ATTITUDE CONTROL SUBSYSTEM (ACS) TRAINING

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DIANE LI

GLENN CREAMER

INTRODUCTORY NOTES

E-Mail Address : **diane.li@specastro.com**

stan.fernandes@specastro.com

All Units Are in SI (kg-m-sec) Unless Otherwise Stated

Spectrum Astro Has Responsibility for Changes to Any ACS Parameters

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ACS DESCRIPTION

Normal Mode Operation Using FSS, MAG and Torqrods

- Spin-Stabilized at 15 RPM
- Exclusive Magnetic Control
- Active Sun-Pointing (Precession) Control to < 0.2^{o}
- Active Nutation Control
- Spin Rate Stability < 180 arcseconds in 10 revs

Initial Acquisition Using CSS, FSS, MAG and Torqrods

- Null Transverse Rates and Establishes Low Spin Rate
- Autonomous Sun Acquisition From Nominal Tip-off Orientation

Mass Balance In Idle Mode Using SAS, IAD

- On-orbit Inertia Adjustment to Align Imager with Spin Axis

ACS PERFORMANCE REQUIREMENTS

			Requirement Traceability		
Parameter	**Requirement**	**Capability**	**Source**	**Implementation**	**Verification Method**
Spacecraft Attitude Stabilization	Spin stabilized	Comply	System Specification	ACS	Analysis/Operation
Spacecraft Spin Rate	15 RPM	15 ± 2 RPM	System Specification	ACS	Analysis
Sun Pointing Control	< 0.2 degrees	0.14 degrees	System Specification	ACS, SMS, FSS PFS (#1110-EW-T10163)	Analysis
Spin Rate Stability	180 arcseconds in 10 revs	125 arcseconds in 10 revs while in Sun	System Specification	ACS	Analysis
SAS Data Compatibility	SAS as backup to FSS	SAS can not be used for ACS	System Specification	ACS	Operation
Maximum LV Tip-Off Rate	4 deg/sec in transverse axes	6 deg/sec	System Specification	ACS	Analysis
Initial Sun Acquisition	The S/C shall autonomously acquire the Sun from the worst Tip-Off orientation & rate upon separation from the LV	Comply	System Specification	ACS	Analysis
CSS Sun Vector Measurement Range	The CSS suite shall provide 4π steradian coverage	Comply	System Specification	ACS, SMS, CSS PFS (#1110-EW-T10164)	Analysis

SPECTRUMASTRO

FSW TIMELINES AND SEQUENCE OF EVENTS

High Energy Solar Spectroscopic Imager (HESSI)

RTS0: Initial Operations RTS				
Sep +	**hh:mm:ss**		**Command Function**	**Comments**
25	0:00:25	FSW	ACS Power Bus Switch ON	Post-Separation Sequence
26	0:00:26	PCB	Magnetometer Power ON	
27	0:00:27	PCB	Fine Sun Sensor Power ON	
28	0:00:28	PCB	NE Heater Power Bus Switch ON	
29	0:00:29	PCB	SSR Heater Power Enable	
30	0:00:30	PCB	Battery Heater Power Enable	Heaters Turn-on
31	0:00:31	PCB	Torque Rod Heaters Power Enable	
32	0:00:32	PCB	FSS Electronics Heater Power Enable	
33	0:00:33	PCB	Transponder Heater Power Enable	
34	0:00:34	PCB	SEM Heater Power Enable	
403	0:06:43	PCB	ACS Acquisition Mode	Start Sun Acquisition
4631	1:17:11	FSW	Execute LEO Downlink RTS	Berkeley Pass 1 (AOS-60s)
10734	2:58:54	FSW	Execute LEO Downlink RTS	Berkeley Pass 2 (AOS-60s)
16853	4:40:53	FSW	Execute LEO Downlink RTS	Berkeley Pass 3 (AOS-60s)
22974	6:22:54	FSW	Execute LEO Downlink RTS	Berkeley Pass 4 (AOS-60s)
29173	8:06:13	FSW	Execute LEO Downlink RTS	Berkeley Pass 5 (AOS-60s)
79625	22:07:05	FSW	Execute LEO Downlink RTS	Berkeley Pass 6 (AOS-60s)

