Guidance and Control

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G&C Requirements–Design Drivers

- Spacecraft pointing–(3 σ)

	Roll	Pitch/Yaw
– Knowledge:	± 20 arcsec	± 0.1 arcsec
– Control:	± 0.1°	± 20 arcsec
– Jitter:	30 arcsec RMS	1.5 arcsec (0.1 to TBD Hz)

(with SCIP error signal, which is ± 0.1 arcsec)

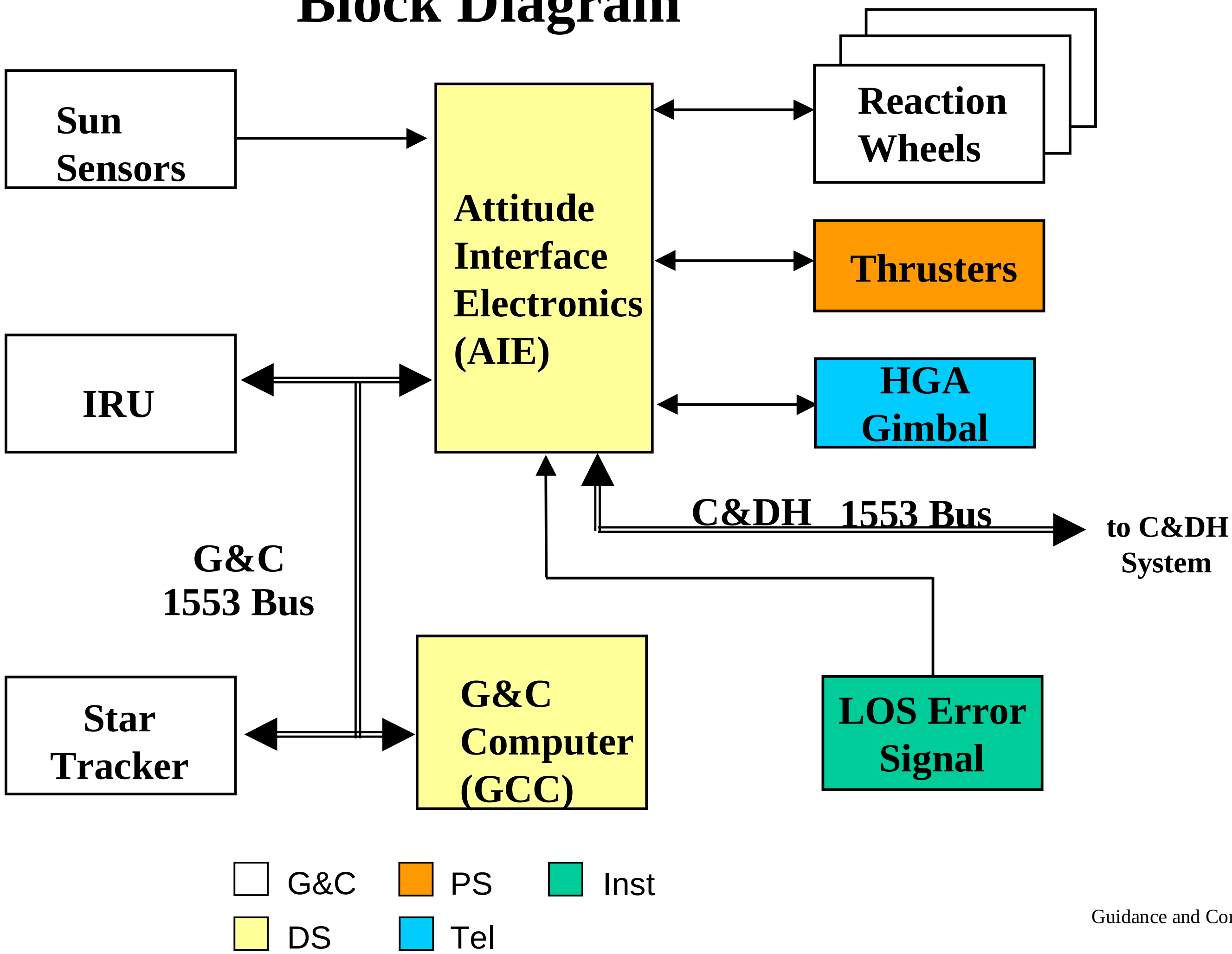
- Jitter is challenge
- Need high control bandwidth =>
  - High wheel torque
  - Fast sampling rate
  - Minimize disturbances
  - Modern control techniques

G&C Requirements–Other

- Point LOS within 5 arcmin of Sun for SCIP acquisition
  - Requires good coalignment
- Nominal HGA pointing to 0.1°; maintain HGA pointing during thrusting; complete autonomous thruster firings within 300 seconds
  - Sets gimbal step frequency
  - Need small impulse bit and small Δt
  - In-flight HGA alignment cal – TBD
  - On-board ephemeris for HGA pointing vectors
- Momentum storage capacity > 4 days in operational mode
  - Sizes wheel momentum
- Return from any attitude in < 12 minutes
  - Thruster attitude control – TBD
  - May size wheel torque
- Solar pressure momentum bias within Sun-angle limit

STEREO Guidance & Control System

Block Diagram



Baseline G&C Equipment

Item	Heritage	Performance
IMU	NEAR	HRG, 0.01°/hr½
Star tracker	TIMED	3 arcsec, 7.5 Mv stars
Reaction Wheels	NEAR	Torque: 0.025 Nm Momentum: 4 Nms
Sun Sensors	NEAR	0.5° quantization 0.25° accuracy
AIE	TIMED	
G&C Computer	TIMED	

