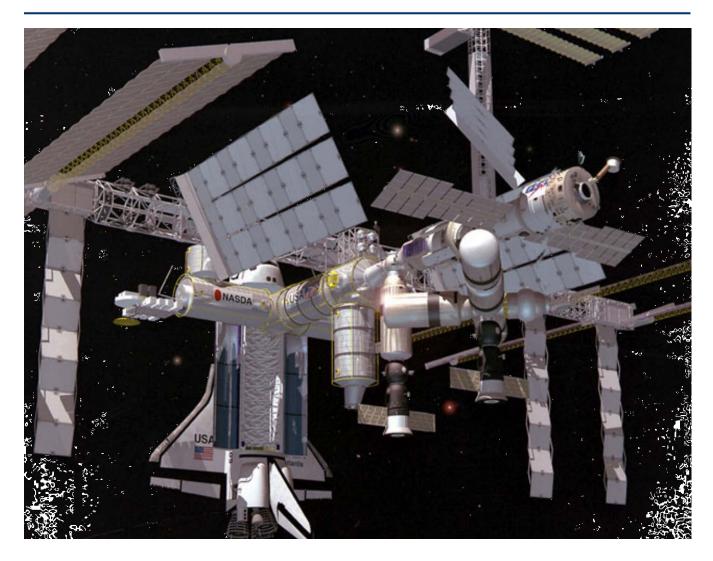
# Flexible Spacecraft Modeling Program



## Introduction

This program is used for creating state-space models of flexible space structures, such as a flexible satellite or a space station with rotating solar arrays and optical sensors. It is not a multi-body non-linear simulation or a finite elements modeling (FEM) program, but it uses modal data generated from a FEM, such as NASTRAN. It essentially provides the capability for the user to manage the FEM and to create state-space systems for control analysis by defining the inputs, outputs and selecting structural modes. Linear models are useful in analyzing spacecraft stability or performance to excitations at a fixed configuration, and not for simulating large angle maneuvering or multi-body payload slewing. They are a lot easier than non-linear multi-body models to analyze because the dynamic modeling is already implemented in the FEM. They can be used in analyzing attitude control stability, appendage gimbal control stability, jitter sensitivity, designing payload pointing servo systems and in general used in applications between the spacecraft structure

and gimbal control loops, perform small angle simulations, and to analyze the effects of spacecraft disturbances to optical or a micro-gravity sensors as a result of the interaction between the structure and the control loops. The inputs to the linear models are either, external forces and moments applied to the structure, such as, reaction control thrusters, control moment gyros, and disturbances, or they can be control torques at the hinges of pivoting appendages, such as solar arrays and payload gimbals. The system outputs are either translation or rotational sensors that measure position, velocity, or acceleration at certain locations on the spacecraft, or gimbal sensors measuring the rotations of pivoting appendages relative to the space structure.

The simplicity offered by the flexible spacecraft modeling program in comparison with the flight vehicle modeling program (that includes equations for both rigid-body motion and flexibility) is that the rigid-body dynamics, structural flexibility, and the dynamics of gimbaling appendages are all included in the modal data and used directly by this program. The rigid-body dynamics can be implemented in a FEM in terms of 3 to 6 rigid-body modes at zero frequency and damping. However, when the rigid-body dynamics is more complex to be implemented by rigid-body modes, such as, in multi-body or non-linear systems, a rigid-body model can be connected in parallel with the flexibility model that has the rigid-body modes removed and only structural modes are included. For example, in Figure 1, the rigid model may be a non-linear simulation or a state-space system generated by the flexible spacecraft modeling program. They both receive the same forces and torques and their responses are combined, as shown.

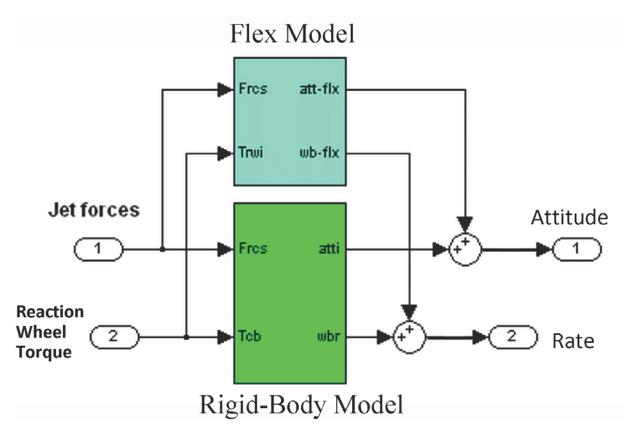


Figure 1 Rigid-Body and Flexible Subsystems can be connected in Parallel to Generate the Flexible Spacecraft Model

## **Data Files**

The flexible spacecraft modeling program uses 4 types of input and output files:

- An input data file (.Inp) which includes the flexible spacecraft dataset that defines the spacecraft configuration, such as, inputs and outputs, flex modes, and it is processed by the program to generate the spacecraft system. This file is also generated interactively by a program utility.
- A modal data file with an extension (.Mod) that includes the structural modes. This file is generated by a finite elements modeling program and reformatted.
- A nodes map file with an extension (.Nod) that defines the spacecraft locations which are included in the modal data, for example, actuator and sensor nodes.
- An output systems file (.Qdr) where the linear state-space models are saved by the program.

These files are described in more detail below

### Modal Data File (.Mod)

The modal data file has a filename extension ".*Mod*", and it contains the modal data of the flexible space structure generated by a finite elements modeling program. In general it includes several hundred modes at increasing frequencies, starting from the first six rigid-body modes which are at zero frequency and they describe the rigid-body behavior of the spacecraft. The remaining are flexible modes associated with structural resonant frequencies. The structural model may also include the flexibility of the attached appendages (if any) with the gimbals "locked". The modal data file is not necessarily a direct output from a FEM program, but it is created by post-processing the FEM output to convert it to the standard format that is recognizable by the Flixan mode selection utility. This modal data reformatting prior to mode selection is also used for reducing the excessive amount of information that is typically generated by the FEM program.

During reformatting we usually include a smaller number of spacecraft locations. We read only the nodes which are possible candidates in the analysis models. Typically 15 to 45 nodes are sufficient to include in the modal data file. In general, the first six modes are the rigid body modes having zero natural frequency and damping coefficients. The remaining modes, starting from mode 7, are structural modes. Each mode in the modal data file consist of the following parameters: the mode frequency  $\omega_f$ , in (rad/sec), the damping coefficient  $\zeta$ , the generalized mass  $m_g$ , and the generalized modal displacements that consist of: 3 translations ( $\varphi$ ) and 3 rotations or slopes ( $\sigma$ ) in (rad/inch) at each node, relative to the spacecraft axes.

The example modal data file below contains modal data for a flexible space station structure consisting of 55 modes and 28 nodes. The shapes and slopes for the first mode are only shown, which is actually a rigid-body mode. The nodes are listed by the node id number, which are the big numbers in the first column. They are used in the original FEM to identify spacecraft locations. There might be several thousands in the original model but only 28 are retained in this file.

STRUCTURAL MODAL DATA FLAXIBLE SPACE STRUCTURE WITH SOLAR ARRAYS NUMBER OF MODES = 55 NODES= 28

Mode #	1, Omega= 0.0,	Zeta=0.0, General.Mass=	1.0000	
Node ID:	Along X	Along Y Along Z	About X	About Y About Z
1060	0.10643D+00	0.74926D-04 -0.64510D-0	3 -0.13631D-07	-0.45285D-04 -0.11342D-04
3000	0.97502D-01	0.74926D-04 -0.63436D-0	3 -0.13631D-07	-0.45285D-04 -0.11342D-04
2060	0.88572D-01	0.74926D-04 -0.62363D-0	3 -0.13631D-07	-0.45285D-04 -0.11342D-04
3100	0.0000D+00	0.0000D+00 0.0000D+0	0 0.0000D+00	0.0000D+00 0.0000D+00
6070	0.41841D-01	0.10176D-03 -0.67460D-0	3 -0.13631D-07	-0.45285D-04 -0.11342D-04
505	0.82939D-01	0.86029D-04 -0.66119D-0	3 -0.13631D-07	-0.45285D-04 -0.11342D-04
6045	0.27333D-01	0.10176D-03 -0.65716D-0	3 -0.13631D-07	-0.45285D-04 -0.11342D-04
6039	0.25100D-01			-0.45285D-04 -0.11342D-04
6001	0.19520D-01	0.10176D-03 -0.64777D-0	3 -0.13631D-07	-0.45285D-04 -0.11342D-04
1000	0.17290D-01			-0.45285D-04 -0.11342D-04
7001	0.12824D-01			-0.45285D-04 -0.11342D-04
7010	0.16632D-02			-0.45285D-04 -0.11342D-04
2000	-0.57120D-03			-0.45285D-04 -0.11342D-04
5001	-0.28039D-02			-0.45285D-04 -0.11342D-04
5039	-0.83810D-02			-0.45285D-04 -0.11342D-04
5045	-0.10614D-01			-0.45285D-04 -0.11342D-04
410	-0.68540D-01			-0.45285D-04 -0.11342D-04
5070	-0.25122D-01			-0.45285D-04 -0.11342D-04
9017	-0.12152D-02			-0.45285D-04 -0.11342D-04
9018				-0.45285D-04 -0.11342D-04
9007	-0.12152D-02			-0.45285D-04 -0.11342D-04
1160	-0.71853D-01			-0.45285D-04 -0.11342D-04
4000	-0.80783D-01			-0.45285D-04 -0.11342D-04
2160	-0.89714D-01			-0.45285D-04 -0.11342D-04
1050	0.97519D-01			-0.45285D-04 -0.11342D-04
2050	0.79657D-01			-0.45285D-04 -0.11342D-04
1150	-0.62938D-01			-0.45285D-04 -0.11342D-04
2150	-0.80800D-01	0.12591D-03 -0.62363D-0	3 -0.13631D-07	-0.45285D-04 -0.11342D-04

Note that not all the flex modes have to be included in the linear analysis model. Some of the modes are weak and they can be excluded from the state-space model by means of a mode selection process to be discussed later.

#### Nodes Look-Up Table (.Nod)

The locations file or nodes map has a filename extension (.Nod). It describes the spacecraft nodes and provides information about the spacecraft locations which are included in the modal data file. The nodes file is used interactively as a look-up table by the mode selection program. It helps the user to identify actuator and sensor locations. A typical nodes file that corresponds to the previous modal data file is shown below and it consists of four columns of data.

- 1. The first column consists of short labels (40 characters long) that describe the spacecraft locations which are included in the modal data file. The nodes are listed in the same order as in the modal data file.
- 2. The second column includes the node numbers beginning from node 1 up to the max number of nodes (28 in this case) which are included in the modal data file (.Mod). The node numbers are used by the mode selection program to identify the actuator and sensor locations.
- 3. The third column contains the node IDs. These are the big numbers that identifying the nodes in the original FEM.
- 4. The last set of column data is optional and it not used by the program. It is only for reference and it includes the coordinates of the corresponding nodes along the spacecraft x, y, and z axes.

NODE IDENTIFICATION TABLE FOR THE LARGE Node Description	Node No	FATION WITH FEM ID	Node I		CMG ,Y,Z (feet)
Payload boom, (top-right)	1	1060			
Payload boom, (center)	2	3000			
Payload boom, (top-left)	3	2060			
Unknown	4	3100			
Right Solar Array Boom	5	6070	0.0	232.35	18.0
Right Solar Array (Connect)	6	505			
Right SA Boom, Outboard the Hinge	7	6045			
Right SA Boom, Inboard the Hinge Servo	8	6039			
Right Boom (Sensor Assembly)	9	6001			
Right Keel/Boom Intrsect, CMG Location	10	1000			
CG Center of Structure	11	7001			
Left Keel/Boom Intersection	12	7010			
Unknown	13	2000			
Left Boom	14	5001			
Left Boom, Inboard the Hinge Servo	15	5039			
Left SA Boom, Outboard the Hinge Servo	16	5045			
Left Solar Array (Connect)	17	410			
Left SA Boom, Extreme end	18	5070	0.0	-224.63	16.0
Right Habitat Module	19	9017			
Module, (Front Dock)	20	9018			
Center Habitat Module	21	9007			
Bottom Payload Boom (Right)	22	1160			
Bottom Payload Boom (Center)	23	4000			
Bottom Payload Boom (Left) Antenna	24	2160			
Top Right RCS Thruster Assembly	25	1050	0.0	73.7	-185.0
Top Left RCS Thrusters Assembly	26	2050	0.0	-65.58	-185.0
Bottom Right RCS Thruster Assembly	27	1150	0.0	73.7	144.0
Bottom Left RCS Thrusters Assembly	28	2150	0.0	-65.58	144.0

#### Input Data File (.Inp)

This file includes several datasets to be used by the Flixan program. It also includes the input dataset used by the flexible spacecraft modeling program. It can be created interactively, saved and processed by the program to generate the spacecraft linear model. It consists of data that describe the spacecraft configuration, inputs, outputs, structural modes, and rotating appendages.

- The data-set begins with an ID label "FLEXIBLE SPACECRAFT FE MODEL ..." that defines the purpose of the dataset and the Flixan flexible spacecraft program that will process the data.
- The next line is the spacecraft title. There are also comment lines below the title that briefly describe the spacecraft model. The title and comment lines are also transferred to the spacecraft system in the (.Qdr) file.
- The next set of data specifies the input forces and torques. It includes the corresponding node location and the directions of the forces or torques. The directions are defined by unit vectors.
- There is also data that define the output sensors. It includes translational or rotational sensors, the sensor location (node number), the sensor direction (1,2,3), for (x, y, and z) translation, or for (roll, pitch, and yaw) rotation. You must also specify the type of sensor, (1,2,3) for (position, rate, or acceleration), and either translation or rotation.
- The input data-set also includes a reduced set of modal data that was selected from the modal data file (.Mod) during the input data file preparation process, as we shall demonstrate. This reduced set of modes consists of: mode frequencies (rad/sec), damping coefficients (ζ), generalized mass, generalized modal shapes (φ) and modal slopes (σ) at specified locations.

• At the bottom of the dataset there is an optional reference to a filename that contains the information required to unlock the appendages gimbals and to apply gimbal torques. This is done by the inertial coupling coefficients (also known as H-parameters matrix) included in this file. This file is only required when the spacecraft includes gimbaling appendages.

The input file may also contain datasets to be processed by other Flixan programs in relationship with the current spacecraft analysis, such as the flight vehicle modeling program, system interconnections, transfer function datasets, etc. A sample input data file for a flexible spacecraft can be found in file *"Surveillance-Sat.Inp"* in folder *"Examples\ Surveillance Satellite React-Wheels"*.

## **Inertial Coupling Coefficients File (.Hpr)**

The inertial coupling coefficients file is optional and it is only required when the spacecraft has rotating bodies, such as solar arrays or gimbaling instruments. It contains the H-parameters matrix that introduces dynamic coupling between gimbaling appendages and spacecraft flexibility. The modal data are calculated assuming that the hinges are locked and they are later released in the simulation equations by the inertial coupling coefficients. The H-parameters matrix is also obtained from the FEM and it is extracted from the mass matrix, the upper and lower right quadrants of the mass matrix. It couples the spacecraft flexibility with the equations that rotate the appendages relative to the spacecraft as a result of the applied torques at the hinges. The inertial coupling coefficients ".*Hpr*" file must have the format shown below in order to be accessible by the Flixan program. The H-parameter matrix rows correspond to the modes. The first six rows correspond to the 6 rigid-body modes, if they are included. The matrix columns correspond to the hinges.