ADB RELEASE TIMELINES AND SEQUENCE OF EVENTS

		ADB Separation Sequence				
45	0:00:45		Release Mechanism Actuate Time			
1	0:00:01		Minimum Delay Between Commands			
Sep +	**hh:mm:ss**	**HCD**	**Command Function**	**State**	**Action**	**Event**
0	0:00:00	N/A	ADB Senses LV Separation			Separation
30	0:00:30	HCD08	Primary Enable	Enable	30 second delay from sep	
31	0:00:31	HCD04	± X Upper Release	Release	± X Upper Primary On	
76	0:01:16	HCD04	± X Upper Release	Standby	± X Upper Primary Off	± X Nominal Break Upper Bolt
77	0:01:17	HCD08	Primary Enable	Disable	Disable Primary Power	
78	0:01:18	HCD09	Redundant Enable	Enable	Enable Redundant Power	
79	0:01:19	HCD04	± X Upper Release	Release	± X Upper Redundant On	
124	0:02:04	HCD04	± X Upper Release	Standby	± X Upper Redundant Off	± X Contingency Break Upper Bolt
125	0:02:05	HCD09	Redundant Enable	Disable	Disable Redundant Power	
126	0:02:06	HCD08	Primary Enable	Enable	Enable Primary Power	
127	0:02:07	HCD05	± Y Upper Release	Release	± Y Upper Primary On	
172	0:02:52	HCD05	± Y Upper Release	Standby	± Y Upper Primary Off	± Y Nominal Break Upper Bolt
173	0:02:53	HCD08	Primary Enable	Disable	Disable Primary Power	
174	0:02:54	HCD09	Redundant Enable	Enable	Enable Redundant Power	
175	0:02:55	HCD05	± Y Upper Release	Release	± Y Upper Redundant On	
220	0:03:40	HCD05	± Y Upper Release	Standby	± Y Upper Redundant Off	± Y Contingency Break Upper Bolt
221	0:03:41	HCD09	Redundant Enable	Disable	Disable Redundant Power	
222	0:03:42	HCD08	Primary Enable	Enable	Enable Primary Power	
223	0:03:43	HCD06	± X Lower Release	Release	± X Lower Primary On	
268	0:04:28	HCD06	± X Lower Release	Standby	± X Lower Primary Off	± X Wing Nominal Release
269	0:04:29	HCD08	Primary Enable	Disable	Disable Primary Power	
270	0:04:30	HCD09	Redundant Enable	Enable	Enable Redundant Power	
271	0:04:31	HCD06	± X Lower Release	Release	± X Lower Redundant On	
316	0:05:16	HCD06	± X Lower Release	Standby	± X Lower Redundant Off	± X Wing Contingency Release
317	0:05:17	HCD09	Redundant Enable	Disable	Disable Redundant Power	
318	0:05:18	HCD08	Primary Enable	Enable	Enable Primary Power	
319	0:05:19	HCD07	± Y Lower Release	Release	± Y Lower Primary On	
364	0:06:04	HCD07	± Y Lower Release	Standby	± Y Lower Primary Off	± Y Wing Nominal Release
365	0:06:05	HCD08	Primary Enable	Disable	Disable Primary Power	
366	0:06:06	HCD09	Redundant Enable	Enable	Enable Redundant Power	
367	0:06:07	HCD07	± Y Lower Release	Release	± Y Lower Redundant On	
412	0:06:52	HCD07	± Y Lower Release	Standby	± Y Lower Redundant Off	± Y Wing Contingency Release
413	0:06:53	HCD09	Redundant Enable	Disable	Disable Redundant Power	

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ON-ORBIT CONFIGURATION

High Energy Solar Spectroscopic Imager (HESSI)

