1 0
AC  24 Mounting point Hinge index, Axis index
AC  24 Rotor spin axis unit vector x,y,z
AC  24 Initial rotor momentum, H
AC  24 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
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AC  24 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  24 Initial length and rate, y(to) and ydot(to)
AC  24 Constants; K1 or wo, n or zeta, Kg, Jm
AC  24 Non-linearities; TLim, Tco, Dz

AC  25 Actuator ID number                                    25
AC  25 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                   MA
AC  25 Actuator location; Node or Hinge (N or H)
AC  25 Mounting point body ID number, node ID number         1 2
AC  25 Second mounting point body ID, second node ID
AC  25 Output axis unit vector x,y,z                         0 0 1
AC  25 Mounting point Hinge index, Axis index
AC  25 Rotor spin axis unit vector x,y,z
AC  25 Initial rotor momentum, H
AC  25 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
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AC  25 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  25 Inner gimbal axis unit vector x,y,z
AC  25 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  25 Initial length and rate, y(to) and ydot(to)
AC  25 Constants; K1 or wo, n or zeta, Kg, Jm
AC  25 Non-linearities; TLim, Tco, Dz

AC  26 Actuator ID number                                    26
AC  26 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                   J
```

```
AC  26 Actuator location; Node or Hinge (N or H)
AC  26 Mounting point body ID number, node ID number           3 2
AC  26 Second mounting point body ID, second node ID
AC  26 Output axis unit vector x,y,z                           1 0 0
AC  26 Mounting point Hinge index, Axis index
AC  26 Rotor spin axis unit vector x,y,z
AC  26 Initial rotor momentum, H
AC  26 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  26 Outer gimbal axis unit vector x,y,z
AC  26 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  26 Inner gimbal axis unit vector x,y,z
AC  26 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  26 Initial length and rate, y(to) and ydot(to)
AC  26 Constants; K1 or wo, n or zeta, Kg, Jm
AC  26 Non-linearities; TLim, Tco, Dz

AC  27 Actuator ID number                                      27
AC  27 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                     J
AC  27 Actuator location; Node or Hinge (N or H)
AC  27 Mounting point body ID number, node ID number           3 2
AC  27 Second mounting point body ID, second node ID
AC  27 Output axis unit vector x,y,z                           0 1 0
AC  27 Mounting point Hinge index, Axis index
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AC  27 Constants; K1 or wo, n or zeta, Kg, Jm
AC  27 Non-linearities; TLim, Tco, Dz

AC  28 Actuator ID number                                      28
AC  28 Type(J,H,MO,T,B,MA,SG,DG,W,L,M1-M7)                     J
AC  28 Actuator location; Node or Hinge (N or H)
AC  28 Mounting point body ID number, node ID number           3 2
AC  28 Second mounting point body ID, second node ID
AC  28 Output axis unit vector x,y,z                           0 0 1
AC  28 Mounting point Hinge index, Axis index
AC  28 Rotor spin axis unit vector x,y,z
AC  28 Initial rotor momentum, H
AC  28 Outer gimbal- angle(deg),inertia,friction(D,S,B,N)
AC  28 Outer gimbal axis unit vector x,y,z
AC  28 Out gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
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AC  28 Inner gimbal axis unit vector x,y,z
AC  28 In gim fric (Tfi,Tgfo,GAM)/(Tfi,M,D,Kf)/(m,M,B,k)
AC  28 Initial length and rate, y(to) and ydot(to)
AC  28 Constants; K1 or wo, n or zeta, Kg, Jm
AC  28 Non-linearities; TLim, Tco, Dz

       CONTROLLER

CO   1 Controller ID number                                    1
CO   1 Controller type (CB,CM,DB,DM,UC,UD)                     UD
CO   1 Sample time (sec)                                       0.10
CO   1 Number of inputs, Number of outputs                     21 16
CO   1 Number of states
CO   1 Output No., Input type (I,S,T), Input ID, Gain