In the following example we have an H-parameters matrix of 100 rows and 4 columns, corresponding to a structure of 100 modes and 4 gimbaling appendages. Each element in this matrix determines the amount of excitation of a flex mode (determined by row) from the rotational acceleration at the appendage gimbal (determined by column). The (.Hpr) data file also includes the moments of inertia matrix of the appendages, that is, (4 x 4) in this case, which is located below the H-parameters matrix. The gimbals are placed in the same order as the columns of the H-parameters. The last set of data in this file includes the unit vector directions of the four hinges, also in the same order. Note that the rotational directions of the hinge vectors are not used by this program because the information is already captured in the rigid-body segment of the H-parameters matrix, which are the first six rows. The directions, however, are included in this file because it is also used by other programs.

When the spacecraft includes gimbaling bodies that require the H-parameters file, the (.Hpr) filename must be included in the last statement of the spacecraft dataset in file (.Inp), below the modal data as already described with file "*Surveillance-Sat.Hpr*" in the example.

#### Inertial Coupling Coefficients (H-Parameters) File Name for the 4 gimbaling bodies: Surveillance-Sat.Hpr

If this line is missing at the end of the dataset, the program will assume that the flexible spacecraft has no gimbals, or that its gimbals are "locked" and the state-space model will not provide the capability to simulate the relative motion at the hinges. It will lack the additional gimbal torque inputs, gimbal rotation states and outputs associated with the gimbaling bodies.

INERTIAL COUPLING COEFFICIENTS (FROM NASTRAN) FOR Surveillance Satellite with Rotating Solar Arrays and Optical Sensor NUMBER OF MODES, GIMBALS: 100, 4 Units (ft-lb-sec<sup>2</sup>) -2.269347606E-01 1.747074520E-01 -1.915053482E-01 -2.195309075E-01 Mode # 1 -1.133417583E+00 -1.374561104E-02 3.669942078E-01 -2.549929767E-01 Mode # 2 4.682515329E-02 7.409226449E-01 -2.031611937E-01 -2.588066122E-01 7.590326391E-02 1.119420489E-01 -5.917569875E-04 -3.510433226E-03 -3.350520970E-02 -3.483536353E-03 -1.103515707E-02 -1.353584642E-02 Mode # 99 -2.108828453E-03 4.130124619E-02 9.495321928E-03 -2.236874122E-03 Mode # 100 MOMENTS OF INERTIA MATRIX OF THE ROTATING BODIES (slug-ft^2) 6.3954598075 -0.049079742633 0.00000000E+00 0.00000000 Payload Inertia (elev) 1.889057024167 -0.049079742633 0.00000000E+00 0.0000000 Payload Inertia (azmth) Right Solar Array 0.00000000E+00 0.0000000E+00 0.0000000E+00 3.1704239175 Left Solar Array Hinge Direction Unit Vectors for the 4 Gimbal Appendages, Payload Elevat, Azimuth, 2 Sol.Arr 1.0 0.0 0.0 0.0 0.0 -1.0 1.0 1.0 0.0 0.0 0.0 0.0

**State-Space Systems File (.Qdr):** The spacecraft state-space model output created by the flexible spacecraft modeling program is saved in a standard Flixan systems file (.Qdr). The system title is the same as the title of the input data set. The definitions of the state-space system variables are listed below the quadruple matrices. This system is usually combined together with the attitude control system and other subsystems to form a closed-loop or open-loop system models that can be used for further analysis. For more details read the Surveillance Satellite example.

## **Flexible Spacecraft Equations**

In the Flexible Spacecraft Modeling program the spacecraft dynamics is defined in terms of mode shapes and frequencies, including the rigid-body modes which are usually the first six modes. The mode shapes and frequencies are imported from the finite elements program assuming that all hinges are "locked" at fixed orientation angles. Rotating appendages are optional, and they are introduced in the model by the H-parameters matrix (H). The gimbals are then released to apply torques and the gimbal rotations can be calculated by the introduction of the H-parameters matrix.

The dynamic model consists of three sets of equations. The first set describes how the structural modes are excited by the external forces and torques. The second set of equations calculates the rotation of the appendage bodies ( $\alpha$ ) relative to the spacecraft as a result of the torques at the joints (T<sub> $\alpha$ </sub>) that control the angles. The third set of equations represents the measurements at the sensors which are mounted on the spacecraft structure. The interaction between the structural modes and the rotating appendages is defined by the inertial coupling coefficients matrix (H). This linear multi-body model is only applicable for small angle simulations, less than 5. For large angle maneuvering, a non-linear multi-body simulation is necessary because the dynamics vary significantly with the orientation angles. However, this linear model is extremely useful for stability analysis, jitter analysis to gimbal or external disturbances, control design, analyze the dynamic interaction between flexibility, attitude control system, and the control systems of the gimbaling appendages, frequency domain analysis, etc. Some of these functions cannot be performed by multi-body non-linear simulations, which require also a lot more effort to develop.

The following second order matrix equation describes the excitation of the bending modes generalized displacement vector (<u>n</u>) by the external forces and torques (F and T) and also by the interaction with the gimbal accelerations  $\underline{\ddot{\alpha}}$ .

$$M_{G}\left(\ddot{\eta}+2\varsigma\Omega\dot{\eta}+\Omega^{2}\eta\right)+H\underline{\ddot{\alpha}}=\Phi^{T}\begin{bmatrix}F\\T\end{bmatrix}$$

The following equation describes the rotations of the gimbaling bodies  $\underline{\alpha}$  relative to the spacecraft, as a result of the applied torques at the hinges ( $\underline{T}_{\alpha}$ ) and also due to coupling with the structural modes  $\underline{n}$  via the transpose of the inertial coupling coefficients matrix (H). The moments of inertia matrix ( $\underline{I}_{\underline{\alpha}}$ ) and the coupling coefficients matrix (H) are extracted from the mass matrix of the finite elements model.

$$I_{\alpha}\,\underline{\ddot{\alpha}} + H^{T}\,\underline{\ddot{\eta}} = \underline{T}_{\alpha}$$

Where:

 $\underline{n}$  is the modal displacement vector for (n) modes

- $M_G$  is a (n x n) diagonal matrix whose elements are the modal masses
- $\Omega$  is a (n x n) diagonal matrix containing the modal frequencies ( $\omega_{fi}$ ) in (rad/sec)
- $\varsigma$  is the modal damping coefficient vector for n modes, typically ( $\varsigma$ =0.005)
- $\underline{\alpha}$  is a vector of dimension (m) representing the rotation angles of the appendages relative to the spacecraft, where (m) is the number of gimbaling bodies
- H is the Inertial Coupling Coefficients matrix of dimension (n x m). It couples the accelerations at the gimbals with the modal displacements <u>n</u> as shown in both equations.
- $\Phi^{T}$  is the mode shapes matrix of size (n x 6) containing the generalized modal displacements at the points where the external forces, moments, and disturbances are applied to the space structure.
- $\underline{F}$  is a vector of the externally applied forces along x, y, and z
- $\underline{T}$  is a vector of the externally applied torques about x, y, and z axes
- $I_{\alpha}$  is an (m x m) moments of inertia matrix of the (m) gimbaling bodies about their axis of rotation in (ft-lf-sec<sup>2</sup>)
- $\underline{T}_{\alpha}$  is a vector of size (m) representing the control torques in (ft-lb) at the payload gimbals.

The sensor measurements vector  $\underline{X}_s$  measure both: rigid and flex spacecraft motion in different locations on the structure, that is, either translations or rotations. Each measurement consists of a linear combination of (n) generalized modal displacements  $\eta_i$ , multiplied with the mode shapes ( $\Phi_s$ ).

$$\underline{X}_{S} = \Phi_{S} \underline{\eta} = \sum_{i=1}^{n} \phi_{si} \eta_{i}$$

Where:

- $\underline{X}_{s}$  is a sensor measurement vector of dimension (6) representing three translations and three rotations at each point (s)
- $\Phi_s$  is a (6 x n) modal matrix containing the mode shapes and slopes for (n) modes at the sensor location (s)

## Flex Spacecraft Model Preparation and Mode Selection

During model preparation we must create a set of data in an input file ".*Inp*" that characterizes the input/ output structure of the spacecraft and includes other parameters, such as input forces, torques, sensor types, directions, etc. The flexible spacecraft input dataset also includes a selected set of dominant flex modes. The dataset may then be processed by the flex spacecraft modeling program to generate the flex spacecraft state-space system. A typical finite element model consists of a large number of element masses and degrees of freedom used for modeling a complex vehicle structure. This results in a very large number of flexible modes. Several hundreds of the FEM modes (usually below a certain cut-off frequency) are extracted and saved in the modal data file (.Mod). It is not practical to include all the modes from the modal data file in the control analysis model, because, (a) it will slow down the analysis, (b) it will complicate the control design, (c) a much smaller number of modes, (20-40 modes), is usually sufficient to approximate the dynamic behavior of the spacecraft within the control bandwidth and a couple of decades higher. During this data preparation process, the user must select certain inputs and outputs that represent the controls, disturbances, gimbals, measurements, and other sensitive locations on the spacecraft. The program searches the modal data file and selects a smaller set of strong modes that should efficiently represent the spacecraft dynamics between the inputs and outputs defined.

The modes are selected by a process that will be described later, based on their modal strength which is calculated by the amount of mode controllability at the points of excitation, and the mode observability at the sensors. The mode strength may vary depending on the locations and directions of the actuators and sensors. The selection of modes in the analysis model strongly depends on what kind of analysis the user intends to perform. If the model is to be used for attitude control stability analysis and it uses attitude sensors for stabilization and thrusters for control, the modes must be selected according to strength between the reaction control jets and the ACS sensors. If, on the other hand, sensitivity analysis is required to determine, for example, the effect of disturbances to on board optical instruments, the modes in the analysis model must be selected based on the modal strengths between the disturbance points and the locations of the optical instruments.

The original FEM output contains also a very large number of nodes that represent locations in the structural model. Each node in the FEM is identified with a long 5 to 7 digits number. For control analysis, however, a much smaller number of modes and nodes are needed in the analysis model. A typical flex model used for control analysis requires between 15 to 40 nodes at locations such as, actuators, sensors, disturbance forces, fuel tanks, etc. The flex spacecraft modeling program activates a mode selection process during model preparation, where the user selects a set of dominant modes from the modal data file (.Mod). Prior to model preparation the analyst must create a nodes map file ".*Nod*" that will be used by the mode selection program in look-up table displays. The modes are presented on a bar plot display and they are selected interactively by the user according to their relative strength calculated between inputs and outputs. The extracted set of modal data is also scaled in this process, if needed, because they may have been created in different units and directions, and they are included in the input data file.

When the spacecraft has gimbaling appendages with coupling coefficients defined in the H-parameters file (.Hpr), the following line must be included as a last statement in the spacecraft input data-set which defines the coefficients filename, as described earlier. If the (.Hpr) filename line is not included, but the spacecraft data-set ends with the selected modal data, the program will assume that the flexible spacecraft has no gimbals.

Inertial Coupling Coefficients (H-Parameters) File Name for the 4 gimbaling bodies: Surveillance-Sat.Hpr

## **Flexible Spacecraft Modeling Process**

The block diagram in Figure 3 highlights the flexible spacecraft modeling program functions of transforming a FEM to flexible spacecraft systems that can be used for control analysis. The characteristics, features, and purpose of those state-space systems are directed by the user choices and the process is described in detail in the following sections.

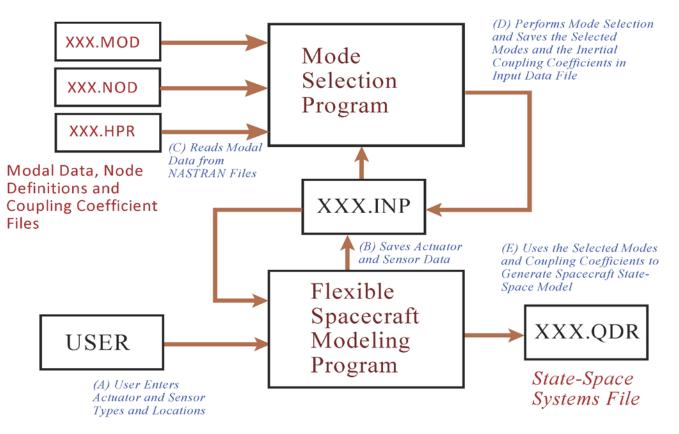


Figure 2 Flexible Spacecraft Modeling Process with Input/ Output Data Files

FLEXIBLE SPACECRAFT FE MODEL Flex Spacecraft with Gimbaling Telescope and Reaction Wheels (67-modes) ! The following is a conceptual multi-body Space Surveillance satellite consisting of ! a core spacecraft body, two rotating Solar Arrays, and an optical payload which can ! gimbal in two directions, azimuth and elevation. It has 3 reaction wheels for ! attitude control, 8 RCS jets for desaturating the reaction wheels, and 4 servos to ! control the 4 gimbals, two for controlling the optical sensor (azimuth and ! elevation) position, and two for rotating the solar arrays. 67 modes were selected ! for this model, 6 rigid and 61 flexible.			
Number of Input Forces applied on flex structure nodes (N force) : 8			
Input Force Number, Node Number (see map), Force Direction unit vector along (x,y,z) : 1	21	1.000	0.000
Input Force Number, Node Number (see map), Force Direction unit vector along (x, v, z) : 2	22	1.000	0.000
Input Force Number, Node Number (see map), Force Direction unit vector along (x,y,z) : 3	23	0.000	1.000
Input Force Number, Node Number (see map), Force Direction unit vector along (x,y,z) : 4	24	0.000	-1.000
Input Force Number, Node Number (see map), Force Direction unit vector along (x,y,z) : 5	25	0.000	-1.000
Input Force Number, Node Number (see map), Force Direction unit vector along (x,y,z) : 6	26	0.000	1.000
Input Force Number, Node Number (see map), Force Direction unit vector along $(x,y,z)$ : 7	27	1.000	0.000
Input Force Number, Node Number (see map), Force Direction unit vector along $(x,y,z)$ : 8	28	1.000	0.000
Number of Input Torques applied on flex structure nodes (N_torque) : 6			
Input Torque Number, Node Number (map), Torque Direction unit vector about $(x,y,z)$ RWA : 1	17	1.000	0.000
Input Torque Number, Node Number (map), Torque Direction unit vector about $(x, y, z)$ RWA : 2	18	0.000	1.000
Input Torque Number, Node Number (map), Torque Direction unit vector about $(x,y,z)$ RWA : 3	19	0.000	0.000
Input Torque Number, Node Number (map), Torque Direction unit vector about $(x,y,z)$ Dist : 4	8	1.000	0.000
Input Torque Number, Node Number (map), Torque Direction unit vector about $(x,y,z)$ Dist : 5	8	0.000	1.000
Input Torque Number, Node Number (map), Torque Direction unit vector about $(x,y,z)$ Dist : 6	8	0.000	0.000
Number of Linear Sensors Measuring Translations on the flex structure nodes (N_transl) : 2	-		
Translation Sensor Numb, Node Numb, Along (1=X, 2=Y, 3=Z), Type (1=Posit, 2=Veloc, 3=Acceler): 1	7	1 3	
Translation Sensor Numb, Node Numb, Along (1=X,2=Y,3=Z), Type (1=Posit,2=Veloc,3=Acceler): 2	7	2 3	
Number of Gyro Sensors Measuring Rotations on the flex structure nodes (N rotat) : 13			
Rotation Sensor Numbr, Node Number, About (1=X,2=Y,3=Z), Type (1=Posit,2=Veloc,3=Acceler): 1	6	1 2	
Rotation Sensor Numbr, Node Number, About (1-X,2-Y,3-Z), Type (1-Fosit,2-Veloc,3-Acceler): 1 Rotation Sensor Numbr, Node Number, About (1-X,2-Y,3-Z), Type (1-Fosit,2-Veloc,3-Acceler): 2	6	2 2	
Rotation Sensor Numbr, Node Number, About (1=X,2=Y,3=Z), Type (1=Fosit,2=Veloc,3=Acceler): 2 Rotation Sensor Numbr, Node Number, About (1=X,2=Y,3=Z), Type (1=Fosit,2=Veloc,3=Acceler): 3	6	3 2	
Rotation Sensor Numbr, Node Number, About $(1-x,2-x)$ , rype $(1-cost,2-vetoc,-acceler)$ . 3 Rotation Sensor Numbr, Node Number, About $(1-x,2-x)$ , Type $(1-cost,2-vetoc,-acceler)$ : 4	6	1 1	
Rotation Sensor Numbr, Node Number, About (1-X,2-Y,3-Z), Type (1-Posit,2-Veloc,3-Acceler): 5 Rotation Sensor Numbr, Node Number, About (1-X,2-Y,3-Z), Type (1-Posit,2-Veloc,3-Acceler): 5	6	2 1	
Rotation Sensor Numbr, Node Number, About (1-X,2-Y,3-Z), Type (1-Fosit,2-Veloc,3-Acceler): 5 Rotation Sensor Numbr, Node Number, About (1-X,2-Y,3-Z), Type (1-Fosit,2-Veloc,3-Acceler): 6	6	3 1	
Rotation Sensor Numbr, Node Number, About (1-4,2-1,3-2), Type (1-Poit,2-Veloc,3-Acceler): 7	9	2 1	
Rotation Sensor Numbr, Node Number, About $(1=x,2=y,3=2)$ , Type $(1=001t,2=v100,3=Acceler)$ : 8	9	3 1	
Rotation Sensor Numbr, Node Number, About (1=x,2=y,3=2), Type (1=0051,2=Veloc,3=Acceler): 9	10	2 1	
Rotation Sensor Numbr, Node Number, About (1=x,2=y,3=2), Type (1=0051,2=Veloc,3=Acceler): 10	10	3 1	
Rotation Sensor Numbr, Node Number, About $(1-x,2-y,3-z)$ , rype $(1-cost,2-vetoc,3-Acceler)$ : 10 Rotation Sensor Numbr, Node Number, About $(1-x,2-y,3-z)$ , rype $(1-cost,2-vetoc,3-Acceler)$ : 11	11	1 1	
Rotation Sensor Numbr, Node Number, About $(1-x,2-y,3-z)$ , rype $(1-cost,2-vetoc,3-Acceler)$ : 12 Rotation Sensor Numbr, Node Number, About $(1-x,2-y,3-z)$ , rype $(1-cost,2-vetoc,3-Acceler)$ : 12	12	2 1	
Rotation Sensor Numbr, Node Number, About $(1=x,2=y,3=2)$ , Type $(1=001t,2=v100,3=Acceler)$ : 13	13	3 1	
ACCELENCE MALE, NOR MALE, ADOR (I-A/L-1/0-2/) Type (I-LOSIO/2-VEIDO, 0-ACCELET). IS	10		