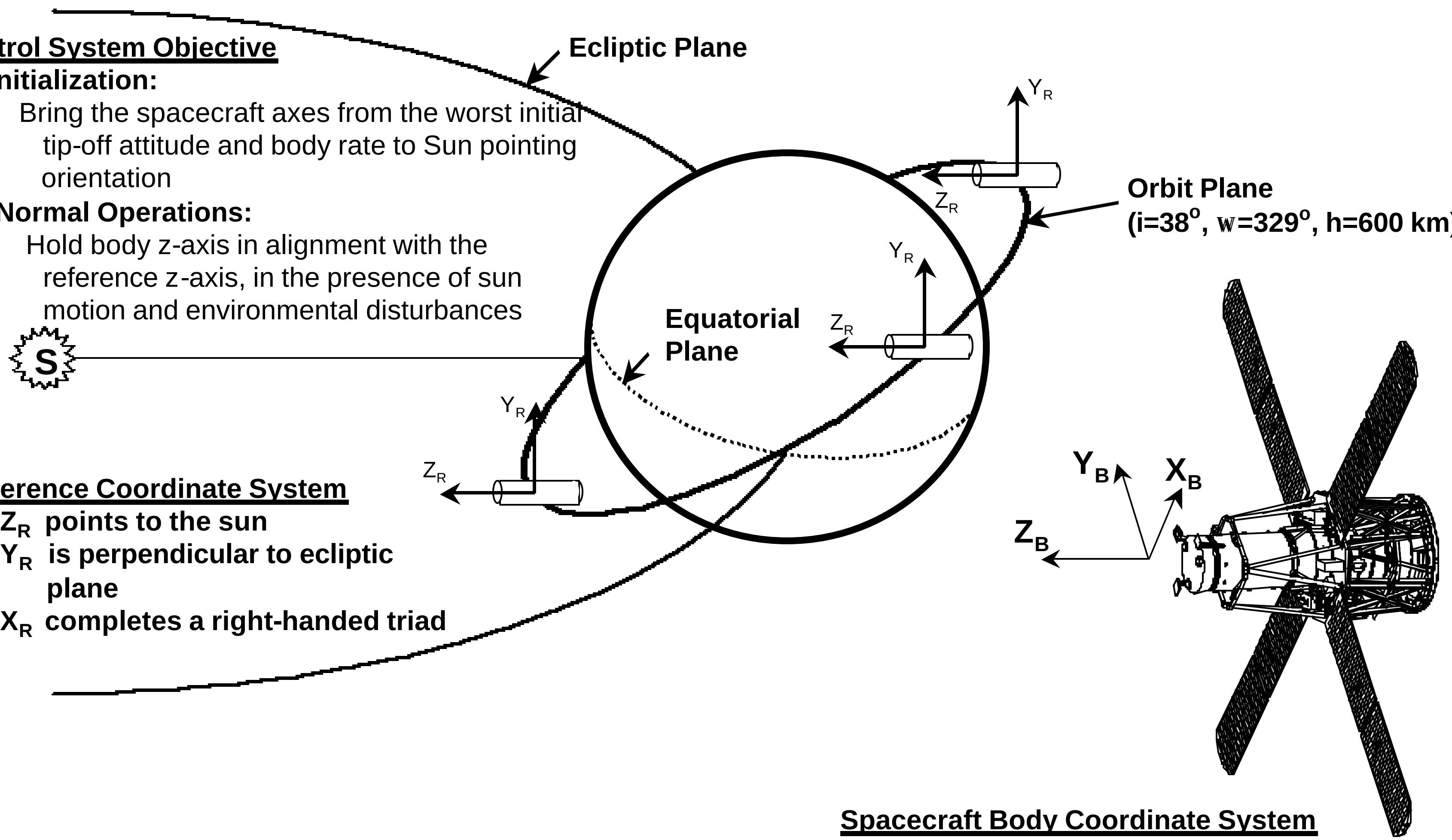
<u>Control System Objective</u>

Initialization:

Bring the spacecraft axes from the worst initial tip-off attitude and body rate to Sun pointing orientation

Normal Operations:

Hold body z-axis in alignment with the reference z-axis, in the presence of sun motion and environmental disturbances