CO   2 Controller ID number                                    2
CO   2 Controller type (CB,CM,DB,DM,UC,UD)                     UC
CO   2 Sample time (sec)
CO   2 Number of inputs, Number of outputs                     6,6
CO   2 Number of states                                        0
CO   2 Output No., Input type (I,S,T), Input ID, Gain
```

INTERCONNECT

```
IN   1 Interconnect ID number                                      1
IN   1 Source type(S,C, or F),Source ID,Source row #               C 1 1
IN   1 Destination type(A or C),Dest ID,Dest row #                 A 1 1
IN   1 Gain                                                        1

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

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

IN   4 Interconnect ID number                                      4
IN   4 Source type(S,C, or F),Source ID,Source row #               C 1 4
IN   4 Destination type(A or C),Dest ID,Dest row #                 A 4 1
IN   4 Gain                                                        1

IN   5 Interconnect ID number                                      5
IN   5 Source type(S,C, or F),Source ID,Source row #               C 1 5
IN   5 Destination type(A or C),Dest ID,Dest row #                 A 5 1
IN   5 Gain                                                        1

IN   6 Interconnect ID number                                      6
IN   6 Source type(S,C, or F),Source ID,Source row #               C 1 6
IN   6 Destination type(A or C),Dest ID,Dest row #                 A 6 1
IN   6 Gain                                                        1

IN   7 Interconnect ID number                                      7
IN   7 Source type(S,C, or F),Source ID,Source row #               C 1 7
IN   7 Destination type(A or C),Dest ID,Dest row #                 A 7 1
IN   7 Gain                                                        1

IN   8 Interconnect ID number                                      8
IN   8 Source type(S,C, or F),Source ID,Source row #               C 1 8
IN   8 Destination type(A or C),Dest ID,Dest row #                 A 8 1
IN   8 Gain                                                        1

IN   9 Interconnect ID number                                      9
IN   9 Source type(S,C, or F),Source ID,Source row #               C 1 9
IN   9 Destination type(A or C),Dest ID,Dest row #                 A 9 1
IN   9 Gain                                                        1

IN  10 Interconnect ID number                                      10
IN  10 Source type(S,C, or F),Source ID,Source row #               C 1 10
IN  10 Destination type(A or C),Dest ID,Dest row #                 A 10 1
IN  10 Gain                                                        1

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

IN  12 Interconnect ID number                                      12
IN  12 Source type(S,C, or F),Source ID,Source row #               C 1 12
IN  12 Destination type(A or C),Dest ID,Dest row #                 A 12 1
IN  12 Gain                                                        1

IN  13 Interconnect ID number                                      13
IN  13 Source type(S,C, or F),Source ID,Source row #               C 1 13
IN  13 Destination type(A or C),Dest ID,Dest row #                 A 13 1
IN  13 Gain                                                        1

IN  14 Interconnect ID number                                      14
IN  14 Source type(S,C, or F),Source ID,Source row #               C 1 14
```

```
IN  14 Destination type(A or C),Dest ID,Dest row #           A 14 1
IN  14 Gain                                                   1

IN  15 Interconnect ID number                                 15
IN  15 Source type(S,C, or F),Source ID,Source row #          C 1 15
IN  15 Destination type(A or C),Dest ID,Dest row #            A 15 1
IN  15 Gain                                                   1

IN  16 Interconnect ID number                                 16
IN  16 Source type(S,C, or F),Source ID,Source row #          C 1 16
IN  16 Destination type(A or C),Dest ID,Dest row #            A 16 1
IN  16 Gain                                                   1

IN  26 Interconnect ID number                                 26
IN  26 Source type(S,C, or F),Source ID,Source row #          S 1 1
IN  26 Destination type(A or C),Dest ID,Dest row #            C 1 1
IN  26 Gain                                                   1

IN  27 Interconnect ID number                                 27
IN  27 Source type(S,C, or F),Source ID,Source row #          S 2 1
IN  27 Destination type(A or C),Dest ID,Dest row #            C 1 2
IN  27 Gain                                                   1

IN  28 Interconnect ID number                                 28
IN  28 Source type(S,C, or F),Source ID,Source row #          S 3 1
IN  28 Destination type(A or C),Dest ID,Dest row #            C 1 3
IN  28 Gain                                                   1