Inertial Reference Unit (IRU)

- Supplier: Delco Electronics
- Gyros:
  - Delco 130Y Hemispherical Resonator Gyros (HRG)
  - Rate bias stability < 0.001°/hr, over 16 hr
  - ARW < $0.01°/hr^{1/2}$
- Redundancy:
  - NEAR: redundant CPU, power; four gyros
  - Cassini: single-string
- Projected P_S (system function) = 0.9996 for mission life
  - (four gyro IRU)

Reaction Wheel Assembly (RWA)

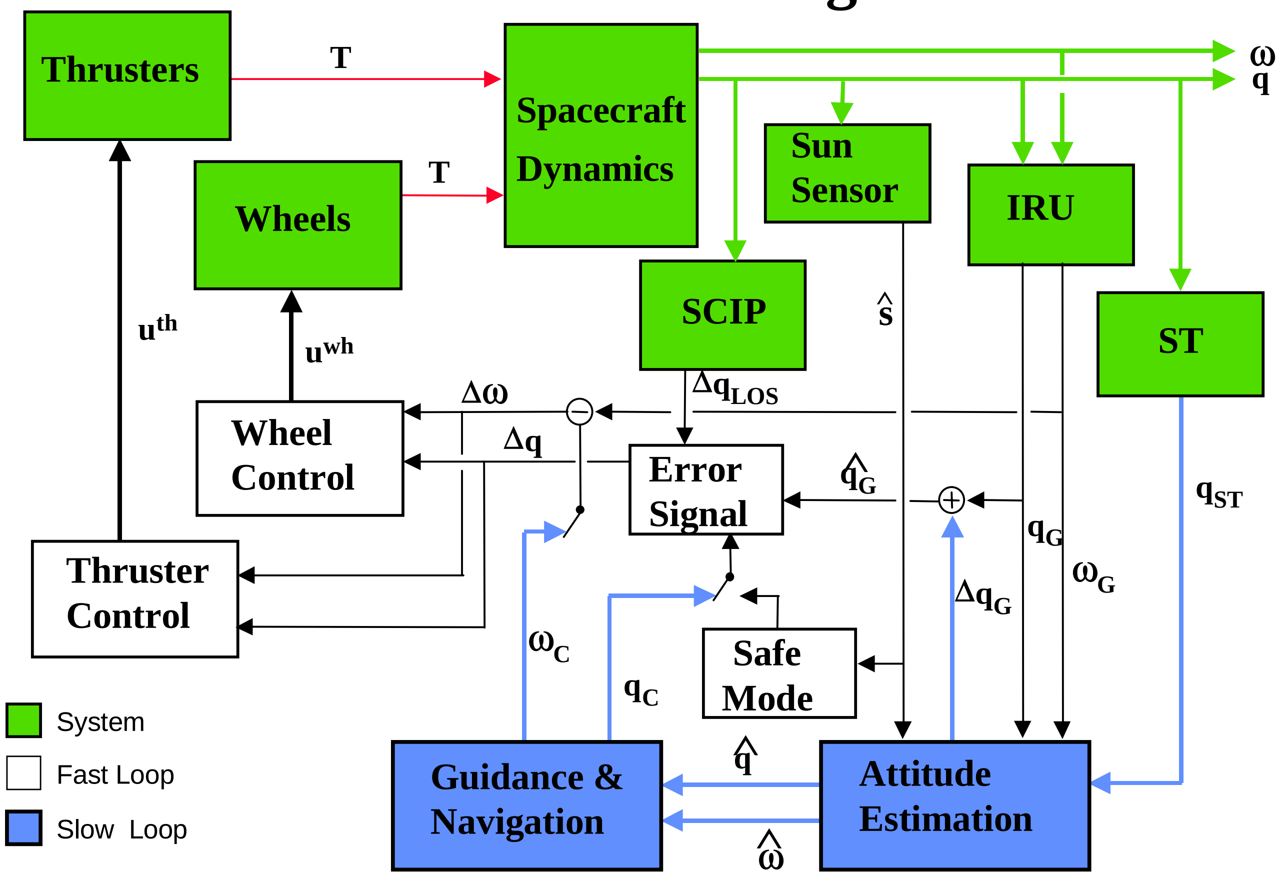
- Supplier: Ithaco, Inc. (Type A)
- Characteristics:
  - Brushless DC motor
  - Bipolar tachometer
  - Separate electronics, stacked to save weight and space
- Performance:
  - Angular Momentum: 4 Nms (@ 5100 RPM)
  - Torque: 0.025 Nm *(higher torque possible)*
  - Unbalance:
    - static < 1.5 gm cm
    - dynamic < 40 gm cm^2
  - Torque noise PSD: 1×10^{-11} $(Nm)^2$/Hz, 0.1 to 1 Hz
  - Continuous operating life: > 4 years