<u>Reference Coordinate System</u>

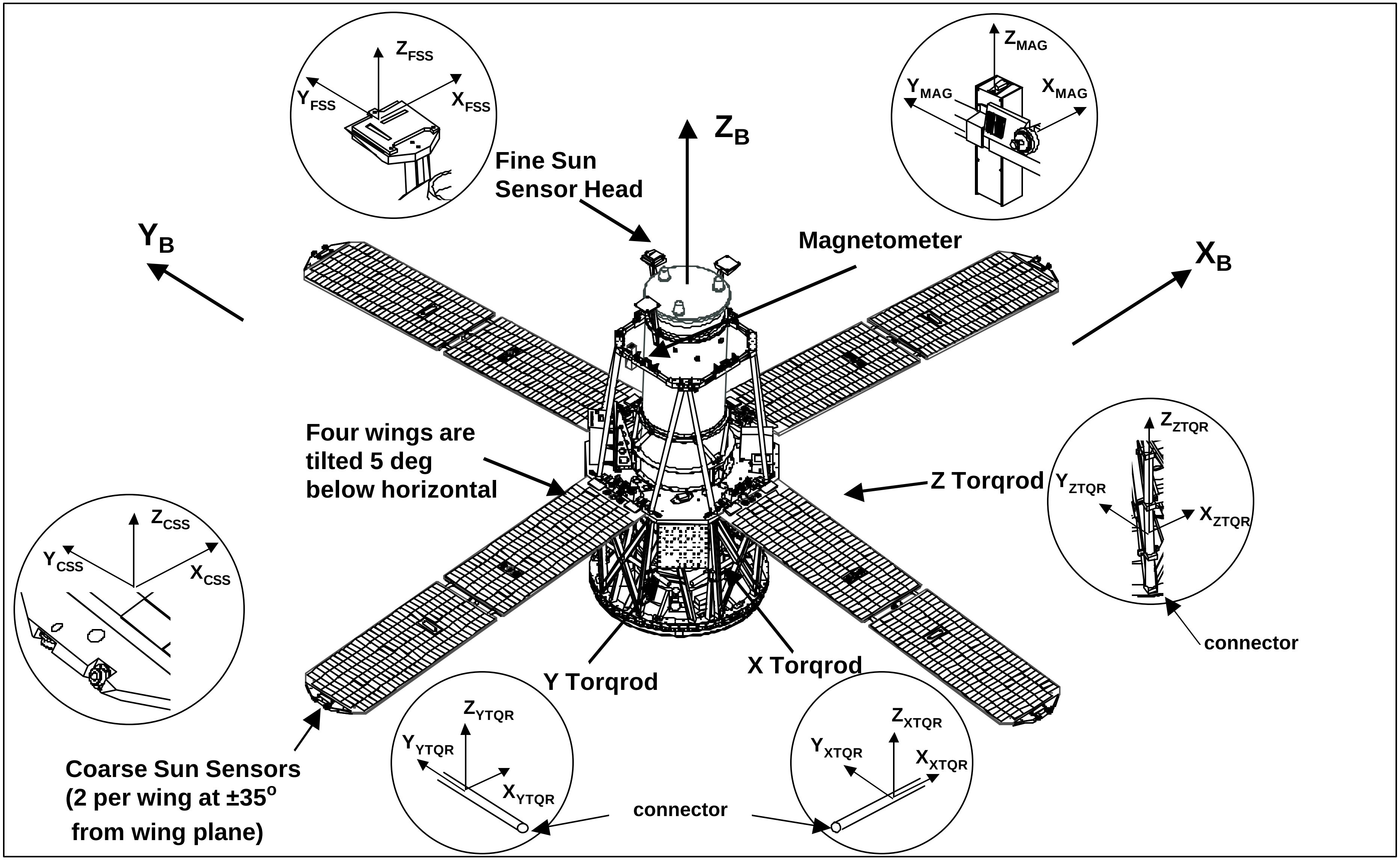
Z_R points to the sun

Y_R is perpendicular to ecliptic plane