IN  29 Interconnect ID number                                 29
IN  29 Source type(S,C, or F),Source ID,Source row #          S 4 1
IN  29 Destination type(A or C),Dest ID,Dest row #            C 1 4
IN  29 Gain                                                   1

IN  30 Interconnect ID number                                 30
IN  30 Source type(S,C, or F),Source ID,Source row #          S 4 2
IN  30 Destination type(A or C),Dest ID,Dest row #            C 1 5
IN  30 Gain                                                   1

IN  31 Interconnect ID number                                 31
IN  31 Source type(S,C, or F),Source ID,Source row #          S 5 1
IN  31 Destination type(A or C),Dest ID,Dest row #            C 1 6
IN  31 Gain                                                   1

IN  32 Interconnect ID number                                 32
IN  32 Source type(S,C, or F),Source ID,Source row #          S 5 2
IN  32 Destination type(A or C),Dest ID,Dest row #            C 1 7
IN  32 Gain                                                   1

IN  33 Interconnect ID number                                 33
IN  33 Source type(S,C, or F),Source ID,Source row #          S 5 3
IN  33 Destination type(A or C),Dest ID,Dest row #            C 1 8
IN  33 Gain                                                   1

IN  34 Interconnect ID number                                 34
IN  34 Source type(S,C, or F),Source ID,Source row #          S 6 1
IN  34 Destination type(A or C),Dest ID,Dest row #            C 1 9
IN  34 Gain                                                   1

IN  35 Interconnect ID number                                 35
IN  35 Source type(S,C, or F),Source ID,Source row #          S 7 1
IN  35 Destination type(A or C),Dest ID,Dest row #            C 1 10
IN  35 Gain                                                   1

IN  36 Interconnect ID number                                 36
IN  36 Source type(S,C, or F),Source ID,Source row #          S 8 1
IN  36 Destination type(A or C),Dest ID,Dest row #            C 1 11
IN  36 Gain                                                   1

IN  37 Interconnect ID number                                 37
IN  37 Source type(S,C, or F),Source ID,Source row #          S 9 1
IN  37 Destination type(A or C),Dest ID,Dest row #            C 1 12
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IN  37 Gain                                                    1

IN  38 Interconnect ID number                                  38
IN  38 Source type(S,C, or F),Source ID,Source row #           S 10 1
IN  38 Destination type(A or C),Dest ID,Dest row #             C 2 1
IN  38 Gain                                                    1

IN  39 Interconnect ID number                                  39
IN  39 Source type(S,C, or F),Source ID,Source row #           S 10 2
IN  39 Destination type(A or C),Dest ID,Dest row #             C 2 2
IN  39 Gain                                                    1

IN  40 Interconnect ID number                                  40
IN  40 Source type(S,C, or F),Source ID,Source row #           S 10 3
IN  40 Destination type(A or C),Dest ID,Dest row #             C 2 3
IN  40 Gain                                                    1

IN  41 Interconnect ID number                                  41
IN  41 Source type(S,C, or F),Source ID,Source row #           S 11 1
IN  41 Destination type(A or C),Dest ID,Dest row #             C 2 4
IN  41 Gain                                                    1

IN  42 Interconnect ID number                                  42
IN  42 Source type(S,C, or F),Source ID,Source row #           S 11 2
IN  42 Destination type(A or C),Dest ID,Dest row #             C 2 5
IN  42 Gain                                                    1

IN  43 Interconnect ID number                                  43
IN  43 Source type(S,C, or F),Source ID,Source row #           S 11 3
IN  43 Destination type(A or C),Dest ID,Dest row #             C 2 6
IN  43 Gain                                                    1

IN  17 Interconnect ID number                                  17
IN  17 Source type(S,C, or F),Source ID,Source row #           C 2 1
IN  17 Destination type(A or C),Dest ID,Dest row #             A 26 1
IN  17 Gain                                                    0

IN  18 Interconnect ID number                                  18
IN  18 Source type(S,C, or F),Source ID,Source row #           C 2 2
IN  18 Destination type(A or C),Dest ID,Dest row #             A 27 1
IN  18 Gain                                                    0