0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000

0.0 0.0 1.0 0.000 0.000 1.000

\_\_\_\_\_

Number of Flexible Modes (max=600), Mode Shapes and Mode Frequencies are included below : 67

MODE# 1/ 1, Frequency (rad/sec), Damping (zeta), Generalized Mass= 0.0000 0.50000E-02 12.000 MODE# 67/ 95, Frequency (rad/sec), Damping (zeta), Generalized Mass= 740.88 0.50000E-02 12.000 DEFINITION OF LOCATIONS (NODES) phi along X phi along Y phi along Z sigm about X sigm about Y sigm about Z

	Node Numb	Modal Data at the 8 Force Application Points	
RCS Jet #1 (+X)	Node Numb 21	0.35959D-01 0.28256D+00 -0.10725D-01 0.41546D-01 0.57240D-02 0.1512	00-01
RCS Jet #1 (+X) RCS Jet #2 (+X)	21	0.89610D-03 -0.29061D-01 0.27685D-01 0.80617D-01 0.77184D-01 -0.2849	
RCS Jet #2 (+X) RCS Jet #3 (+Y)	22	0.46756D-01 -0.10690D+00 -0.23578D-01 0.40200D-01 0.75886D-01 -0.1172	
	23		
RCS Jet #4 (-Y)	24		
RCS Jet #5 (-Y)		-0.57787D-02 -0.61323D-01 0.57778D-01 0.10965D+00 0.12716D+00 0.5973	
RCS Jet #6 (+Y)	26	-0.30158D-01 -0.45443D-01 -0.76508D-01 0.75504D-01 0.52528D-01 -0.5320	
RCS Jet #7 (+X)	27	-0.32138D-01 -0.12351D+00 -0.12644D+00 0.96364D+00 -0.13267D+00 0.1084	
RCS Jet #8 (+X)	28	-0.76304D-01 -0.42040D+00 -0.12345D+00 0.96360D+00 -0.13264D+00 0.1084	2D+01
	Node Numb	Modal Data at the 6 Torque Application Points	
Reaction Wheel #1 Spin Axis	17	-0.38234D-01 0.54279D-02 -0.12327D-01 0.15698D+00 -0.54276D-01 0.1621	1D+00
Reaction Wheel #2 Spin Axis	18	0.23872D-02 -0.32136D-01 0.14296D-01 -0.73282D-01 0.71947D-01 0.1466	5D+00
Reaction Wheel #3 Spin Axis	19	-0.41638D-01 -0.34842D-01 -0.32082D-01 -0.92395D-01 -0.95136D-01 0.1596	
Cryo Cooler Pump	8	0.27854p-01 0.27903p+00 0.18476p+00 0.18584p+00 -0.40835p-01 0.4467	
Cryo Cooler Pump	8	0.27854D-01 0.27903D+00 0.18476D+00 0.18584D+00 -0.40835D-01 0.4467	
Cryo Cooler Pump	8	0.27854D-01 0.27903D+00 0.18476D+00 0.18584D+00 -0.40835D-01 0.4467	
cryo coordr ramp	0		
	Node Numb	Modal Data at the 2 Linear Translation Measurement Points	
Accelerometers	7	0.54855D-02 -0.25231D-01 -0.31773D-01 -0.57026D-01 -0.61675D-01 0.1594	7D-01
Accelerometers	7	0.54855D-02 -0.25231D-01 -0.31773D-01 -0.57026D-01 -0.61675D-01 0.1594	7D-01
	Node Numb	Modal Data at the 13 Rotation Measurement Points	
	Node Numb		F. 0.1
Inertial Attitude Sensors	-		
Inertial Attitude Sensors	6		
Inertial Attitude Sensors	6	0.20068D-01 -0.41742D-01 -0.56465D-01 -0.56683D-01 -0.42977D-01 0.1709	
Inertial Attitude Sensors	6	0.20068D-01 -0.41742D-01 -0.56465D-01 -0.56683D-01 -0.42977D-01 0.1709	
Inertial Attitude Sensors	6	0.20068D-01 -0.41742D-01 -0.56465D-01 -0.56683D-01 -0.42977D-01 0.1709	
Inertial Attitude Sensors	6	0.20068D-01 -0.41742D-01 -0.56465D-01 -0.56683D-01 -0.42977D-01 0.1709	
Second Mirror	9	-0.22816D-01 0.13193D+00 0.19216D+00 0.17636D+00 -0.40523D-01 0.5133	
Second Mirror	9	-0.22816D-01 0.13193D+00 0.19216D+00 0.17636D+00 -0.40523D-01 0.5133	
Sensitive Instrument 2	10	-0.69981D-01 0.84027D-02 -0.16241D+00 -0.79921D-01 -0.75637D-01 0.2084	
Sensitive Instrument 2	10	-0.69981D-01 0.84027D-02 -0.16241D+00 -0.79921D-01 -0.75637D-01 0.2084	
Sensitive Instrument 3	11	-0.43498D-01 0.20726D-01 -0.45681D-01 -0.61583D-01 -0.55313D-01 0.3051	1D-01
Sensitive Instrument 4	12	-0.51402D-01 0.24421D-01 -0.54644D-01 -0.63424D-01 -0.58200D-01 0.2956	7D-01
Sensitive Instrument 5	13	-0.43168D-01 0.13531D-01 -0.58378D-01 -0.63422D-01 -0.58252D-01 0.2958	7D-01
Inertial Coupling Coefficien	ts (H-Parame	ters) File Name for the 4 gimbaling bodies : Surveillance-Sat.Hpr	

Figure 3 Flexible Spacecraft Input Dataset Used to Generate the Flexible Spacecraft Model

- 1. We begin with a finite elements model of the spacecraft generated using NASTRAN or any other FEM program. If the spacecraft has gimbaling appendages, such as, rotating instruments, antennas, solar arrays, telescopes, etc. the modal data must be calculated with the gimbals locked at fixed positions. To release and rotate the gimbals we also need an (.Hpr) file with the H-parameters. This file is also created by the FEM program. Otherwise, if there are no gimbaling bodies you will not need an (.Hpr) file. You may need to generate several FEMs with the joints locked at different orientation angles in order to analyze the system performance at different hinge positions.
- 2. The FEM data must be reduced by retaining a smaller number of spacecraft locations (15-45 nodes), that correspond to points that may possibly be used for actuators, sensors, disturbance excitations, sloshing tanks, etc. The generalized mode shapes, slopes, generalized masses, modal frequencies, and nodes are extracted from the FEM output, reformatted in order to be accessible by Flixan, and saved as a file having an extension (.Mod). After reformatting we typically retain several hundred modes below a cut-off frequency that may be 100 times higher than the control system bandwidth.
- 3. We must also prepare a nodes file having an extension (.Nod) that contains a table of the nodes which are included in the modal data file, and in the same sequence. It consists of a short description of the location, the node number, the node ID number in the FEM, and the x, y, z location of the node (optional). The nodes file will be used in the interactive menus for the purpose of selecting spacecraft locations during model preparation and flex mode selection.
- 4. If the spacecraft has pivoting appendages such as rotating sensors, or solar arrays, the program also requires a coupling coefficients data file (.Hpr). This file is a matrix with columns equal to the number of gimbaling bodies, and rows equal to the number of modes. The moments of inertia matrix of the gimbaling appendages and the hinge direction vectors are also included at the bottom of the (Hpr) file.
- 5. If the dataset of the flexible spacecraft is already created in the input file, the user simply selects the spacecraft title from a menu and runs it using the flexible spacecraft modelling program. The program reads the effector and sensor data, the selected modal data, the coupling coefficients file, it will processes the dataset, generates the state-space system, and save it in the systems file (.Qdr). It will also save the definitions of the state-space variables below the system matrices.
- 6. Otherwise, if the spacecraft dataset is not present, the next step is to prepare the dataset, save it in an input file (.Inp) and process it. This is an interactive process of defining the spacecraft effector and sensor data, title, selecting modes, and the coupling coefficients file, and it will be described in the next section. The flexible spacecraft data-set is finally saved in the input file (.*Inp*) under the label "*Flexible Spacecraft FE Model* ..." and processed by the program.

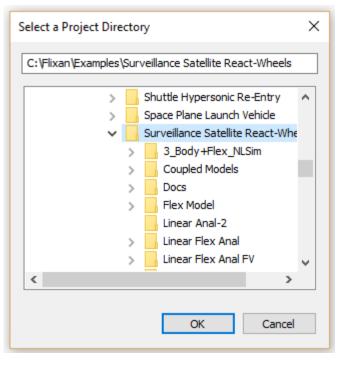
## Generating the Spacecraft Model from Scratch

Let us now create a flexible spacecraft dataset interactively using the model preparation utility and

process it to generate the flexible structure system. We must first define locations and directions of the input forces and torques, that is, RCS jets inputs, reaction wheel torques, and disturbances. We must also define sensors locations and directions, for example, attitude control measurements, accelerometers, and structure locations to be used for various types of sensitive instruments. This example is located in directory "*Flixan*\ *Examples*\ *Surveillance Satellite React-Wheels*".

Start the Flixan program and select the project directory, as shown. Then go to Flixan main menu and select, "*Program Functions*", "*Flight Vehicle/ Spacecraft Modeling Tools*", and then "*Flexible Spacecraft from Modal Data*" program, as shown below. You must also select an input filename to save the spacecraft dataset that will be created, and a systems filename for saving the spacecraft state-space system.

🛰 Flixan, Flight Vehicle Modeling & Control System Analysis



#### Utilities File Management Program Functions View Quad Help Files Flight Vehicle/Spacecraft Modeling Tools Flight Vehicle, State-Space > Frequency Control Analysis > Actuator State-Space Models Robust Control Synthesis Tools > Flex Spacecraft (Modal Data) Creating and Modifying Linear Systems > Create Mixing Logic/ TVC Trim/ Static Perform Analysis Flex Mode Selection

Introduction	
Cancel Flexible Spacecraft Dynamic Modeling Mor	e Info Contir
The Flight Vehicle Modeling program creates a linear model of a flight vehic is controlled by rocket engines, control surfaces, and reaction control jets. be measured by different type of sensors. The program reads the vehicle da mass properties, trajectory, basic aero, engine and control surface data, be parameters, etc, from an input file. The dynamic model can vary from a simp model to a complex multi-axis model including fuel slosh, bending, and tail-w dynamics. The state-space model is saved in a systems file "xxx.qdr", and it other programs. Other options generate actuator models, bending mode preper mixing logic for the effectors.	le. The vehicle Its motion can ta, such as nding, slosh le rigid body vags-dog can be used by

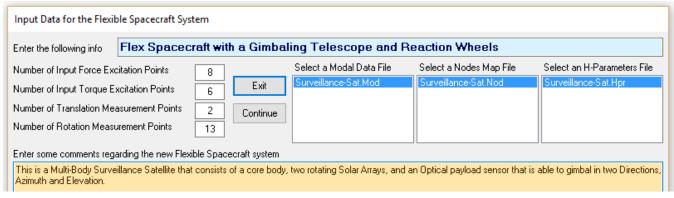
#### Select Input and System Filenames

Select a File Name containing	Select a File Name containing
the Input Data Set (x.Inp)	the State Systems (x.Qdr)
Surveillance-Sat.Inp	Surveillance-Sat.Qdr
Surveillance-Sat.Inp	Surveillance-Sat.Qdr
Surv_Sat_RB+Flx.Inp	Surv_Sat_RB+Flx.Qdr
NewFile.Inp	NewFile.Qdr
Create New Input Set Ex	Process Files

The following menu shows the titles of the "Flexible Spacecraft" datasets which are already saved in the input file (.Inp). There are four spacecraft datasets already there, but in this example we do not select and process any, but we click on "*Create New*" to create a new flexible spacecraft dataset interactively.



The next dialog is used for entering the number and type of spacecraft inputs and outputs that will define the configuration of the spacecraft structure. Enter the new spacecraft title and the number of inputs and outputs. In this example we have 8 RCS input forces, and 6 torque inputs which are: 3 reaction wheel control torques and 3 disturbance torques. We also specify 2 translational measurements for accelerometers and 13 rotational measurements for control, plus other types of sensitivity measurements. We must also use the three menus on the right to select filenames: for the modal data file *"Surveillance-Sat.Mod"*, the nodes file *"Surveillance-Sat.Nod"*, and the H-parameters file for the 4 gimbaling appendages, *"Surveillance-Sat.Hpr"*. We may also enter a short paragraph in the yellow field at the bottom of the dialog describing the flexible spacecraft features. This paragraph will appear as comments in the data files, below the title.