Sun Sensors

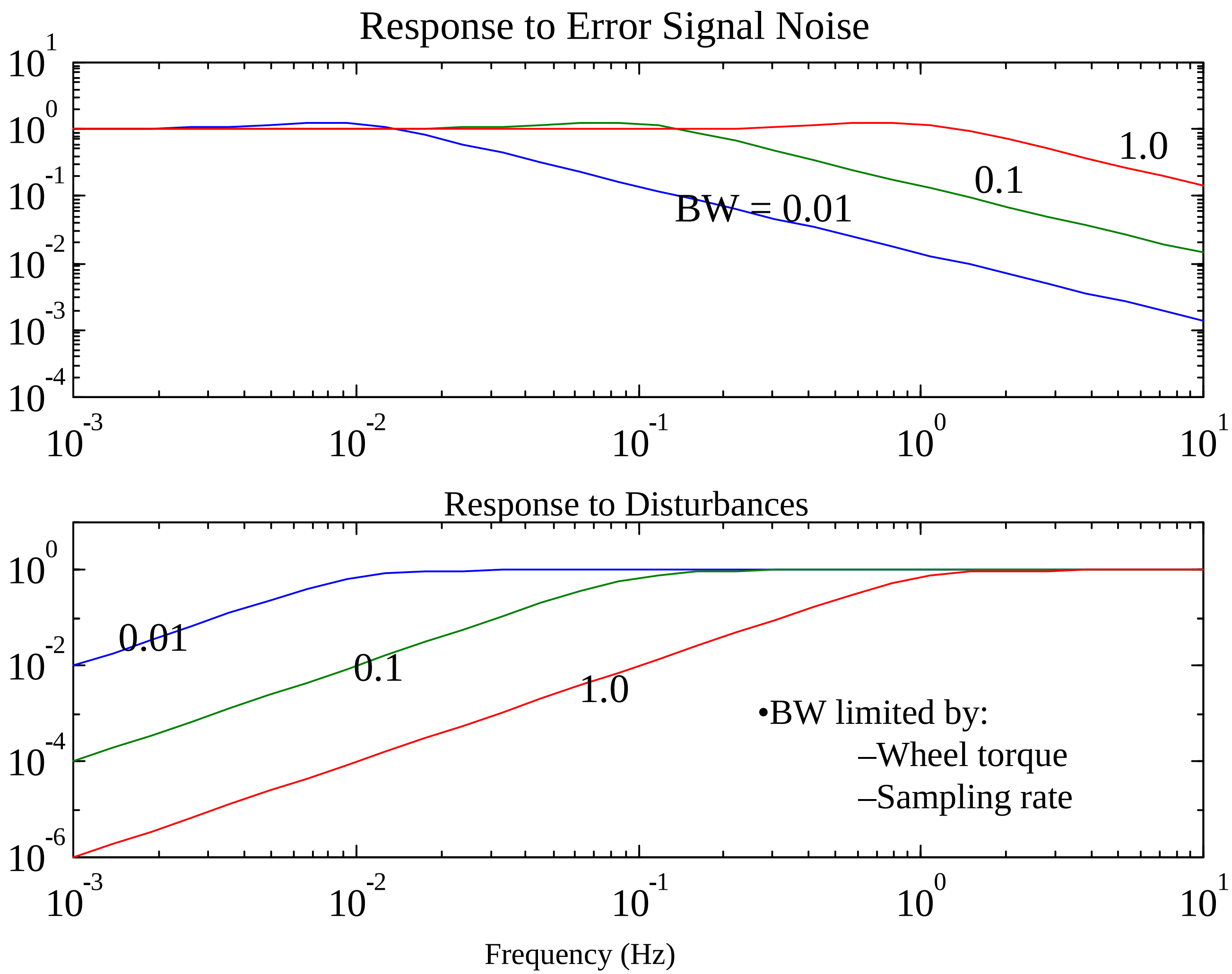
- Supplier: Adcole
- Digital Solar Attitude Detector (DSAD) system
  - Five detector heads, each measures 2-axis Sun vector in ±64° FOV
- Accuracy:
  - 0.5° quantization
  - 0.25° bit transition-angle accuracy
- Flight proven, many times

Guidance & Control

Functional Block Diagram



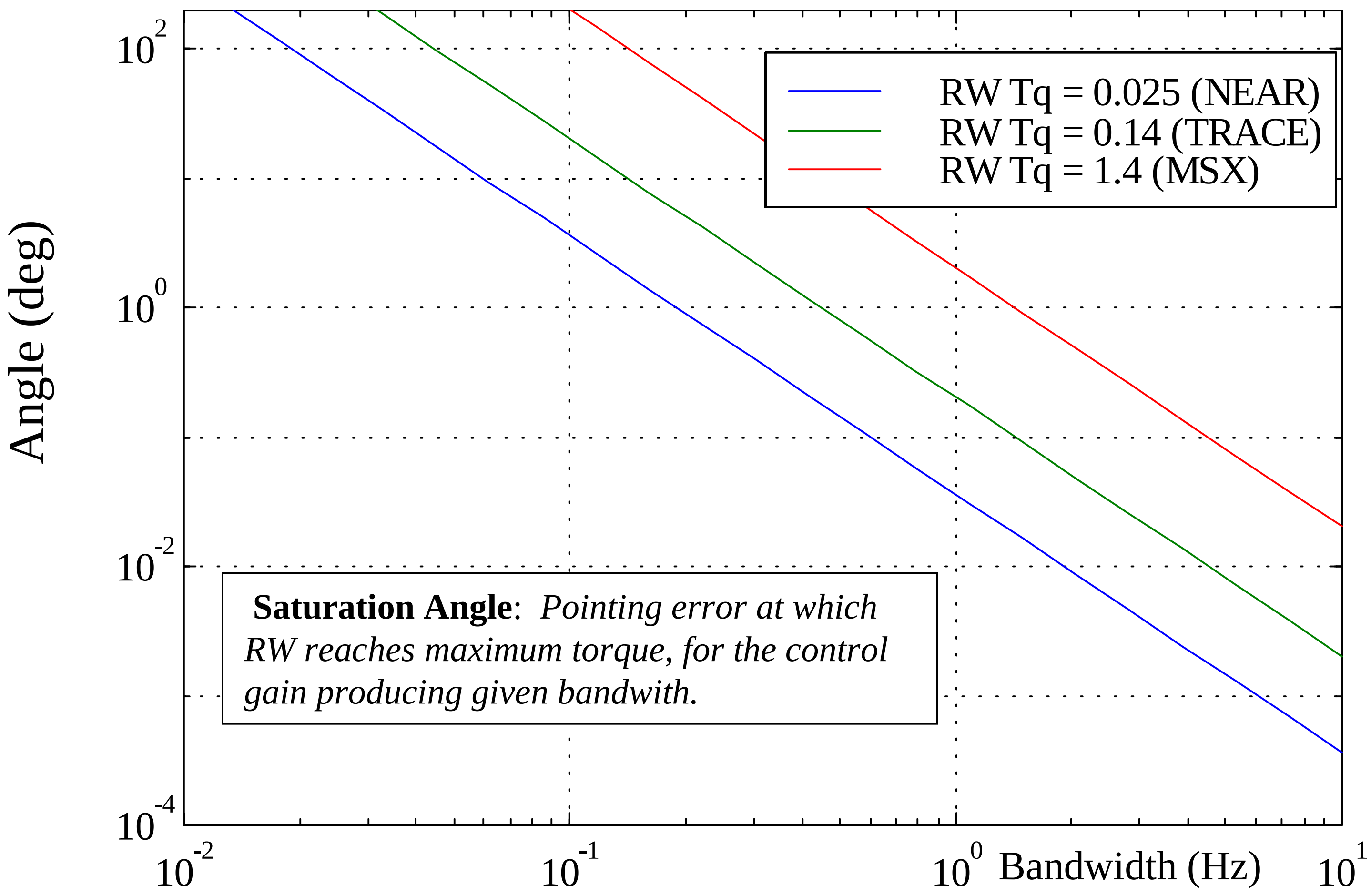
Control Bandwidth (BW) Effects)