IN  19 Interconnect ID number                                  19
IN  19 Source type(S,C, or F),Source ID,Source row #           C 2 3
IN  19 Destination type(A or C),Dest ID,Dest row #             A 28 1
IN  19 Gain                                                    0

IN  20 Interconnect ID number                                  20
IN  20 Source type(S,C, or F),Source ID,Source row #           C 2 4
IN  20 Destination type(A or C),Dest ID,Dest row #             A 23 1
IN  20 Gain                                                    1

IN  21 Interconnect ID number                                  21
IN  21 Source type(S,C, or F),Source ID,Source row #           C 2 5
IN  21 Destination type(A or C),Dest ID,Dest row #             A 24 1
IN  21 Gain                                                    1

IN  22 Interconnect ID number                                  22
IN  22 Source type(S,C, or F),Source ID,Source row #           C 2 6
IN  22 Destination type(A or C),Dest ID,Dest row #             A 25 1
IN  22 Gain                                                    1

IN  23 Interconnect ID number                                  23
IN  23 Source type(S,C, or F),Source ID,Source row #           S 17 1
IN  23 Destination type(A or C),Dest ID,Dest row #             C 1 13
IN  23 Gain                                                    1

IN  24 Interconnect ID number                                  24
IN  24 Source type(S,C, or F),Source ID,Source row #           S 17 2
IN  24 Destination type(A or C),Dest ID,Dest row #             C 1 14
IN  24 Gain                                                    1
```

```
IN  25 Interconnect ID number                               25
IN  25 Source type(S,C, or F),Source ID,Source row #        S 17 3
IN  25 Destination type(A or C),Dest ID,Dest row #          C 1 15
IN  25 Gain                                                 1

IN  44 Interconnect ID number                               44
IN  44 Source type(S,C, or F),Source ID,Source row #        S 17 4
IN  44 Destination type(A or C),Dest ID,Dest row #          C 1 16
IN  44 Gain                                                 1

IN  45 Interconnect ID number                               45
IN  45 Source type(S,C, or F),Source ID,Source row #        S 17 5
IN  45 Destination type(A or C),Dest ID,Dest row #          C 1 17
IN  45 Gain                                                 1

IN  46 Interconnect ID number                               46
IN  46 Source type(S,C, or F),Source ID,Source row #        S 17 6
IN  46 Destination type(A or C),Dest ID,Dest row #          C 1 18
IN  46 Gain                                                 1

IN  47 Interconnect ID number                               47
IN  47 Source type(S,C, or F),Source ID,Source row #        S 17 7
IN  47 Destination type(A or C),Dest ID,Dest row #          C 1 19
IN  47 Gain                                                 1

IN  48 Interconnect ID number                               48
IN  48 Source type(S,C, or F),Source ID,Source row #        S 17 8
IN  48 Destination type(A or C),Dest ID,Dest row #          C 1 20
IN  48 Gain                                                 1

IN  49 Interconnect ID number                               49
IN  49 Source type(S,C, or F),Source ID,Source row #        S 17 9
IN  49 Destination type(A or C),Dest ID,Dest row #          C 1 21
IN  49 Gain                                                 1
```

AEROD

```
AE   1 Aerodynamic Model ID #                               1
AE   1 Body ID, Center of Pressure Node ID                  1 13
AE   1 Atmosphere Type (C,J,M)                              J
AE   1 Constant Density for Atmosphere Type=C
AE   1 Model Type (P,C,T,B)                                 T
AE   1 Dimensions D,L (meters)
AE   1 Unit Normal Vector x,y,z
AE   1 Aero Ref Area, Ref Length (meters)                   16.6051 2.2990
AE   1 Name of Aero Coefficient Table Input File            .\newttae.dat
AE   1 Axial unit vector in body (alpha=0,phi=0)            0. 0. 1.
AE   1 Vert  unit vector in body (alpha=90,phi=0)           .7071 -.7071 0.
AE   1 Horiz unit vector in body (alpha=90,phi=90)          .7071 .7071 0.
```