After defining the number of spacecraft inputs and outputs our next step is to define structural locations for the input and output points specified in the previous dialog. That is, to associate the 8 RCS jet forces, the 6 torques, the two accelerometer measurements, and the 13 rotational sensors defined in the dialog above, with structural locations in the modal data file. The next two dialogs show how to select nodes for the RCS jet forces and also force directions. The menu is created from the Nodes file as already described. The excitation locations are defined by the node number and the directions are unit vectors. Node numbers #21 through #28 were selected and they correspond to RCS force excitations 1 through 8. Node #21 corresponds to force #1, representing RCS #1, where the force direction is along x: (1, 0, 0). Similarly, force #2 from RCS jet #2 corresponds to node #22 and it is also along x: (1, 0, 0). Force excitation #6 is from RCS jet #6 corresponding to node #26 and it is along y: (0, 1, 0). Force excitation #7 is from RCS jet #7 corresponding to node #27 and it is along x: (1, 0, 0), etc.

	nputs			2
Define a Direction Vector for Force Excitation : 1	1.00	0.00	0.00	OK
Select a Location (Node) for Force Excitation : 1				Cancel
Moving Mirror	1	2101		
Fixed Mirror	2	2102		
Focal Plane	3	2103		
Moving Antenna	4	2104		
Fixed Antenna Inertial Attitude Sensors	5	2105	0.747	0 114
Accelerometers	7	31001 31002	-0.747 0.338	0.114
Cryo Cooler Pump	é é	40101	0.330	0.040
Second Mirror	9	40102		
Sensitive Instrument 2	10	40103		
Sensitive Instrument 3	11	40104		
Sensitive Instrument 4	12	40105		
Sensitive Instrument 5	13	40106		
Right Solar Array Attachm	14	62131	-0.37	1.832
Left Solar Array Attachm	15	62231	-0.37	-1.832
Left Horizon Sensor	16	10001	1.0	-1.446
Reaction Wheel #1 CG	17	58041	-0.792	0.049
Reaction Wheel #2 CG Reaction Wheel #3 CG	18 19	58042 58043	0.354	-0.71 0.661
Right Horizon Sensor	20	10002	0.907	
RCS Jet #1 (+X)	21	98001	-2.362	
RCS Jet #2 (+X)	22	98002	-2.362	0.0
RCS Jet #3 (+Y)	23	98003	1.271	-1.433
RCS Jet #4 (-Y)	24	98004	1.271	1.433
RCS Jet #5 (-Y)	25	98005	-1.787	0.708
RCS Jet #6 (+Y)	26	98006	-1.787	-0.708
RCS Jet #7 (+X)	27	98007	-2.362	0.0
RCS Jet #8 (+X)	28	98008	-2.34	0.0
efine a Direction Vector for Force Excitation : 7	1.00	0.00	0.00	OK
elect a Location (Node) for Force Excitation : 7			[	Cancel
Noving Mirror	1	2101		
lixed Mirror	2	2102		
Yocal Plane	3	2103		
Noving Antenna	4	2104		
/ixed Antenna	5	2105		
nertial Attitude Sensors	6	31001	-0.747	0.114
Accelerometers	7	31002	0.338	0.648
ryo Cooler Pump	8	40101		
Second Mirror	9	40102		
Sensitive Instrument 2	10	40103		
Sensitive Instrument 3 Sensitive Instrument 4	11 12	40104		
Sensitive Instrument 4 Sensitive Instrument 5	12	40105 40106		
Right Solar Array Attachm	13	40108 62131	-0.37	1.832
Seft Solar Array Attachm	15	62231	-0.37	-1.832
-	16	10001	1.0	-1.446
eit Horizon Sensor	17	58041	-0.792	0.049
				-0.71
eaction Wheel #1 Spin Axis	18	58042	0.004	
Reaction Wheel #1 Spin Axis Reaction Wheel #2 Spin Axis	18 19	58042 58043	0.438	
Reaction Wheel #1 Spin Axis Reaction Wheel #2 Spin Axis Reaction Wheel #3 Spin Axis				0.661
Reaction Wheel #1 Spin Axis Reaction Wheel #2 Spin Axis Reaction Wheel #3 Spin Axis Right Horizon Sensor	19	58043	0.438	0.661 1.57
Reaction Wheel #1 Spin Axis Reaction Wheel #2 Spin Axis Reaction Wheel #3 Spin Axis Right Horizon Sensor RCS Jet #1 (+X)	19 20	58043 10002	0.438 0.907	0.661 1.57 0.0
	19 20 21	58043 10002 98001	0.438 0.907 -2.362 -2.362	0.661 1.57 0.0
Reaction Wheel #1 Spin Axis Reaction Wheel #2 Spin Axis Reaction Wheel #3 Spin Axis Right Horizon Sensor RCS Jet #1 (+X) RCS Jet #2 (+X) RCS Jet #3 (+Y)	19 20 21 22	58043 10002 98001 98002	0.438 0.907 -2.362 -2.362	0.661 1.57 0.0 0.0 -1.433
Reaction Wheel #1 Spin Axis Reaction Wheel #2 Spin Axis Reaction Wheel #3 Spin Axis Right Horizon Sensor RCS Jet #1 (+X) RCS Jet #2 (+X) RCS Jet #3 (+Y) RCS Jet #4 (-Y) RCS Jet #5 (-Y)	19 20 21 22 23	58043 10002 98001 98002 98003	0.438 0.907 -2.362 -2.362 1.271 1.271 -1.787	0.661 1.57 0.0 0.0 -1.433 1.433 0.708
Reaction Wheel #1 Spin Axis Reaction Wheel #2 Spin Axis Reaction Wheel #3 Spin Axis Right Horizon Sensor RCS Jet #1 (+X) RCS Jet #2 (+X) RCS Jet #3 (+Y) RCS Jet #4 (-Y)	19 20 21 22 23 24	58043 10002 98001 98002 98003 98004	0.438 0.907 -2.362 -2.362 1.271 1.271	0.661 1.57 0.0 0.0 -1.433 1.433 0.708

In the next three dialogs we must select locations and directions for the first 3 torques which are reaction wheel torques. Nodes #17, #18, #19, correspond to RW #1, #2, and #3. The torque directions in body axes are about x, y, and z respectively. The dialog below is used to select the first wheel. The next two are selected from similar dialogs. Note that the wheels are usually very near to each other and are mounted inside a solid structure. A single node is therefore sufficient for the reaction wheel array, but in this example we may select 3 separate nodes to apply the roll, pitch, and yaw torques.

Pefine a Direction Vector for Torque Excitation: 1	1.00	0.00	0,00	04	
long x,y,z	1.00	0.00	quu	OK	
elect a Location (Node) for Torque Excitation: 1				Cancel	
Moving Mirror	1	2101			
Fixed Mirror	2	2102			
Focal Plane	3	2103			
Moving Antenna	4	2104			
Fixed Antenna	5	2105			
Inertial Attitude Sensors	6	31001	-0.747	0.114	
Accelerometers	7	31002	0.338	0.648	
Cryo Cooler Pump	8	40101			
Second Mirror	9	40102			
Sensitive Instrument 2	10	40103			
Sensitive Instrument 3	11	40104			
Sensitive Instrument 4	12	40105			
Sensitive Instrument 5	13	40106			
Right Solar Array Attachm	14	62131	-0.37	1.832	
Left Solar Array Attachm	15	62231	-0.37	-1.832	
Left Horizon Sensor	16	10001	1.0	-1.446	
Reaction Wheel #1 CG	17	58041	-0.792	0.049	
Reaction Wheel #2 CG	18	58042	0.354	-0.71	
Reaction Wheel #3 CG	19	58043	0.438	0.661	
Right Horizon Sensor	20	10002	0.907	1.57	
RCS Jet #1 (+X)	21	98001	-2.362	0.0	
RCS Jet #2 (+X)	22	98002	-2.362	0.0	
RCS Jet #3 (+Y)	23	98003	1.271	-1.433	
RCS Jet #4 (-Y)	24	98004	1.271	1.433	
RCS Jet #5 (-Y)	25	98005	-1.787	0.708	
RCS Jet #6 (+Y)	26	98006	-1.787	-0.708	
RCS Jet #7 (+X)	27	98007	-2.362	0.0	
	28	98008	-2.34	0.0	

We must also select 3 structural locations for the cryo-cooler disturbance torques. The cryo-cooler is located at node #8. The disturbance torques, (4, 5, and 6) are applied in roll, pitch, and yaw respectively. Only the roll and pitch disturbance torque selections are shown below. Roll is (1, 0, 0), pitch is (0, 1, 0) and yaw is (0, 0, 1). All 3 torques are applied at the same node #8 location.

Define a Direction Vector for Torque Excitation: 4				
along x,y,z	1.00	0.00	0.00	OK
Select a Location (Node) for Torque Excitation: 4				Cancel
Moving Mirror	1	2101		
Fixed Mirror	2	2102		
Focal Plane	3	2103		
Moving Antenna	4	2104		
Fixed Antenna	5	2105		
Inertial Attitude Sensors	6	31001	-0.747	0.114
Accelerometers	7	31002	0.338	0.648
Cryo Cooler Pump	8	40101		
Second Mirror	9	40102		
Sensitive Instrument 2	10	40103		
Sensitive Instrument 3 Sensitive Instrument 4	11 12	40104		
Sensitive Instrument 4 Sensitive Instrument 5	12	40105 40106		
Right Solar Array Attachm	13	62131	-0.37	1.832
Left Solar Array Attachm	15	62231	-0.37	
Left Horizon Sensor	16	10001	1.0	
Reaction Wheel #1 Spin Axis	17	58041	-0.792	
Reaction Wheel #2 Spin Axis	18	58041		-0.71
Reaction Wheel #3 Spin Axis	19	58043	0.438	
Right Horizon Sensor	20	10002	0.907	
RCS Jet #1 (+X)	21	98001	-2.362	
RCS Jet #2 (+X)	22	98002	-2.362	
RCS Jet #3 (+Y)	23	98003	1.271	-1.433
RCS Jet #4 (-Y)	24	98004	1.271	1.433
RCS Jet #5 (-Y)	25	98005	-1.787	0.708
RCS Jet #6 (+Y)	26	98006	-1.787	-0.708
RCS Jet #7 (+X)	27	98007	-2.362	0.0
RCS Jet #8 (+X)	28	98008	-2.34	0.0
Define a Direction Vector for Torque Excitation: 5	0.00	1.00	0.00	OK
along x,y,z	0.00	1.00	0.00	OK Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5			0.00	
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror	1	2101	0.00	
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror		2101 2102	0.00	
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane	1 2	2101	0.00	
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror	1 2 3	2101 2102 2103	0.00	
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna	1 2 3 4	2101 2102 2103 2104	-0.747	
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna	1 2 3 4 5	2101 2102 2103 2104 2105	-0.747	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump	1 2 3 4 5 6 7 8	2101 2102 2103 2104 2105 31001 31002 40101	-0.747	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror	1 2 3 4 5 6 7 8 9	2101 2102 2103 2104 2105 31001 31002 40101 40102	-0.747	Cancel
along x,y,2 Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2	1 2 3 4 5 6 7 7 8 9 10	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103	-0.747	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3	1 2 3 4 5 6 7 7 8 9 10 11	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104	-0.747	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4	1 2 3 4 5 6 7 7 8 9 10 11 12	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105	-0.747	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 5	1 2 3 4 5 6 7 8 9 10 11 12 13	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106	-0.747 0.338	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm	1 2 3 4 5 6 7 8 9 10 11 12 13 14	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131	-0.747 0.338 -0.37	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm Left Solar Array Attachm	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131 62231	-0.747 0.338 -0.37 -0.37	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm	1 2 3 4 5 6 7 8 9 10 11 12 13 14	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131 62231 10001	-0.747 0.338 -0.37 -0.37	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm Left Solar Array Attachm Left Horizon Sensor	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131 62231 10001	-0.747 0.338 -0.37 -0.37 1.0 -0.792	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm Left Solar Array Attachm Left Horizon Sensor Reaction Wheel #1 CG	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131 62231 10001 58041	-0.747 0.338 -0.37 -0.37 1.0 -0.792	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm Left Solar Array Attachm Left Horizon Sensor Reaction Wheel #1 CG Reaction Wheel #2 CG	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131 62231 10001 58041 58042	-0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm Left Solar Array Attachm Left Horizon Sensor Reaction Wheel #1 CG Reaction Wheel #3 CG	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131 62231 10001 58041 58042 58043	-0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.438	Cancel
along x,y,2 Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm Left Solar Array Attachm Left Horizon Sensor Reaction Wheel #1 CG Reaction Wheel #2 CG Reaction Wheel #3 CG Right Horizon Sensor RCS Jet #1 (+X) RCS Jet #2 (+X)	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131 62231 10001 58041 58042 58043 10002	-0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.438 0.907	Cancel
along x,y,2 Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm Left Solar Array Attachm Left Solar Array Attachm Left Horizon Sensor Reaction Wheel #1 CG Reaction Wheel #3 CG Right Horizon Sensor RCS Jet #1 (+X) RCS Jet #2 (+X) RCS Jet #3 (+Y)	1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	2101 2102 2103 2104 2105 31001 31002 40103 40104 40105 40106 62131 62231 10001 58041 58042 58043 10002 98001 98002 98003	-0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.438 0.907 -2.362 -2.362 1.271	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm Left Solar Array Attachm Left Horizon Sensor Reaction Wheel #1 CG Reaction Wheel #2 CG Reaction Wheel #3 CG Right Horizon Sensor RCS Jet #1 (+X) RCS Jet #2 (+X) RCS Jet #3 (+Y) RCS Jet #4 (-Y)	1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	2101 2102 2103 2104 2105 31001 31002 40103 40104 40105 40106 62131 62231 10001 58041 58042 58043 10002 98001 98002 98003 98004	-0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.438 0.907 -2.362 -2.362 1.271 1.271	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm Left Solar Array Attachm Left Horizon Sensor Reaction Wheel #1 CG Reaction Wheel #3 CG Right Horizon Sensor RCS Jet #1 (+X) RCS Jet #2 (+X) RCS Jet #4 (-Y) RCS Jet #5 (-Y)	1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131 62231 10001 58041 58043 10002 98001 98002 98003 98004 98005	-0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.438 0.907 -2.362 -2.362 1.271 1.271 -1.787	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm Left Solar Array Attachm Left Horizon Sensor Reaction Wheel #1 CG Reaction Wheel #3 CG Right Horizon Sensor RCS Jet #1 (+X) RCS Jet #2 (+X) RCS Jet #3 (+Y) RCS Jet #5 (-Y) RCS Jet #6 (+Y)	1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131 62231 10001 58041 58042 58043 10002 98001 98002 98003 98004 98005 98006	-0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.438 0.907 -2.362 -2.362 1.271 1.271 1.271 -1.787 -1.787	Cancel
along x,y,z Select a Location (Node) for Torque Excitation: 5 Moving Mirror Fixed Mirror Focal Plane Moving Antenna Fixed Antenna Inertial Attitude Sensors Accelerometers Cryo Cooler Pump Second Mirror Sensitive Instrument 2 Sensitive Instrument 3 Sensitive Instrument 4 Sensitive Instrument 4 Sensitive Instrument 5 Right Solar Array Attachm Left Solar Array Attachm Left Horizon Sensor Reaction Wheel #1 CG Reaction Wheel #3 CG Right Horizon Sensor RCS Jet #1 (+X) RCS Jet #2 (+X) RCS Jet #4 (-Y) RCS Jet #5 (-Y)	1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25	2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131 62231 10001 58041 58042 58043 10002 98001 98002 98003 98004 98005 98006 98007	-0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.438 0.907 -2.362 -2.362 1.271 1.271 1.271 -1.787 -1.787	Cancel

The sensors are also defined by the node number, the direction of measurement (roll, pitch, yaw) or along (x, y, z), and the type of measurement (position, rate, or acceleration). For the translational sensors (1 and 2) we select node #7 to define the location of two accelerometers measuring along the x and y axes respectively. The selection of the first accelerometer measuring in the x direction is shown below. The second accelerometer is measuring along y.