Star Tracker

- Supplier: Lockheed Martin
- Accuracy:
  - 3 arcsec P/Y; 32 arcsec R (1σ)
  - 7.5 Mv stars
  - 8.8° square FOV
- Quaternion output
  - Autonomous star ID within ~2 sec
  - 5 Hz update, 1553 interface
- Flown on DS1, P59; to fly on TIMED, EO1, MAP, IMAGE, ...

RW Saturation Angle (deg) vs. Control Bandwidth



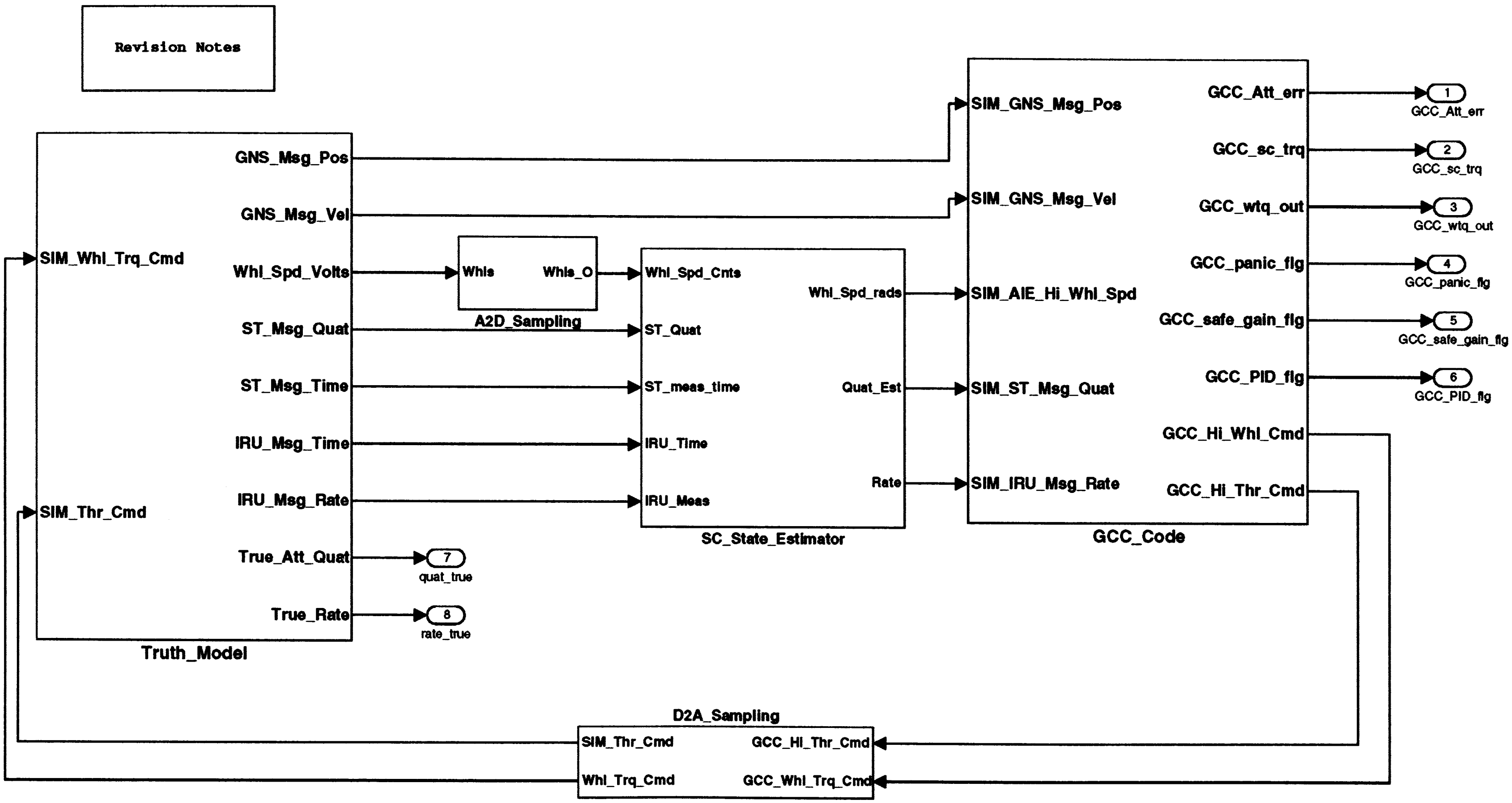
Redundancy Considerations

- Four Wheels
  - Full capability if any one fails
  - Enable wheel speed control to avoid troublesome frequencies
- Four Gyros
  - Full capability if any one fails
  - Lower noise if all four used
- Fine Sun Sensor
  - In addition to, or in place of, coarse DSADs
  - Enable mission pointing without LOS error signal
- ST gives some backup to LOS error signal

Momentum Bias Mode

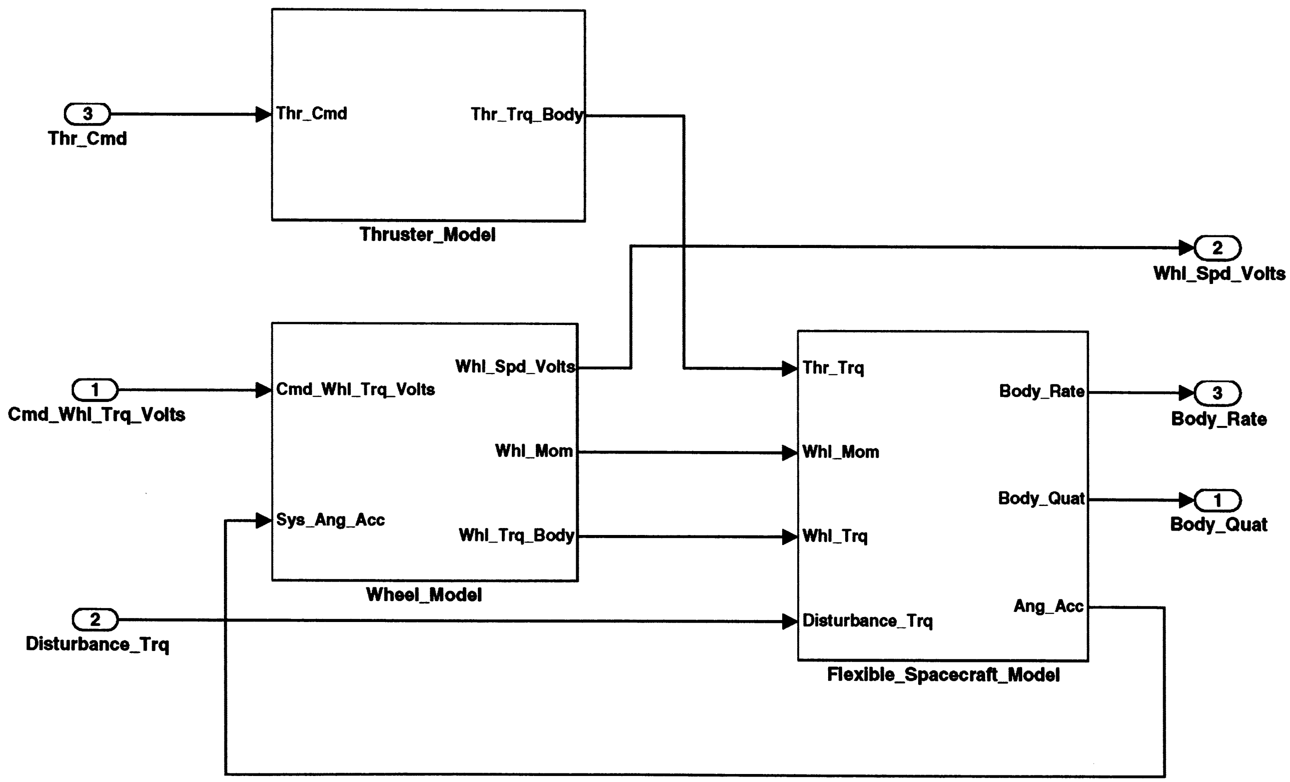
- Possible for safe mode, or if y or z wheel fails–
  - x wheel runs at large fraction of its max speed
  - Other wheel(s) used to damp nutation
  - Precession by thruster firings
- Degraded pointing accuracy –
  - Stability dominated by nutation
  - Accuracy limited by momentum precession
- Fuel for angular momentum precession:
  - About 150 mgm/day for 1°/day precession (H=4 Nms, Isp=65 s)
- If x wheel fails –
  - y and z RW control still possible
  - Two-sided thruster limit cycle for x

Top Level STEREO



Preliminary STEREO Dynamics

Dynamics



Flexible Spacecraft Dynamics

$$I\ddot{\theta} + M_I\ddot{\xi} = N - \dot{h} - \dot{\theta}\times(I\dot{\theta} + h + M_I\dot{\xi})$$
$$\ddot{\xi} + D\dot{\xi} + \Lambda\xi + M_I^T\ddot{\theta} = 0$$

where ξ **-- modal coordinates of flexible structures;**

M_I **-- interaction matrix between flexible structures and rigid spacecraft body**

