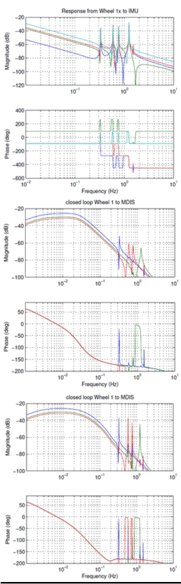
The **CSI Analysis Tool** is used to evaluate control-structure interaction and control system stability, and to compute the pointing error response of spacecraft and optical payloads to disturbances and sensor noise. This Matlab tool models the rigid-body and flexible structure, attitude sensors and gyros, reaction wheels, the steady-state attitude determination (Kalman) filter, a three-axis PID controller, structural mode filters, payload dynamics (including line-of-sight stabilizers), and time delays. The component transfer functions are interconnected to form system matrices, from which the open-loop and closed-loop frequency response to inputs and disturbances, and the covariance response to noise can be evaluated.

The algorithms incorporated into the CSI tool were previously applied to the STEREO and MESSENGER spacecraft, and was used to investigate and resolve a control-structure interaction problem on the TIMED spacecraft. The frequency response plots below were generated from the structural model for the MESSENGER spacecraft. These plots show the frequency response from the spin axis of reaction wheel 1 to the four IMU sense axes and to the Mercury Dual Imaging System (MDIS) payload interface.

Stability margins are evaluated by breaking the feedback loop at various locations, including the star trackers, IMU, and reaction wheels. This is done for single channels and multiple channels. The frequency response is evaluated by using a phase-gain tracker so that modal peaks are not missed, which yields accurate structural mode gain margins and peak response in attitude and rate. (The frequencies at the modal peaks are known also from the modes and modal dampings in the structural model.) In the case of phase stabilization, a time-delay margin is appropriate and can be evaluated.

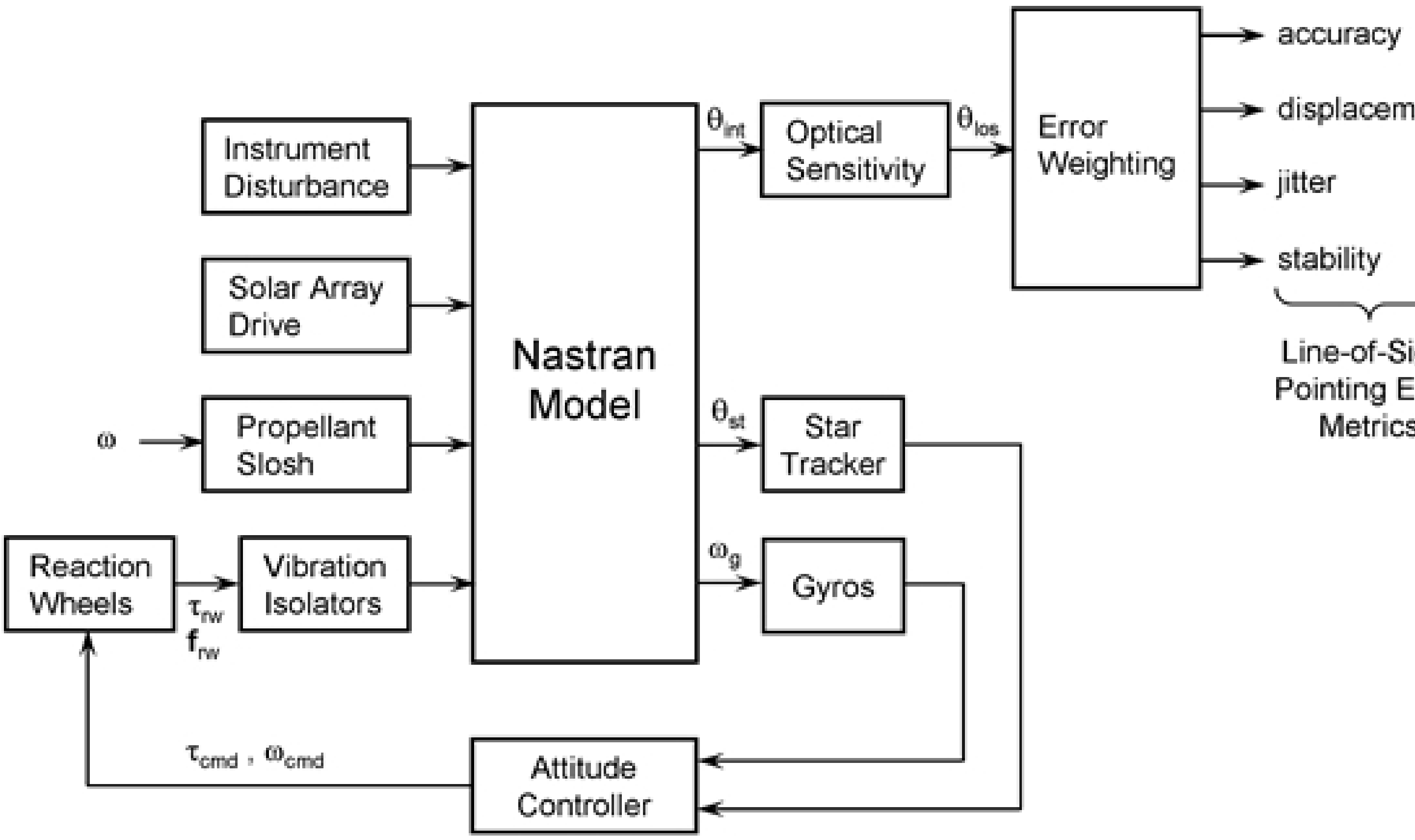
Because of variations in control system designs amongst various spacecraft, this tool generally usually requires minor customization for each spacecraft. However, the modular structure of the Matlab software makes this a relatively easy task. The tool is not limited to three-axis attitude control systems; the same approach can be applied to other types of control systems.



Pointing Error Analysis

The figure below illustrates a flexible-body system with various inputs and outputs, including disturbances, actuator inputs, sensor outputs, and a payload line of sight. Particular nodes in the Nastran model correspond to the locations of the actuators, sensors, and payload. There can be other nodes of interest that define additional inputs and outputs, such as the locations of thrusters, accelerometers, the tip of a boom, or the end of a solar array.

The reduced-order Nastran model shown in the figure is obtained from the Structural Model Reduction tool. The closed-loop response is evaluated by using the CSI Analysis tool, and the pointing errors are evaluated by the Pointing Error Analysis tool.



Pointing Error Analysis