Define Locations and Directions of the	System Outputs				
Select a Location (Node) for Translation Se	ensor 1				
Moving Mirror	1	2101			
Fixed Mirror	2	2102			
Focal Plane	3	2103			
Moving Antenna	4	2104			
Fixed Antenna	5	2105			
Inertial Attitude Sensors	6	31001	-0.747	0.114	2
Accelerometers	7	31002	0.338	0.648	2
Cryo Cooler Pump	8	40101			
Second Mirror	9	40102			
Sensitive Instrument 2	10	40103			
Sensitive Instrument 3	11	40104			
Sensitive Instrument 4	12	40105			
Sensitive Instrument 5	13	40106			
Right Solar Array Attachm	14	62131	-0.37	1.832	1
Left Solar Array Attachm	15		-0.37	-1.832	1
Left Horizon Sensor	16	10001		-1.446	- 2
Reaction Wheel #1 CG	17		-0.792	0.049	- 2
Reaction Wheel #2 CG	18			-0.71	- 2
Reaction Wheel #3 CG	19	58043	0.438	0.661	- 2
Right Horizon Sensor	20			1.57	2
RCS Jet #1 (+X)	21				1
RCS Jet #2 (+X)	22				2
RCS Jet #3 (+Y)	23			-1.433	2
RCS Jet #4 (-Y)	24			1.433	2
RCS Jet #5 (-Y)	25			0.708	2
RCS Jet #6 (+Y)		98006		-0.708	2
RCS Jet #7 (+X)	27				2
RCS Jet #8 (+X)	28	98008	-2.34	0.0	2
	Sensor Direction	Sensor T	upe		
			ype	Select	
Define a Direction Vector for	Along-X	Position		JEIECI	
Translation Sensor 1 and also what	Along-Y	Velocity			
type of measurement	Along-Z	Accelera	tion	Cancel	
			L	Sansor	

We must finally define locations and directions for our 13 rotational sensors. We have 3 rate gyros at node #6 measuring roll, pitch, and yaw rates, 3 gyro measurements also at node #6 measuring roll, pitch, and yaw rotation angles. They are used for attitude control. We also have two angular pitch and yaw measurements at node #9, two additional angular measurements in pitch and yaw at node #10, and three angular measurements at nodes #11, #12, and #13 measuring roll, pitch, and yaw respectively. They are used for measuring sensitivity at those locations. The following dialogs show the node selection for some of these 13 rotational sensors.

Define Locations and Directions of the Syst	em Outputs				
Select a Location (Node) for Rotational Sensor:	1				
Moving Mirror	1	2101			
Fixed Mirror	2	2102			
Focal Plane	3	2103			
Moving Antenna	4	2104			
Fixed Antenna	5	2105			
Inertial Attitude Sensors	6	31001	-0.747	0.114	
Accelerometers	7	31002	0.338	0.648	1
Cryo Cooler Pump	8	40101			
Second Mirror	9	40102			
Sensitive Instrument 2	10	40103			
Sensitive Instrument 3	11	40104			
Sensitive Instrument 4	12	40105			
Sensitive Instrument 5	13	40106			
Right Solar Array Attachm	14	62131	-0.37	1.832	
Left Solar Array Attachm	15	62231	-0.37	-1.832	
Left Horizon Sensor	16	10001	1.0	-1.446	1
Reaction Wheel #1 CG	17	58041	-0.792	0.049	1
Reaction Wheel #2 CG	18	58042	0.354	-0.71	1
Reaction Wheel #3 CG	19	58043	0.438	0.661	1
Right Horizon Sensor	20	10002	0.907	1.57	
RCS Jet #1 (+X)	21	98001	-2.362	0.0	
RCS Jet #2 (+X)	22	98002	-2.362	0.0	1
RCS Jet #3 (+Y)	23	98003	1.271	-1.433	1
RCS Jet #4 (-Y)	24	98004	1.271	1.433	1
RCS Jet #5 (-Y)	25	98005	-1.787	0.708	1
RCS Jet #6 (+Y)	26	98006	-1.787	-0.708	1
RCS Jet #7 (+X)	27	98007	-2.362	0.0	1
RCS Jet #8 (+X)	28	98008	-2.34	0.0	1
Sens Define a Direction Vector for <b>Roll</b> Rotational Sensor: 1 and also what Pitcl	sor Direction	Sensor T Position		Select	
type of measurement Yaw		Velocity Accelera		Cancel	

Define Locations and Directions of th	e System Outputs					
Select a Location (Node) for Rotational Se	ensor: 7					
Moving Mirror		1	2101			
Fixed Mirror		2	2102			
Focal Plane		3	2103			
Moving Antenna		4	2104			
Fixed Antenna		5	2105			
Inertial Attitude Sensors		6	31001	-0.747	0.114	2
Accelerometers		7	31002	0.338	0.648	2
Cryo Cooler Pump		8	40101			
Second Mirror		9	40102			
Sensitive Instrument 2		10	40103			
Sensitive Instrument 3		11	40104			
Sensitive Instrument 4		12	40105			
Sensitive Instrument 5		13				
Right Solar Array Attachm		14		-0.37		1
Left Solar Array Attachm		15		-0.37		1
Left Horizon Sensor		16		1.0		2
Reaction Wheel #1 CG		17		-0.792		2
Reaction Wheel #2 CG		18		0.354		2
Reaction Wheel #3 CG		19		0.438		2
Right Horizon Sensor		20		0.907		2
RCS Jet #1 (+X)		21		-2.362		1
RCS Jet #2 (+X)		22		-2.362		2
RCS Jet #3 (+Y)		23		1.271		2
RCS Jet #4 (-Y)		24				2
RCS Jet #5 (-Y)		25		-1.787		2
RCS Jet #6 (+Y)		26		-1.787		2
RCS Jet #7 (+X)		27		-2.362		2
RCS Jet #8 (+X)		28	98008	-2.34	0.0	2
	Sensor Direction		Sensor Ty	pe –		
Define a Direction Vector for			-		Select	
Rotational Sensor: 7 and also what	Roll		Position Velocity			
type of measurement	Yaw		Accelerati	ion 🔽		
The structure structure of			Accelerati	on	Cancel	
		_				_

					_
Define Locations and Directions of the System Outputs	;				
Select a Location (Node) for Rotational Sensor: 10					
Moving Mirror	1	2101			_
Fixed Mirror	2	2102			
Focal Plane	3	2103			
Moving Antenna	4	2104			
Fixed Antenna	5	2105			
Inertial Attitude Sensors	6	31001	-0.747	0.114	
Accelerometers	7	31002	0.338	0.648	
Cryo Cooler Pump	8	40101			
Second Mirror	9	40102			
Sensitive Instrument 2	10	40103			
Sensitive Instrument 3	11	40104			
Sensitive Instrument 4	12	40105			
Sensitive Instrument 5	13	40106			
Right Solar Array Attachm	14	62131	-0.37	1.832	
Left Solar Array Attachm	15		-0.37		
Left Horizon Sensor	16			-1.446	
Reaction Wheel #1 CG	17		-0.792		
Reaction Wheel #2 CG	18		0.354		
Reaction Wheel #3 CG	19	58043	0.438	0.661	
Right Horizon Sensor	20	10002			
RCS Jet #1 (+X)	21	98001			
RCS Jet #2 (+X)	22		-2.362		
RCS Jet #3 (+Y)	23			-1.433	
RCS Jet #4 (-Y)	24			1.433	
RCS Jet #5 (-Y)	25			0.708	
RCS Jet #6 (+Y)	26		-1.787		
RCS Jet #7 (+X)	27				
RCS Jet #8 (+X)	28	98008	-2.34	0.0	
Sensor Direction		Course T.			
		Sensor Ty	pe	Select	
Define a Direction Vector for Roll		Position		Select	
Rotational Sensor: 10 and also what Pitch		Velocity			
type of measurement Yaw		Accelerat	tion	Connel	٦
				Cancel	