$M_I\dot{\xi}$ **-- total momentum from flexible structures;**

$M_I\ddot{\xi}$ **-- total acceleration from flexible structures;**

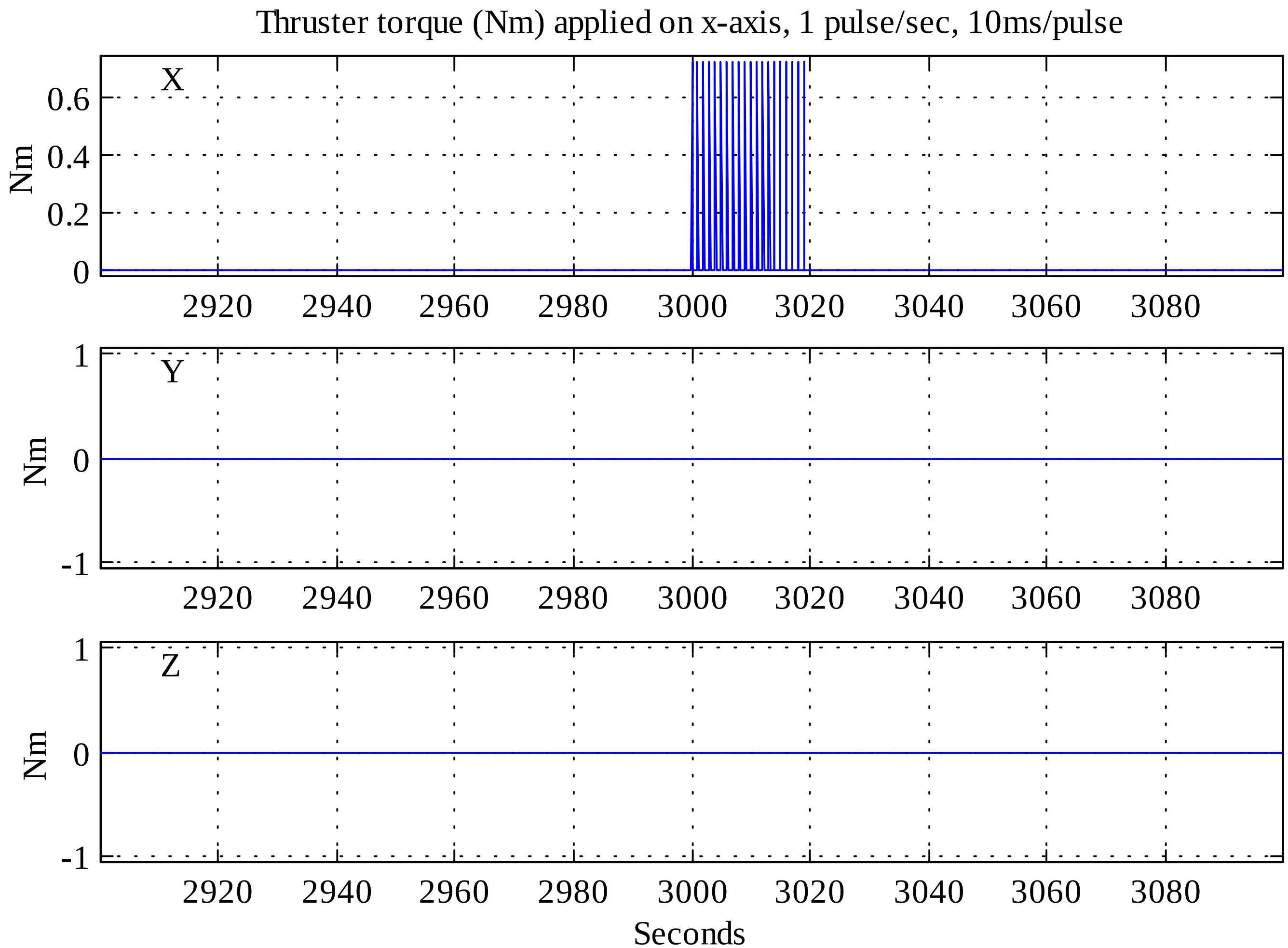
$D = 2k \cdot diag\{\omega_{f1},...,\omega_{fN}\}$ **-- natural damping matrix of flexible structure;**

$\Lambda = diag\{\omega_{f1}^2,...,\omega_{fN}^2\}$ **-- stiffness matrix of flexible structure.**