Left Solar Array Attachm   15   62231   -0.37   -1.832     Left Horizon Sensor   16   10001   1.0   -1.446     Reaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #2   (+X)   22   98002   -2.362   0.0     RCS Jet #3   (+Y)   23   98003   1.271   -1.433     RCS Jet #4   (-Y)   24   98004   1.271   1.433     RCS Jet #5   (-Y)   25   98005   -1.787   0.708     RCS Jet #6   (+Y)   26   98006   -1.787   0.708     RCS Jet #7   (+X)   27   98008   -2.34   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0     Define a Direction Vector for R	elect a Location (Node) for Rotational Se	sor: 12				
Focal Plane   3   2103     Moving Antenna   4   2104     Fixed Antenna   5   2105     Inertial Attitude Sensors   6   31001   -0.747   0.114     Accelerometers   7   31002   0.338   0.648     Cryo Cooler Pump   8   40101     Second Mirror   9   40102     Sensitive Instrument 2   10   40103     Sensitive Instrument 4   12   40105     Sensitive Instrument 5   13   40106     Right Solar Array Attachm   14   62131   -0.37   1.832     Left Solar Array Attachm   15   62231   -0.37   -1.832     Left Horizon Sensor   16   10001   1.0   -1.446     Reaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98003   1.271   1.433     RCS Jet #1   (+X)   22	Moving Mirror	1	2101			
Moving Antenna   4   2104     Fixed Antenna   5   2105     Inertial Attitude Sensors   6   31001   -0.747   0.114     Accelerometers   7   31002   0.338   0.648     Cryo Cooler Pump   8   40101     Second Mirror   9   40102     Sensitive Instrument 2   10   40103     Sensitive Instrument 3   11   40104     Sensitive Instrument 4   12   40105     Sensitive Instrument 5   13   40106     Right Solar Array Attachm   14   62131   -0.37   1.832     Left Horizon Sensor   16   10001   1.0   -1.446     Reaction Wheel #1 CG   17   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #2   (+X)   22   98003   1.271   -1.433     RCS Jet #3   (+Y)   24   98004   1.271   -1.433     RCS Jet #4   (-Y)	-	2	2102			
Fixed Antenna   5   2105     Inertial Attitude Sensors   6   31001   -0.747   0.114     Accelerometers   7   31002   0.338   0.648     Cryo Cooler Pump   8   40101     Second Mirror   9   40102     Sensitive Instrument 2   10   40103     Sensitive Instrument 3   11   40104     Sensitive Instrument 4   12   40105     Sensitive Instrument 5   13   40106     Right Solar Array Attachm   14   62131   -0.37   1.832     Left Solar Array Attachm   15   62231   -0.37   -1.832     Left Horizon Sensor   16   10001   1.0   -1.446     Reaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Resction Wheel #2 CG   18   58042   0.354   -0.71     Resction Wheel #3 CG   19   58043   0.438   0.661     RCS Jet #2   (+X)   22   98001   -2.362   0.0	Focal Plane	3	2103			
Inertial Attitude Sensors   6   31001   -0.747   0.114     Accelerometers   7   31002   0.338   0.648     Cryo Cooler Pump   8   40101     Second Mirror   9   40102     Sensitive Instrument 2   10   40103     Sensitive Instrument 3   11   40104     Sensitive Instrument 4   12   40105     Sensitive Instrument 5   13   40106     Right Solar Array Attachm   14   62131   -0.37   -1.832     Left Solar Array Attachm   15   62231   -0.37   -1.832     Left Solar Array Attachm   15   62231   -0.792   0.049     Reaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #3   (+Y)   23   98003 <td>Moving Antenna</td> <td>4</td> <td>2104</td> <td></td> <td></td> <td></td>	Moving Antenna	4	2104			
Accelerometers   7   31002   0.338   0.648     Cryo Cooler Pump   8   40101     Second Mirror   9   40102     Sensitive Instrument 2   10   40103     Sensitive Instrument 3   11   40104     Sensitive Instrument 4   12   40105     Sensitive Instrument 5   13   40106     Right Solar Array Attachm   14   62131   -0.37   1.832     Left Horizon Sensor   16   10001   1.0   -1.446     Reaction Wheel #1 CG   17   58041   -0.72   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #1   (+X)   21   98003   1.271   -1.433     RCS Jet #3   (+Y)   24   98004   1.271   1.433     RCS Jet #5   (-Y)   25   98005 </td <td>Fixed Antenna</td> <td>5</td> <td>2105</td> <td></td> <td></td> <td></td>	Fixed Antenna	5	2105			
Cryo Cooler Fump   8   40101     Second Mirror   9   40102     Sensitive Instrument 2   10   40103     Sensitive Instrument 3   11   40104     Sensitive Instrument 4   12   40105     Sensitive Instrument 5   13   40106     Right Solar Array Attachm   14   62131   -0.37   1.832     Left Solar Array Attachm   15   62231   -0.37   -1.832     Left Horizon Sensor   16   10001   1.0   -1.446     Reaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #1   (+X)   23   98003   1.271   -1.433     RCS Jet #3   (+Y)   24   98004   1.271   1.433     RCS Jet #5   (-Y)   25	Inertial Attitude Sensors	6	31001	-0.747	0.114	1
Becond Mirror   9   40102     Sensitive Instrument 2   10   40103     Sensitive Instrument 3   11   40104     Sensitive Instrument 4   12   40105     Sensitive Instrument 5   13   40106     Sight Solar Array Attachm   14   62131   -0.37   1.832     Left Solar Array Attachm   15   62231   -0.37   -1.832     Left Horizon Sensor   16   10001   1.0   -1.446     Reaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     QCS Jet #1   (+X)   21   98001   -2.362   0.0     QCS Jet #3   (+Y)   23   98003   1.271   -1.433     QCS Jet #4   (-Y)   24   98004   1.271   1.433     QCS Jet #5   (-Y)   25   98005   -1.787   0.708	Accelerometers	7	31002	0.338	0.648	1
Sensitive Instrument 2   10   40103     Sensitive Instrument 3   11   40104     Sensitive Instrument 4   12   40105     Sensitive Instrument 5   13   40106     Sight Solar Array Attachm   14   62131   -0.37   1.832     Seft Solar Array Attachm   15   62231   -0.37   1.832     Seft Horizon Sensor   16   10001   1.0   -1.446     Seaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #3   (+Y)   23   98003   1.271   -1.433     RCS Jet #4   (-Y)   24   98004   1.271   -1.433     RCS Jet #5   (-Y)   26   98005   -1.787   0.708     RCS Jet #6   (+Y)   26   98006   -	Cryo Cooler Pump	8	40101			
Sensitive Instrument 3   11   40104     Sensitive Instrument 4   12   40105     Sensitive Instrument 5   13   40106     Right Solar Array Attachm   14   62131   -0.37   1.832     Left Solar Array Attachm   15   62231   -0.37   1.832     Left Horizon Sensor   16   10001   1.0   -1.446     Reaction Wheel ‡1 CG   17   58041   -0.792   0.049     Reaction Wheel ‡2 CG   18   58042   0.354   -0.71     Reaction Wheel ‡3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet ‡1   (+X)   21   98001   -2.362   0.0     RCS Jet ‡3   (+Y)   23   98003   1.271   -1.433     RCS Jet ‡3   (-Y)   24   98004   1.271   1.433     RCS Jet ‡4   (-Y)   25   98005   -1.787   0.708     RCS Jet ‡7   (+X)   27   98007   -2.362   0.0     RCS Jet ‡7   (+X)	Second Mirror	9	40102			
Sensitive Instrument 4     12     40105       Sensitive Instrument 5     13     40106       Right Solar Array Attachm     14     62131     -0.37     1.832       Left Solar Array Attachm     15     62231     -0.37     1.832       Left Solar Array Attachm     15     62231     -0.37     1.832       Left Horizon Sensor     16     10001     1.0     -1.446       Reaction Wheel #1 CG     17     58041     -0.792     0.049       Reaction Wheel #2 CG     18     58042     0.354     -0.71       Reaction Wheel #3 CG     19     58043     0.438     0.661       Right Horizon Sensor     20     10002     0.907     1.57       RCS Jet #1     (+X)     21     98001     -2.362     0.0       RCS Jet #3     (+Y)     23     98003     1.271     1.433       RCS Jet #4     (-Y)     24     98004     1.271     1.433       RCS Jet #5     (-Y)     25     98005     -1.787     0.708       RCS Jet	Sensitive Instrument 2	10	40103			
Sensitive Instrument 5   13   40106     Right Solar Array Attachm   14   62131   -0.37   1.832     Left Solar Array Attachm   15   62231   -0.37   -1.832     Left Solar Array Attachm   15   62231   -0.37   -1.832     Left Solar Array Attachm   16   10001   1.0   -1.446     Reaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #2   (+X)   22   98002   -2.362   0.0     RCS Jet #3   (+Y)   23   98003   1.271   -1.433     RCS Jet #4   (-Y)   24   98004   1.271   1.433     RCS Jet #6   (+Y)   26   98006   -1.787   0.708     RCS Jet #7   (+X)   27   98007 <t< td=""><td>Sensitive Instrument 3</td><td>11</td><td>40104</td><td></td><td></td><td></td></t<>	Sensitive Instrument 3	11	40104			
Right Solar Array Attachm   14   62131   -0.37   1.832     Left Solar Array Attachm   15   62231   -0.37   -1.832     Left Horizon Sensor   16   10001   1.0   -1.446     Reaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #2   (+X)   22   98002   -2.362   0.0     RCS Jet #3   (+Y)   23   98003   1.271   -1.433     RCS Jet #4   (-Y)   24   98004   1.271   1.433     RCS Jet #5   (-Y)   25   98005   -1.787   0.708     RCS Jet #6   (+Y)   26   98006   -1.787   0.708     RCS Jet #8   (+X)   28   98008   -2.34   0.0     RCS Jet #8   (+X) <td>Sensitive Instrument 4</td> <td>12</td> <td>40105</td> <td></td> <td></td> <td></td>	Sensitive Instrument 4	12	40105			
Left Solar Array Attachm   15   62231   -0.37   -1.832     Left Horizon Sensor   16   10001   1.0   -1.446     Reaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #2   (+X)   22   98002   -2.362   0.0     RCS Jet #3   (+Y)   23   98003   1.271   -1.433     RCS Jet #4   (-Y)   24   98004   1.271   1.433     RCS Jet #5   (-Y)   25   98005   -1.787   0.708     RCS Jet #6   (+Y)   26   98006   -1.787   0.708     RCS Jet #8   (+X)   28   98008   -2.34   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0     Define a Direction Vector for R	Sensitive Instrument 5	13	40106			
Left Horizon Sensor   16   10001   1.0   -1.446     Reaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #2   (+X)   22   98002   -2.362   0.0     RCS Jet #3   (+Y)   23   98003   1.271   -1.433     RCS Jet #4   (-Y)   24   98004   1.271   1.433     RCS Jet #5   (-Y)   25   98005   -1.787   0.708     RCS Jet #6   (+Y)   26   98006   -1.787   0.708     RCS Jet #7   (+X)   27   98007   -2.362   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0	Right Solar Array Attachm	14	62131	-0.37	1.832	
Reaction Wheel #1 CG   17   58041   -0.792   0.049     Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #2   (+X)   22   98002   -2.362   0.0     RCS Jet #3   (+Y)   23   98003   1.271   -1.433     RCS Jet #4   (-Y)   24   98004   1.271   1.433     RCS Jet #5   (-Y)   25   98005   -1.787   0.708     RCS Jet #6   (+Y)   26   98006   -1.787   -0.708     RCS Jet #7   (+X)   27   98007   -2.362   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0	left Solar Array Attachm	15	62231	-0.37	-1.832	
Reaction Wheel #2 CG   18   58042   0.354   -0.71     Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #2   (+X)   22   98002   -2.362   0.0     RCS Jet #3   (+Y)   23   98003   1.271   -1.433     RCS Jet #4   (-Y)   24   98004   1.271   1.433     RCS Jet #5   (-Y)   25   98005   -1.787   0.708     RCS Jet #6   (+Y)   26   98006   -1.787   -0.708     RCS Jet #7   (+X)   27   98007   -2.362   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0     Roll   Pitch   Position   Velocity   Select   Select	left Horizon Sensor	16	10001	1.0	-1.446	
Reaction Wheel #3 CG   19   58043   0.438   0.661     Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #2   (+X)   22   98002   -2.362   0.0     RCS Jet #3   (+Y)   23   98003   1.271   -1.433     RCS Jet #4   (-Y)   24   98004   1.271   1.433     RCS Jet #5   (-Y)   25   98005   -1.787   0.708     RCS Jet #6   (+Y)   26   98006   -1.787   -0.708     RCS Jet #7   (+X)   27   98007   -2.362   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0     Roll   Pitch   Position   Velocity   Select	Reaction Wheel #1 CG	17			0.049	
Right Horizon Sensor   20   10002   0.907   1.57     RCS Jet #1   (+X)   21   98001   -2.362   0.0     RCS Jet #2   (+X)   22   98002   -2.362   0.0     RCS Jet #3   (+Y)   23   98003   1.271   -1.433     RCS Jet #4   (-Y)   24   98004   1.271   1.433     RCS Jet #5   (-Y)   25   98005   -1.787   0.708     RCS Jet #6   (+Y)   26   98006   -1.787   -0.708     RCS Jet #7   (+X)   27   98007   -2.362   0.0     RCS Jet #7   (+X)   27   98007   -2.362   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0	Reaction Wheel #2 CG	18	58042	0.354	-0.71	
RCS   Jet #1   (+X)   21   98001   -2.362   0.0     RCS   Jet #2   (+X)   22   98002   -2.362   0.0     RCS   Jet #3   (+Y)   23   98003   1.271   -1.433     RCS   Jet #4   (-Y)   24   98004   1.271   1.433     RCS   Jet #5   (-Y)   25   98005   -1.787   0.708     RCS   Jet #6   (+Y)   26   98006   -1.787   -0.708     RCS   Jet #7   (+X)   27   98007   -2.362   0.0     RCS   Jet #8   (+X)   28   98008   -2.34   0.0     RCS   Jet #8   (+X)   28   98008   -2.34   0.0     Define a Direction Vector for Rotational Sensor: 12 and also what   Roll   Position   Velocity   Select	Reaction Wheel #3 CG	19	58043	0.438	0.661	
RCS Jet #2   (+X)   22   98002   -2.362   0.0     RCS Jet #3   (+Y)   23   98003   1.271   -1.433     RCS Jet #4   (-Y)   24   98004   1.271   1.433     RCS Jet #5   (-Y)   25   98005   -1.787   0.708     RCS Jet #6   (+Y)   26   98006   -1.787   -0.708     RCS Jet #6   (+Y)   26   98007   -2.362   0.0     RCS Jet #7   (+X)   27   98007   -2.362   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0     RCS Jet #8   (+X)   28   98008   -2.34   0.0     Define a Direction Vector for Rotational Sensor: 12 and also what   Sensor Direction   Sensor Type   Select	Right Horizon Sensor	20	10002	0.907	1.57	
RCS Jet #3 (+Y)   23   98003   1.271   -1.433     RCS Jet #4 (-Y)   24   98004   1.271   1.433     RCS Jet #5 (-Y)   25   98005   -1.787   0.708     RCS Jet #6 (+Y)   26   98006   -1.787   0.708     RCS Jet #7 (+X)   27   98007   -2.362   0.0     RCS Jet #8 (+X)   28   98008   -2.34   0.0     RCS Jet #8 (+X)   28   98008   -2.34   0.0     RCS Jet #8 (+X)   28   98008   -2.34   0.0	RCS Jet #1 (+X)	21	98001	-2.362	0.0	
RCS Jet #4 (-Y)   24   98004   1.271   1.433     RCS Jet #5 (-Y)   25   98005   -1.787   0.708     RCS Jet #6 (+Y)   26   98006   -1.787   -0.708     RCS Jet #7 (+X)   27   98007   -2.362   0.0     RCS Jet #8 (+X)   28   98008   -2.34   0.0     Define a Direction Vector for Rotational Sensor: 12 and also what   Sensor Direction   Sensor Type   Select     Ptch   Position   Velocity   Select   Select	RCS Jet #2 (+X)	22	98002	-2.362	0.0	
RCS Jet #5 (-Y)   25   98005   -1.787   0.708     RCS Jet #6 (+Y)   26   98006   -1.787   -0.708     RCS Jet #7 (+X)   27   98007   -2.362   0.0     RCS Jet #8 (+X)   28   98008   -2.34   0.0     Define a Direction Vector for Rotational Sensor: 12 and also what   Sensor Direction   Sensor Type   Select	RCS Jet #3 (+Y)	23	98003	1.271	-1.433	
RCS Jet #6 (+Y)   26 98006 -1.787 -0.708     RCS Jet #7 (+X)   27 98007 -2.362 0.0     RCS Jet #8 (+X)   28 98008 -2.34 0.0     Define a Direction Vector for Rotational Sensor: 12 and also what   Sensor Direction   Sensor Type     Select   Position   Velocity	RCS Jet #4 (-Y)	24	98004	1.271	1.433	
RCS Jet #7 (+X)   27 98007 -2.362 0.0     RCS Jet #8 (+X)   28 98008 -2.34 0.0     Define a Direction Vector for Rotational Sensor: 12 and also what   Sensor Direction Vector for Position Velocity	RCS Jet #5 (-Y)	25	98005	-1.787	0.708	
RCS Jet #8 (+X) 28 98008 -2.34 0.0   Define a Direction Vector for Rotational Sensor: 12 and also what Sensor Direction Rotational Sensor: 12 and also what Sensor Direction Pitch Sensor Type Position Velocity Select	RCS Jet #6 (+Y)	26	98006	-1.787	-0.708	
Sensor Direction Sensor Type       Sensor Direction     Sensor Type       Define a Direction Vector for     Roll       Rotational Sensor: 12 and also what     Pitch	RCS Jet #7 (+X)	27	98007	-2.362	0.0	
Define a Direction Vector for Roll Position   Rotational Sensor: 12 and also what Pitch Velocity	RCS Jet #8 (+X)	28	98008	-2.34	0.0	
Rotational Sensor: 12 and also what Pitch Velocity				ype	Select	
T Non						
type of measurement Yaw Acceleration	Hotational Sensor: 12 and also what	Pitch				

The previous light-blue menus were used to associate the vehicle model inputs and outputs with locations that correspond to the FEM. We must now use similar node menus to define excitation and sensor points (structure nodes) to be used by the mode selection program only for mode strength comparison. These locations are not necessarily the same as those defined in the spacecraft model, but they could be any nodes used only for mode selection purposes. The program calculates the modal strength between those inputs and outputs in order to select some of the strongest modes to represent the flexible spacecraft. The remaining modes are ignored.

Use the next dialog to enter some parameters for mode selection. The range of modes to be compared, in this case we include the full range from 1 to 100. The mode strength in this case is calculated between 2 force excitation points, 6 torque excitation points, and 6 rotational measurements. There are no translational measurements used in this mode selection case. Select the "Graphic" option to manually select the modes using the mode strength comparison plot and click "OK". In the next dialog choose not to modify or rescale the modal data because the units and x, y, z directions are acceptable.

🛰 Select Range of Modes, Number of Vehicle	Locations 🔀
You must define some points on the flex model where and torques are applied to the structure, and the dire also define points where motion (rotational or translat also the sensing direction.	ection axis. You must
Compare Strength Between Mode: 1	and Mode 100
Number of Excitation Points, Forces: 2	Torques 6
Number of Sensor Points, Translations: 0	Rotations 6
Mode Selection Process Automatic or Manual using the Bar Chart Number of Modes to be Selected	ΟΚ
	Data Scaling Option ×
	Yes No

The menu below is similar to the previous light-blue dialogs but has different (amber) background to avoid mix-up with the spacecraft modeling dialogs. It is also created from the nodes file showing the spacecraft structure locations in the order they appear in the modal data file, and is used to select the nodes where we shall apply the two excitation forces specified. In this case, node #21 is selected to apply a force in the +X direction, and node #26 is also selected (not shown) to apply the second force in the +Y direction. This is only for mode comparison and mode selection purposes.

lirections.					-	Canad
imilarly, you must also define the sensor points (tra	anslations or rotatio	ons) and the s	ensing direc	tions.		Cancel
Select a Location (Node) for Force	Excitation :	1				Axis
Moving Mirror	1	2101				Along-X
Fixed Mirror	2	2102				Along-Y
Focal Plane	3	2103				Along-Z
Moving Antenna	4	2104				
Fixed Antenna	5	2105				
Inertial Attitude Sensors	6	31001	-0.747	0.114	25.572	
Accelerometers	7	31002	0.338	0.648	25.57	D:
Cryo Cooler Pump	8	40101				Direction
Second Mirror	9	40102				+ (positive)
Sensitive Instrument 2	10	40103				- (negative
Sensitive Instrument 3	11	40104				
Sensitive Instrument 4	12	40105				
Sensitive Instrument 5	13	40106				
Right Solar Array Attachm	14	62131		1.832		
Left Solar Array Attachm	15	62231	-0.37		17.075	
Left Horizon Sensor	16	10001		-1.446	21.604	
Reaction Wheel #1 CG	17	58041	-0.792		21.594	
Reaction Wheel #2 CG	18		0.354		21.594	
Reaction Wheel #3 CG	19	58043		0.661		
Right Horizon Sensor RCS Jet #1 (+X)	20	10002 98001	0.907		21.142	
RCS Jet #1 (+X) RCS Jet #2 (+X)	21	98001	-2.362		24.675	
RCS Jet #2 (+X) RCS Jet #3 (+Y)	22	98002	1.271		24.802	
RCS Jet #4 (-Y)	23	98003	1.271		24.802	
RCS Jet #5 (-Y)	25	98005	-1.787		24.675	
RCS Jet #6 (+Y)	26	98006	-1.787		24.675	
RCS Jet #7 (+X)	27	98007	-2.362		21.45	
RCS Jet #8 (+X)	28	98008	-2.34		21.783	

Similarly, we must define six points where we shall apply torques for mode strength comparison purposes. We select 3 points, the reaction wheel nodes #17, #18, #19 to apply torques (1, 2, 3) in +roll, +pitch, and +yaw directions respectively. The next three torques: 4, 5, and 6 represent disturbances coming from a noisy cryo-cooler pump inside the spacecraft that is located at node #8. All 3 excitation torques are applied at the same node #8, in +roll, +pitch, and +yaw directions respectively, only for mode selection. Two of the torque definitions are shown below.

efine some node points in the Nastran model whe irections.	re the excitation fo	rces or torqu	ies will be applied	l and also the fo	-
imilarly, you must also define the sensor points (tra	Inslations or rotatio	ins) and the s	sensing direction:	s.	Cancel
Select a Location (Node) for Torqu	e Excitation:	2			Axis
loving Mirror	1	2101			Roll
'ixed Mirror 'ocal Plane	2	2102 2103			Pitch Yaw
oving Antenna	4	2104			, and
ixed Antenna	5	2105			
nertial Attitude Sensors	6	31001		.114 25.57	2
ccelerometers	7	31002	0.338 0.	.648 25.57	Direction
ryo Cooler Pump	8	40101 40102			
econd Mirror ensitive Instrument 2	10	40102			+ (positiv
ensitive Instrument 3	11	40104			- (negativ
ensitive Instrument 4	12	40105			
ensitive Instrument 5	13	40106			
ight Solar Array Attachm	14	62131		.832 17.07	
eft Solar Array Attachm	15	62231	-0.37 -1.		
eft Horizon Sensor eaction Wheel #1 CG	16	10001 58041		.446 21.604	
eaction Wheel #1 CG	18	58041	0.354 -0.		
eaction Wheel #3 CG	19	58043	0.438 0.		
ight Horizon Sensor	20	10002		.57 21.14	-
CS Jet #1 (+X)	21	98001		.0 18.07	
CS Jet #2 (+X)	22	98002	-2.362 0.		
CS Jet #3 (+Y)	23	98003	1.271 -1.		
CS Jet #4 (-Y)	24 25	98004	1.271 1. -1.787 0.	.433 24.802 .708 24.675	
CS Jet #5 (-Y) CS Jet #6 (+Y)	26	98005 98006	-1.787 -0.		
CS Jet #7 (+X)	20	98007	-2.362 0.		2
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nertial Attitude Sensors	6	31001	-0.747	0.114	25.572	
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ensitive Instrument 2 ensitive Instrument 3	10 11	40103 40104				- (negativ
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ight Solar Array Attachm	14	62131	-0.37	1.832	17.075	
eft Solar Array Attachm	15	62231		-1.832	17.075	
eft Horizon Sensor	16	10001		-1.446	21.604	
eaction Wheel #1 CG	17	58041	-0.792		21.594	
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CS Jet #2 (+X)	22	98002	-2.362	0.0	24.675	
CS Jet #3 (+Y)	23	98003	1.271	-1.433	24.802	
CS Jet #4 (-Y)	24	98004	1.271		24.802	
CS Jet #5 (-Y)						
	25	98005	-1.787		24.675	
CS Jet #6 (+Y)	26	98006	-1.787	-0.708	24.675	
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CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) node Description, Node Number, Nastran No mode selection, in order to calculate the relative ine some node points in the Nastran model when actions. milarly, you must also define the sensor points (tra- <b>elect a Location (Node) for Torqu</b> oving Mirror tred Mirror tred Mirror tred Mirror by ing Antenna	26 27 28 ode ID Number, mode strength of . re the excitation for inslations or rotation e Excitation:	98006 98007 98008 Location Co a number of incres or torquents ins) and the incres of torquents <b>6</b> 2101 2102 2103 2104	-1.787 -2.362 -2.34 ordinates (X, modes in a sp tes will be ap	-0.708 0.0 0.0 Y,Z) pecified di	24.675 21.45 21.783	Cano Axi Roll Pitch
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) Node Description, Node Number, Nastran No mode selection, in order to calculate the relative ine some node points in the Nastran model when sections. nilarly, you must also define the sensor points (tra <b>elect a Location (Node) for Torqu</b> oving Mirror Lxed Mirror cal Plane oving Antenna xed Antenna	26 27 28 ode ID Number, mode strength of a re the excitation for instations or rotation <b>e Excitation:</b> 1 2 3 4 5	98006 98007 98008 Location Co a number of i rces or torqu ns) and the : 6 2101 2102 2103 2104 2105	-1.787 -2.362 -2.34 ordinates (X, modes in a sj les will be ap	-0.708 0.0 0.0 Y,Z) pecified di plied and	24.675 21.45 21.783 rection you mutalso the forcing	Canc Axi Roll Pitch
25 Jet #6   (+Y)     25 Jet #7   (+X)     25 Jet #8   (+X)     25 Jet #8   (+X)     ode Description,   Node Number,   Nastran No     node selection, in order to calculate the relative ine some node points in the Nastran model when tections.   Node Number,   Nastran model when tections.     illarly, you must also define the sensor points (tra elect a Location (Node) for Torque wing Mirror teal Plane wing Antenna tertial Attitude Sensors	26 27 28 ode ID Number, mode strength of . re the excitation for inslations or rotation e Excitation:	98006 98007 98008 Location Co a number of 1 rces or torqu ns) and the : 6 2101 2102 2103 2104 2105 31001	-1.787 -2.362 -2.34 ordinates (X, modes in a spies will be ap sensing direc	-0.708 0.0 0.0 Y, Z) pecified di plied and stions.	24.675 21.45 21.783 rection you mu: also the forcing	Cano Axi Roll Pitch
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) ode Description, Node Number, Nastran No node selection, in order to calculate the relative ine some node points in the Nastran model when ictions. illarly, you must also define the sensor points (tra- elect a Location (Node) for Torque wing Mirror .xed Mirror .xed Mirror .xed Antenna .xed Antenna .xed Antenna .xed Intrine Sensors .xeelerometers	26 27 28 ode ID Number, mode strength of a re the excitation for inslations or rotation <b>e Excitation:</b> 1 2 3 4 5 6	98006 98007 98008 Location Co a number of i rces or torqu ns) and the : 6 2101 2102 2103 2104 2105	-1.787 -2.362 -2.34 ordinates (X, modes in a sj les will be ap	-0.708 0.0 0.0 Y,Z) pecified di plied and	24.675 21.45 21.783 rection you mutalso the forcing	Cano Cano Axi Pitch Yaw
25 Jet #6 (+Y)     25 Jet #7 (+X)     25 Jet #8 (+X)     25 Jet #8 (+X)     ande Description, Node Number, Nastran Note     node selection, in order to calculate the relative ine some node points in the Nastran model when ctions.     ilarly, you must also define the sensor points (tra select a Location (Node) for Torqu     ving Mirror     xed Mirror     cal Plane     ving Antenna     xed Antenna     celerometers     yo Cooler Pump     cond Mirror	26 27 28 ode ID Number, mode strength of a re the excitation for inslations or rotation <b>e Excitation:</b> 1 2 3 4 5 6 7 7 8 9	98006 98007 98008 Location Co a number of i rces or torqu ns) and the : 6 2101 2102 2103 2104 2105 31001 31002	-1.787 -2.362 -2.34 ordinates (X, modes in a spies will be ap sensing direc	-0.708 0.0 0.0 Y, Z) pecified di plied and stions.	24.675 21.45 21.783 rection you mu: also the forcing	Cano Axi Pitch Yaw Direct
25 Jet #6 (+Y) 25 Jet #7 (+X) 25 Jet #7 (+X) 25 Jet #8 (+X) ode Description, Node Number, Nastran No node selection, in order to calculate the relative ine some node points in the Nastran model when inclines. illarly, you must also define the sensor points (tra elect a Location (Node) for Torqu wing Mirror iscal Plane wing Antenna iscretial Attitude Sensors iscelerometers yo Cooler Pump iscond Mirror insitive Instrument 2	26 27 28 ode ID Number, mode strength of a re the excitation for inslations or rotation <b>e Excitation:</b> 1 2 3 4 5 6 7 8 9 10	98006 98007 98008 Location Co a number of i rces or torqu ns) and the : 6 2101 2102 2103 2104 2104 2105 31001 31002 40101 40102	-1.787 -2.362 -2.34 ordinates (X, modes in a spies will be ap sensing direc	-0.708 0.0 0.0 Y, Z) pecified di plied and stions.	24.675 21.45 21.783 rection you mu: also the forcing	Canc Canc Axi Pitch Yaw Directi
25 Jet #6 (+Y) 25 Jet #7 (+X) 25 Jet #7 (+X) 25 Jet #8 (+X) and Description, Node Number, Nastran No mode selection, in order to calculate the relative ine some node points in the Nastran model when ctions. illarly, you must also define the sensor points (tra- elect a Location (Node) for Torque ving Mirror xed Mirror xed Mirror xed Antenna xet al Attitude Sensors celerometers yo Cooler Pump cond Mirror nsitive Instrument 2 nsitive Instrument 3	26 27 28 ode ID Number, mode strength of a re the excitation for instations or rotation <b>e Excitation:</b> 1 2 3 4 5 6 7 7 8 9	98006 98007 98008 Location Co a number of i rces or torqu ns) and the : 6 2101 2102 2103 2104 2105 31001 31002	-1.787 -2.362 -2.34 ordinates (X, modes in a spies will be ap sensing direc	-0.708 0.0 0.0 Y, Z) pecified di plied and stions.	24.675 21.45 21.783 rection you mu: also the forcing	Canc Canc Axi Pitch Yaw Directi
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) ode Description, Node Number, Nastran No mode selection, in order to calculate the relative ine some node points in the Nastran model when sections. illarly, you must also define the sensor points (tra <b>elect a Location (Node) for Torqu</b> wring Mirror .xed Mirror .xed Mirror .xed Mirror .xed Antenna .xed Antenna .xed Antenna .xed Antenna .xed Antenna .xed Antenna .xed Antenna .xed Antenna .xed Mirror msitive Instrument 2 msitive Instrument 3 msitive Instrument 4 msitive Instrument 5	26 27 28 ode ID Number, mode strength of a re the excitation for instations or rotation <b>e Excitation:</b> 1 2 3 4 4 5 6 7 7 8 9 10 11 12 13	98006 98007 98008 Location Co a number of inces or torqu ns) and the s 6 2101 2102 2103 2104 2105 31001 2104 2105 31001 31002 40101 40102 40103 40104	-1.787 -2.362 -2.34 ordinates (X, modes in a spectrum of the ap sensing direct -0.747 0.338	-0.708 0.0 0.0 Y,Z) pecified di plied and tions.	24.675 21.45 21.783 rection you mutalso the forcing 25.572 25.572	Canc Canc Axi Pitch Yaw Directi
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) ode Description, Node Number, Nastran No mode selection, in order to calculate the relative ine some node points in the Nastran model when sections. illarly, you must also define the sensor points (tra elect a Location (Node) for Torqu wing Mirror .xed Mirror .xed Mirror .xed Antenna .xet Antenna .xet Antenna .xet Antenna .xet Antenna .xet Antenna .xet Instrument 2 msitive Instrument 3 msitive Instrument 4 	26 27 28 ode ID Number, re the excitation for instations or rotation <b>e Excitation:</b> 1 2 3 4 5 6 7 8 9 10 11 12 3 4 5 6 7 8 9 10 11 12 3 14	98006 98007 98008 Location Co a number of i rces or torqu ns) and the : 6 2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 62131	-1.787 -2.362 -2.34 ordinates (X, modes in a s ues will be ap sensing direc -0.747 0.338	-0.708 0.0 0.0 Y, Z) pecified di plied and tions.	24.675 21.45 21.783 rection you muralso the forcing 25.572 25.57 25.57 25.57	Canc Canc Axi Pitch Yaw Directi
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) ode Description, Node Number, Nastran No mode selection, in order to calculate the relative ine some node points in the Nastran model when rections. milarly, you must also define the sensor points (tra- <b>elect a Location (Node) for Torqu</b> oving Mirror txed Mirror txed Mirror txed Antenna txed Antenna txed Antenna txed Antenna txed Antenna txed I Plane voing Antenna txed Antenna txed I Plane voing Instrument 2 ensitive Instrument 3 ensitive Instrument 4 ensitive Instrument 5 Sight Solar Array Attachm	26 27 28 ode ID Number, mode strength of a re the excitation for inslations or rotation <b>e Excitation:</b> 1 2 3 4 5 6 7 7 8 9 9 10 11 12 13 14 15	98006 98007 98008 Location Co a number of i rces or torqu ns) and the : 6 2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62231	-1.787 -2.362 -2.34 ordinates (X, modes in a s ies will be ap sensing direc -0.747 0.338	-0.708 0.0 0.0 Y,Z) pecified di plied and tions. 0.114 0.648	24.675 21.45 21.783 rection you mutalso the forcing 25.572 25.57 25.57 17.075	Canc Canc Axi Pitch Yaw Directi
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) ode Description, Node Number, Nastran No mode selection, in order to calculate the relative ine some node points in the Nastran model when excloses. will and you must also define the sensor points (tra- <b>elect a Location (Node) for Torqu</b> oving Mirror Lxed Mirror wing Antenna hertial Attitude Sensors cocler Pump excond Mirror ensitive Instrument 2 misitive Instrument 3 misitive Instrument 4 misitive Instrument 4 misitive Instrument 5 .ght Solar Array Attachm eft Solar Array Attachm eft Horizon Sensor	26 27 28 ode ID Number, re the excitation for instations or rotation <b>e Excitation:</b> 1 2 3 4 5 6 7 8 9 10 11 12 3 4 5 6 7 8 9 10 11 12 3 14	98006 98007 98008 Location Co a number of i rces or torqu ns) and the : 6 2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 62131	-1.787 -2.362 -2.34 ordinates (X, modes in a s ues will be ap sensing direc -0.747 0.338	-0.708 0.0 0.0 Y,Z) pecified di plied and stions.	24.675 21.45 21.783 rection you mu: also the forcing 25.572 25.57 17.075 17.075 21.604	Canc Canc Axi Pitch Yaw Directi
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) Node Description, Node Number, Nastran No mode selection, in order to calculate the relative ime some node points in the Nastran model when sections. milarly, you must also define the sensor points (tra <b>elect a Location (Node) for Torqu</b> oving Mirror ixed Mirror by Mirror ixed Mirror cal Plane oving Antenna hertial Attitude Sensors celerometers ryo Cooler Pump second Mirror ensitive Instrument 2 ensitive Instrument 3 ensitive Instrument 4 ensitive Instrument 4 ensitive Instrument 5 light Solar Array Attachm eft Horizon Sensor saction Wheel #1 Spin Axis saction Wheel #2 Spin Axis	26 27 28 ode ID Number, re the excitation for inslations or rotation <b>e Excitation:</b> 1 2 3 4 5 6 7 8 9 10 11 12 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18	98006 98007 98008 Location Co a number of inces or torqu ns) and the s 6 2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40106 62131 62231 10001 58041 58042	-1.787 -2.362 -2.34 ordinates (X, modes in a spes will be ap sensing direc -0.747 0.338 -0.37 -0.37 -0.37 -0.37 -0.37 -0.37 -0.37	-0.708 0.0 0.0 Y,Z) pecified di plied and stions. 0.114 0.648 1.832 -1.832 -1.832 -1.832 -1.832 -1.832	24.675 21.45 21.783 rection you muralso the forcing 25.572 25.57 25.57 17.075 17.075 21.604 21.594	Canc Canc Axi Pitch Yaw Directi
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) mode Description, Node Number, Nastran No mode selection, in order to calculate the relative ine some node points in the Nastran model when actions. milarly, you must also define the sensor points (tra- elect a Location (Node) for Torque wing Mirror txed Mirror txed Mirror txed Antenna txed Antenna txed Antenna txed Antenna txed Antenna txed Antenna txed Infror escond Mirror escond Mirror estive Instrument 2 ensitive Instrument 3 ensitive Instrument 4 emsitive Instrument 4 eft Solar Array Attachm eft Solar Array Attachm eft Horizon Sensor eaction Wheel #1 Spin Axis eaction Wheel #2 Spin Axis	26 27 28 ode ID Number, re the excitation for instations or rotation e Excitation: 1 2 3 4 5 6 7 7 8 9 9 10 11 12 13 14 15 16 17 18 19	98006 98007 98008 Location Co a number of i rces or torqu ns) and the : 6 2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40104 40105 40104 40105 40106 62231 10001 58042 58043	-1.787 -2.362 -2.34 ordinates (X, modes in a spessive will be ap sensing direct -0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.438	-0.708 0.0 0.0 Y,Z) pecified di plied and tions. 0.114 0.648 1.832 -1.832 -1.832 -1.832 -1.446 0.049 -0.71 0.661	24.675 21.45 21.783 rection you mutalso the forcing 25.572 25.57 25.57 17.075 17.075 21.604 21.594 21.594	Canc Canc Axi Pitch Yaw Directi
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) Node Description, Node Number, Nastran No mode selection, in order to calculate the relative ine some node points in the Nastran model when excloses. milarly, you must also define the sensor points (tra- elect a Location (Node) for Torque oving Mirror tred Mirror tred Mirror tred Antenna hertial Attitude Sensors coclerometers cyo Cooler Pump econd Mirror ensitive Instrument 2 ensitive Instrument 3 ensitive Instrument 4 ensitive Instrument 4 ensitive Instrument 5 light Solar Array Attachm eft Solar Array Attachm eft Solar Array Attachm eft Horizon Sensor eaction Wheel #1 Spin Axis eaction Wheel #3 Spin Axis light Horizon Sensor	26 27 28 ode ID Number, mode strength of a re the excitation for inslations or rotatio <b>e Excitation:</b> 1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20	98006 98007 98008 Location Co a number of i rces or torqu ns) and the : 6 2101 2102 2103 2104 2103 2104 2105 31001 2102 40101 40102 40101 40102 40101 40102 40101 58041 58042 58043 10002	-1.787 -2.362 -2.34 ordinates (X, modes in a speed will be ap sensing direct sensing direct -0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.907	-0.708 0.0 0.0 Y,Z) pecified di plied and stions. 0.114 0.648 1.832 -1.832 -1.446 0.049 -0.71 0.611 1.57	24.675 21.45 21.783 rection you mutalso the forcing 25.572 25.57 17.075 21.604 21.594 21.594 21.594 21.142	Canc Canc Axi: Pitch Yaw Directi
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) Node Description, Node Number, Nastran No mode selection, in order to calculate the relative fine some node points in the Nastran model when ections. milarly, you must also define the sensor points (tra <b>elect a Location (Node) for Torqu</b> oving Mirror ixed Mirror oral Plane oving Antenna hertial Attitude Sensors celerometers typ Cooler Pump scond Mirror ensitive Instrument 2 ensitive Instrument 3 ensitive Instrument 4 ensitive Instrument 4 ensitive Instrument 5 ight Solar Array Attachm eft Horizon Sensor saction Wheel #1 Spin Axis saction Wheel #3 Spin Axis eaction Wheel #3 Spin Axis ight Horizon Sensor 25 Jet #1 (+X)	26 27 28 ode ID Number, re the excitation for instations or rotation e Excitation: 1 2 3 4 5 6 7 7 8 9 9 10 11 12 13 14 15 16 17 18 19	98006 98007 98008 Location Co a number of i rces or torqu ns) and the : 6 2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40104 40105 40104 40105 40104 40105 40106 62231 10001 58042 58043	-1.787 -2.362 -2.34 ordinates (X, modes in a spessive will be ap sensing direct -0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.438	-0.708 0.0 0.0 Y,Z) pecified di plied and tions. 1.832 -1.832 -1.832 -1.832 -1.446 0.049 -0.71 0.661 1.57 0.0	24.675 21.45 21.783 rection you mutalso the forcing 25.572 25.57 25.57 17.075 17.075 21.604 21.594 21.594	Canc Canc Axi: Pitch Yaw Directi
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) Node Description, Node Number, Nastran No mode selection, in order to calculate the relative fine some node points in the Nastran model when actions. milarly, you must also define the sensor points (tra <b>elect a Location (Node) for Torqu</b> by ing Mirror ixed Mirror by Cooler Pump account Mirror cal Plane by ing Antenna ixed Antenna hertial Attitude Sensors coelerometers cyo Cooler Pump account Mirror ensitive Instrument 2 ensitive Instrument 3 ensitive Instrument 4 ensitive Instrument 4 ensitive Instrument 5 light Solar Array Attachm aft Horizon Sensor acction Wheel #1 Spin Axis action Wheel #3 Spin Axis action Wheel #4 (+x) CS Jet #2 (+x) CS Jet #2 (+x)	26 27 28 ode ID Number, re the excitation for inslations or rotation e Excitation: 1 2 3 4 5 6 7 7 8 9 9 10 11 12 13 14 15 16 17 18 19 20 21 12 23	98006 98007 98008 Location Co a number of i rces or torqu ns) and the 5 2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40102 40103 40104 40103 40104 40105 40104 40105 40104 40105 40106 62131 62231 10001 58041 58042 58043 10002 98003	-1.787 -2.362 -2.34 ordinates (X, modes in a spes will be ap sensing direct -0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.438 0.907 -2.362 -2.362 -2.362	-0.708 0.0 0.0 Y, Z) pecified di plied and stions. 0.114 0.648 1.832 -1.832 -1.832 -1.446 0.049 -0.71 0.661 1.57 0.0 -1.433	24.675 21.45 21.783 rection you muralso the forcing 25.572 25.57 25.57 17.075 25.57 17.075 21.604 21.594 21.594 21.594 21.594 21.42 18.075 24.675 24.802	Canc Canc Axi Pitch Yaw Directi
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) Indee Description, Node Number, Nastran Not mode selection, in order to calculate the relative fine some node points in the Nastran model where extinness and the sensor points (tra- extination of the sensor points (tra- elect a Location (Node) for Torque oving Mirror ixed Mirror ixed Mirror ixed Antenna hertial Attitude Sensors ccelerometers cyo Cooler Pump accond Mirror ensitive Instrument 2 ensitive Instrument 3 ensitive Instrument 4 ensitive Instrument 4 ensitive Instrument 5 light Solar Array Attachm aft Solar Array Attachm aft Solar Array Attachm aft Horizon Sensor caction Wheel #1 Spin Aris action Wheel #3 Spin Aris ight Horizon Sensor CS Jet #1 (+X) CS Jet #2 (+X) CS Jet #3 (+Y) CS Jet #4 (-Y)	26 27 28 ode ID Number, mode strength of a re the excitation for inslations or rotatio e Excitation: 1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 9 10 11 12 13 14 15 16 17 18 9 20 21 22 23 24	98006 98007 98008 Location Co a number of f rces or torqu ns) and the : 6 2101 2102 2103 2104 2103 2104 2105 31001 2102 40101 40102 40102 40103 40104 40103 40104 40105 40106 62131 10001 58041 58042 58043 10002 98001 98002 98003 98004	-1.787 -2.362 -2.34 ordinates (X, modes in a spees will be ap sensing direct sensing direct -0.747 0.338 -0.37 -0.37 1.0 -0.792 0.354 0.438 0.907 -2.362 -2.362 -2.362 -2.362 -2.362 -2.362	-0.708 0.0 0.0 Y,Z) pecified di plied and tions. 0.114 0.648 1.832 -1.446 0.049 -0.71 0.661 1.57 0.0 0.0 0.1 433 1.433	24.675 21.45 21.783 rection you mutalso the forcing 25.572 25.57 17.075 21.604 21.594 21.594 21.594 21.142 18.075 24.675 24.675 24.802	Canc Canc Axi: Pitch Yaw Directi
CS Jet #6 (+Y) CS Jet #7 (+X) CS Jet #7 (+X) CS Jet #8 (+X) Mode Description, Node Number, Nastran No mode selection, in order to calculate the relative fine some node points in the Nastran model when ections. milarly, you must also define the sensor points (tra <b>elect a Location (Node) for Torqu</b> oving Mirror ixed Mirror ocal Plane oving Antenna iretial Attitude Sensors ccelerometers ryo Cooler Pump econd Mirror ensitive Instrument 2 ensitive Instrument 3 ensitive Instrument 4 ensitive Instrument 5 ight Solar Array Attachm eft Horizon Sensor eaction Wheel #1 Spin Axis eaction Wheel #2 Spin Axis eaction Wheel #3 Spin Axis ight Horizon Sensor CS Jet #1 (+X) CS Jet #2 (+X) CS Jet #3 (+Y)	26 27 28 ode ID Number, re the excitation for inslations or rotation e Excitation: 1 2 3 4 5 6 7 7 8 9 9 10 11 12 13 14 15 16 17 18 19 20 21 12 23	98006 98007 98008 Location Co a number of i rces or torqu ns) and the 5 2101 2102 2103 2104 2105 31001 31002 40101 40102 40103 40102 40103 40104 40103 40104 40105 40104 40105 40104 40105 40106 62131 62231 10001 58041 58042 58043 10002 98003	-1.787 -2.362 -2.34 ordinates (X, modes in a spessive will be ap sensing direct -0.747 0.338 -0.37 -0.	-0.708 0.0 0.0 Y, Z) pecified di plied and stions. 0.114 0.648 1.832 -1.832 -1.832 -1.446 0.049 -0.71 0.661 1.57 0.0 -1.433	24.675 21.45 21.783 rection you mutalso the forcing 25.572 25.572 25.57 17.075 17.075 17.075 21.604 21.594 21.594 21.594 21.594 21.594 21.594 21.594 21.594 21.604 21.594 21.605 24.605	Canc Canc Axis Roll Pitch