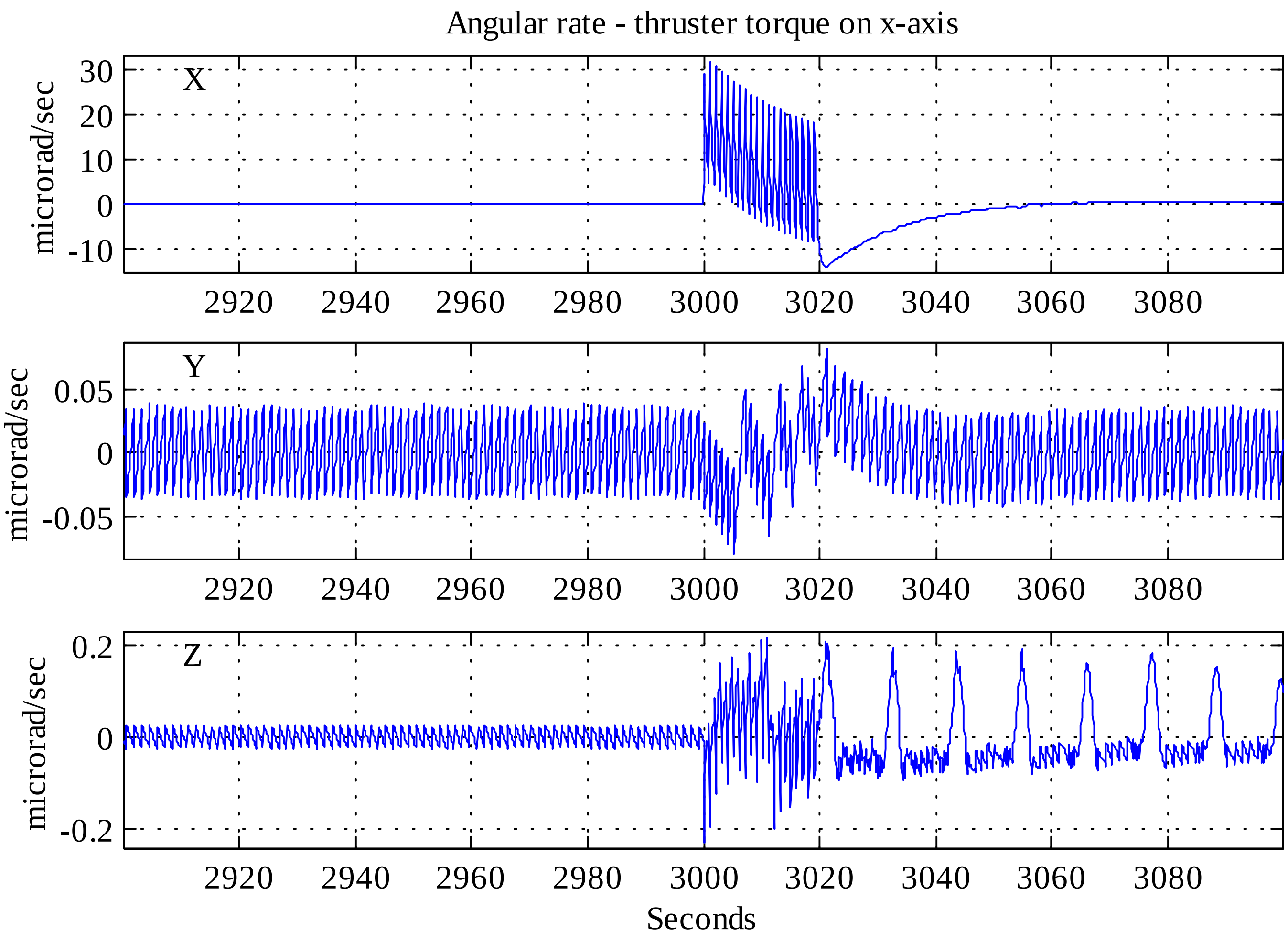
Assumptions:

- **Uniformly distributed beam like structure**
- **Normalized modal model, with lowest frequency** $f_0 = \frac{1}{2\pi}\sqrt{\frac{3EI}{(M + 0.243\rho l)l^3}}Hz$ **, and**
  $f_i = i \cdot f_0, i = 1,2,...N$ **, based on preliminary structure parameters.**
- **Simplified interaction matrix, based on preliminary geometry of flexible structures**
- **Uncoupled flexible structure models**
- **No external force on flexible structures**

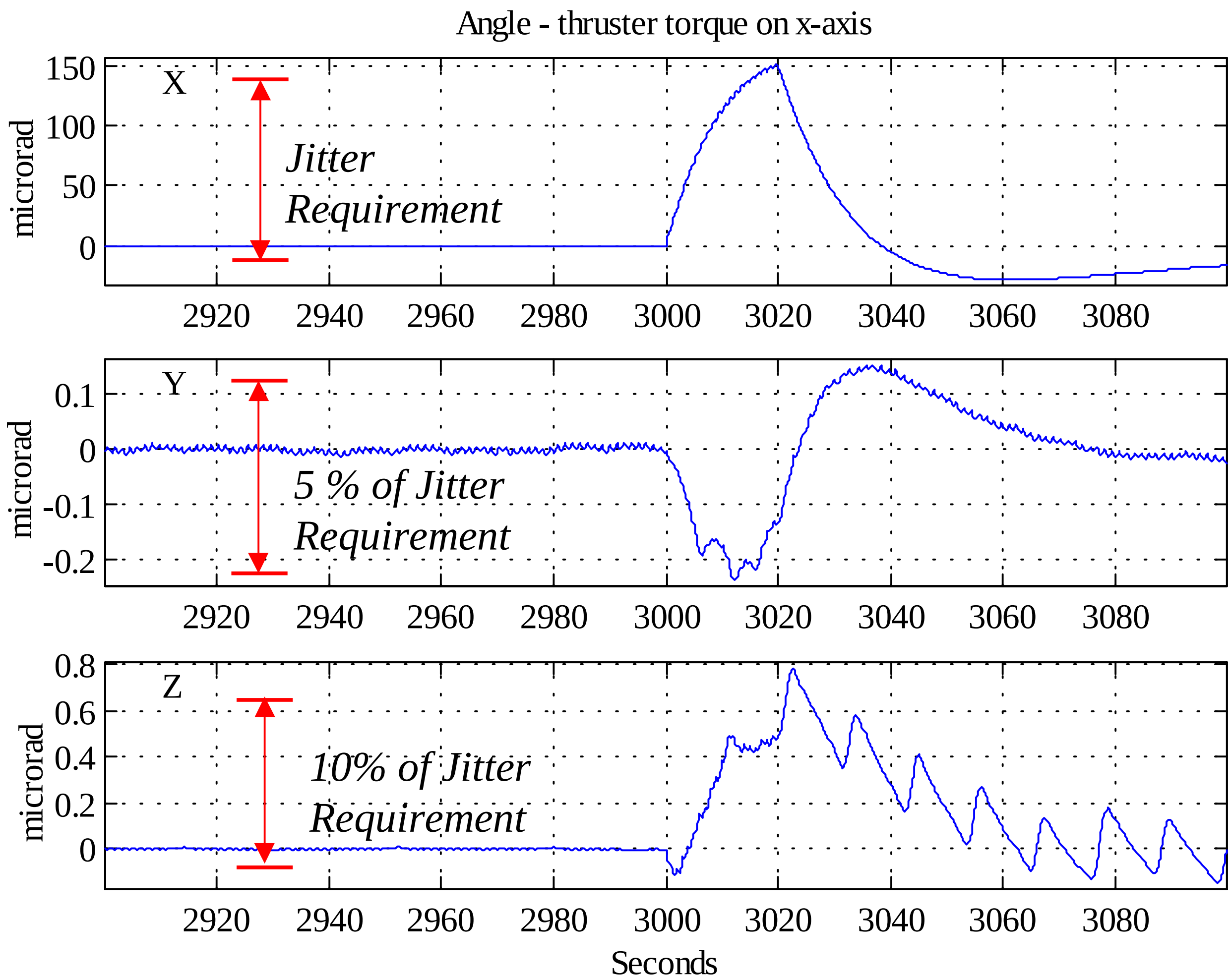
Thruster Torque, Flexible Simulation



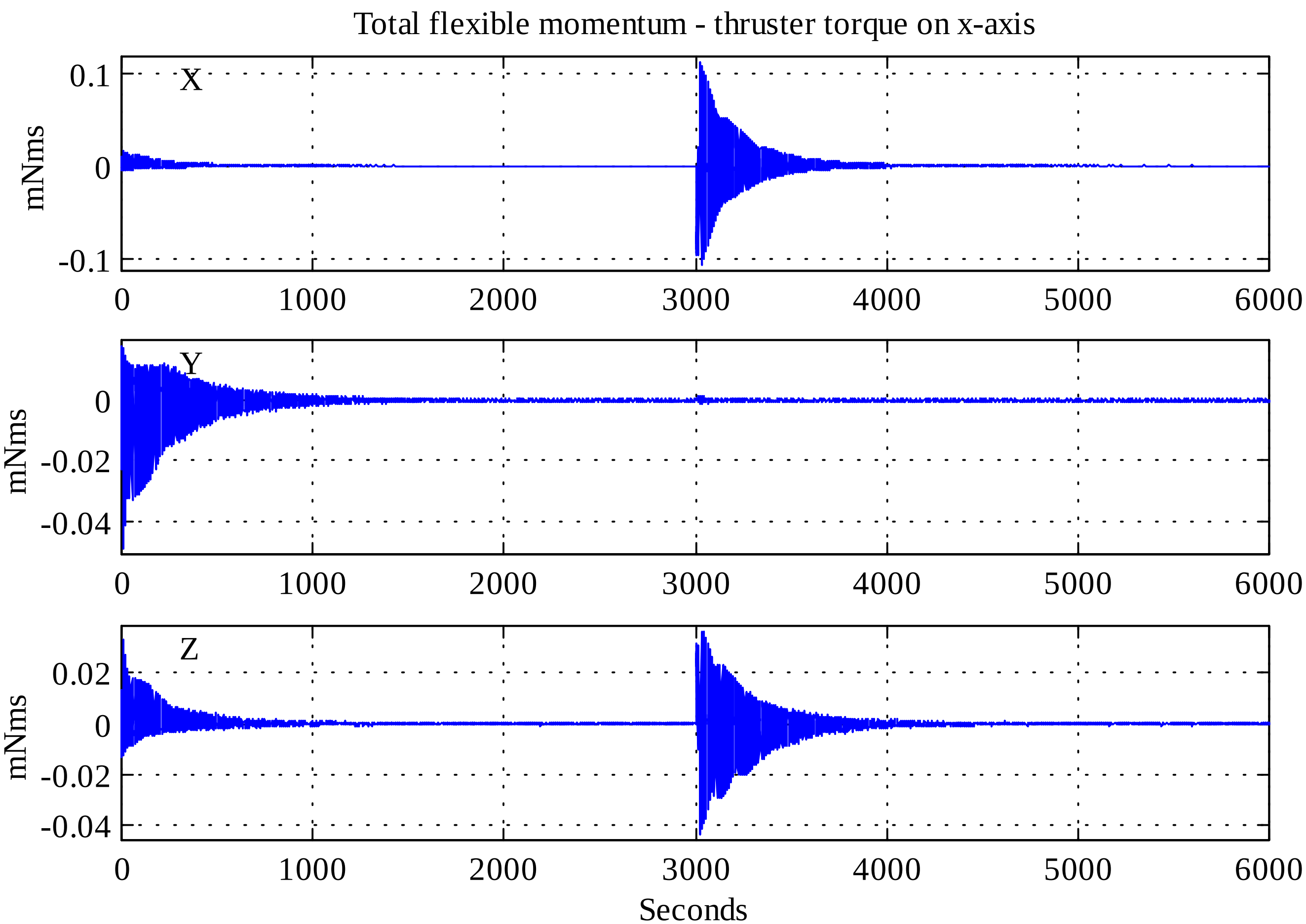
Angular Rate, Flexible Simulation



Pointing Error, Flexible Simulation



Angular Momentum in Flexible Modes



Linear Acceleration, Flexible Modes