We must also select nodes and directions for the 6 rotational sensors that were defined earlier, only for mode selection purposes. Node #6 was selected for the rotational sensors (1, 2, 3), measuring in the +roll, +pitch, and +yaw directions respectively. Similarly, nodes #11, #12, and #13 were selected to represent the rotational sensors (4, 5, 6), measuring in +roll, +pitch, and +yaw directions respectively.

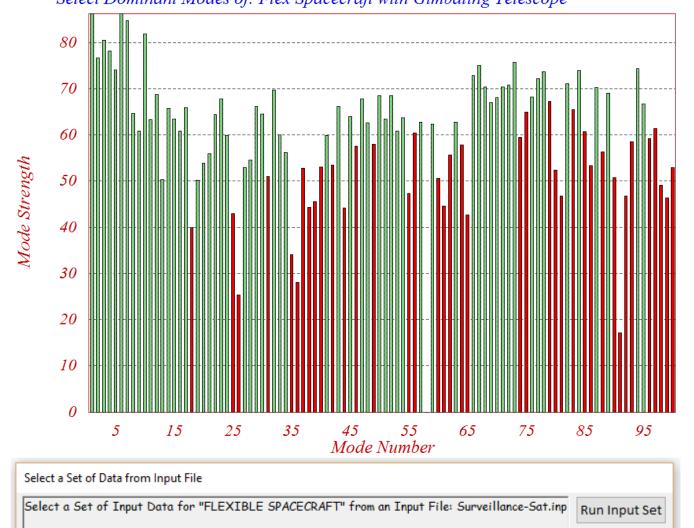
efine some node points in the Nastran model whe irections.		·		also the forcing	OK Cancel
imilarly, you must also define the sensor points (tra	inslations or rotatio	ns) and the s	ensing directions.		Cancer
Select a Location (Node) for Rotati	onal Sensor	: 1			Axis
Noving Mirror	1	2101			Roll
Tixed Mirror	2	2102			Pitch
Focal Plane	3	2103			Yaw
foving Antenna	4	2104			
fixed Antenna	5	2105			
Inertial Attitude Sensors	6	31001	-0.747 0.114		
Accelerometers	7	31002	0.338 0.648	25.57	
Cryo Cooler Pump	8	40101			Direction
Second Mirror	9	40102			+ (positive
Sensitive Instrument 2	10	40103			- (negative
Sensitive Instrument 3	11	40104			
Sensitive Instrument 4	12	40105			
Sensitive Instrument 5	13	40106			
Right Solar Array Attachm	14	62131	-0.37 1.832		
Left Solar Array Attachm	15	62231	-0.37 -1.832		
Left Horizon Sensor	16	10001	1.0 -1.446		
Reaction Wheel #1 CG	17	58041	-0.792 0.049		
Reaction Wheel #2 CG	18	58042	0.354 -0.71		
Reaction Wheel #3 CG	19		0.438 0.661		
Right Horizon Sensor	20		0.907 1.57	21.142	
RCS Jet #1 (+X)	21	98001	-2.362 0.0	18.075	
RCS Jet #2 (+X)	22		-2.362 0.0	24.675	
RCS Jet #3 (+Y)	23		1.271 -1.433		
RCS Jet #4 (-Y)	24		1.271 1.433		
RCS Jet #5 (-Y)	25		-1.787 0.708		
RCS Jet #6 (+Y)	26		-1.787 -0.708		
RCS Jet #7 (+X)	27	98007	-2.362 0.0	21.45	
RCS Jet #8 (+X)	28	98008	-2.34 0.0	21.783	

Node Description, Node Number, Nastran Node ID Number, Location Coordinates (X, Y, Z)

Select a Location (Node) for Rotatic	onal Sensor:	6			Axis
Moving Mirror	1	2101			Roll
Fixed Mirror	2	2102			Pitch
Focal Plane	3	2103			Yaw
Moving Antenna	4	2104			
Fixed Antenna	5	2105			
Inertial Attitude Sensors	6	31001	-0.747 0.11	4 25.572	
Accelerometers	7	31002	0.338 0.64	8 25.57	
Cryo Cooler Pump	8	40101			Direction
Second Mirror	9	40102			+ (positive)
Sensitive Instrument 2	10	40103			- (negative)
Sensitive Instrument 3	11	40104			(nogative)
Sensitive Instrument 4	12	40105			
Sensitive Instrument 5	13	40106			
Right Solar Array Attachm	14	62131	-0.37 1.83	2 17.075	
Left Solar Array Attachm	15	62231	-0.37 -1.83	2 17.075	
Left Horizon Sensor	16	10001	1.0 -1.44	6 21.604	
Reaction Wheel #1 Spin Axis	17	58041	-0.792 0.04	9 21.594	
Reaction Wheel #2 Spin Axis	18	58042	0.354 -0.71	21.594	
Reaction Wheel #3 Spin Axis	19	58043	0.438 0.66	1 21.594	
Right Horizon Sensor	20	10002	0.907 1.57	21.142	

At this point the program calculates the mode strength from all modes and it displays the mode strength comparison bar-plot showing the mode numbers in the horizontal axis and the corresponding relative mode strength on a vertical logarithmic scale. Initially all the modes appear in red. The user can select some of the strong modes by clicking on the corresponding bar and the color of the bar changes to green when the mode is selected. Notice, that in this demo the first 6 rigid-body modes are included in the mode. We also created a flex model without the 6 rigid-body modes for different analysis. When the mode selection is complete the user must press the "Enter" key to complete the creation of the spacecraft dataset, and it will be saved in file "*Surveillance-Sat.Inp*". The program continues to process it, and it displays a menu that includes titles of spacecraft datasets already saved in the input file, including the latest one from our recent demo. The user selects one of the titles and clicks on "*Run Input Set*" to process it and to compute the flexible spacecraft state-space system in file "*Surveillance\_Sat.Qdr*".

Mode Strength (use mouse to select the strongest modes in the specified axis) Select Dominant Modes of: Flex Spacecraft with Gimbaling Telescope



Exit Program

Create New

Flex Spacecraft with Gimbaling Telescope and Reaction Wheels (67-modes) Rigid-Body Spacecraft with Gimbaling Telescope and Reaction Wheels

Flex Spacecraft with Gimbaling Telescope and Reaction Wheels (61-Only Flex)

Flex Spacecraft with Gimbaling Telescope and Reaction Wheels (100-modes) Flex Spacecraft Title

Flex Spacecraft with Gimbaling Telescope