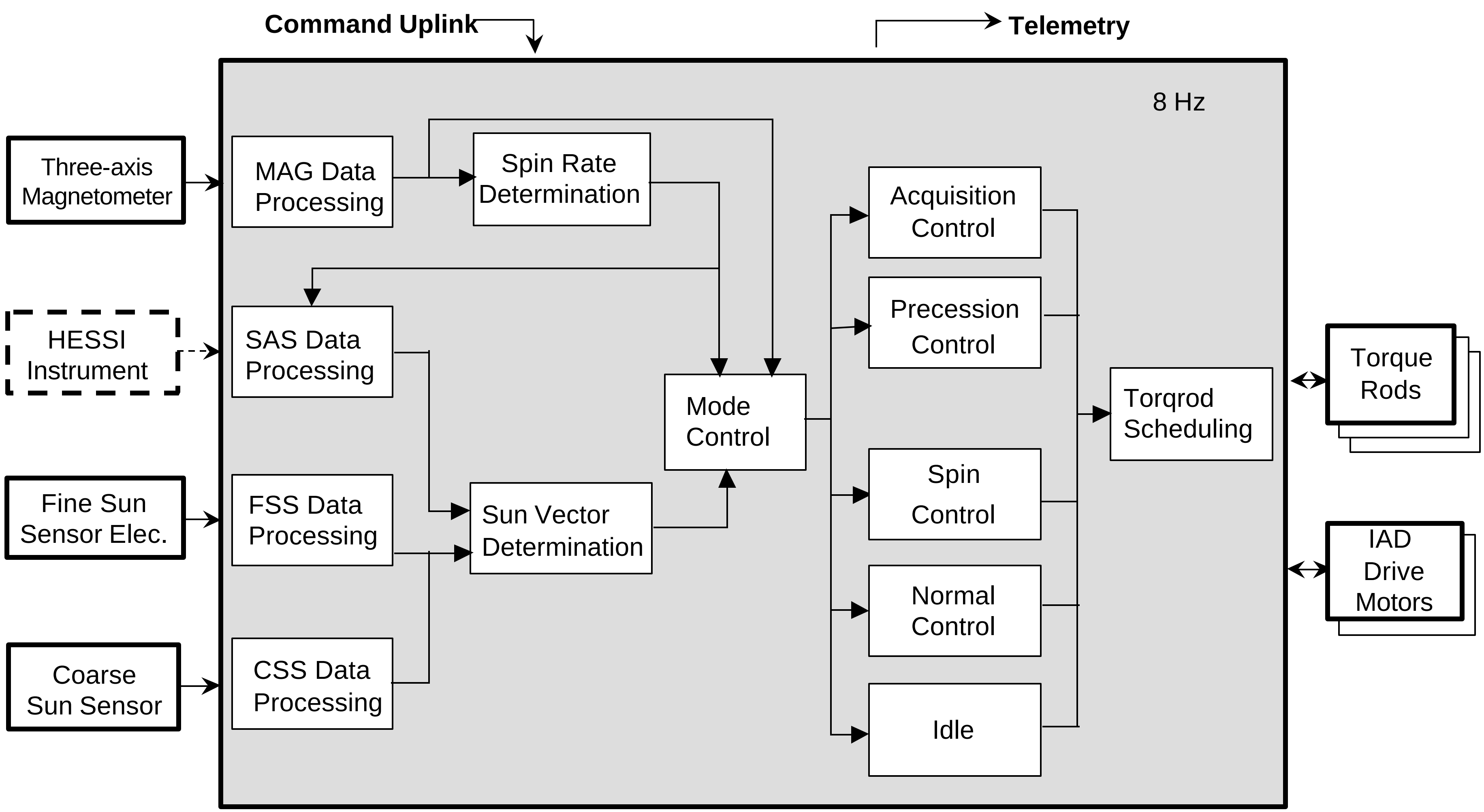
X_R completes a right-handed triad

<u>Spacecraft Body Coordinate System</u>

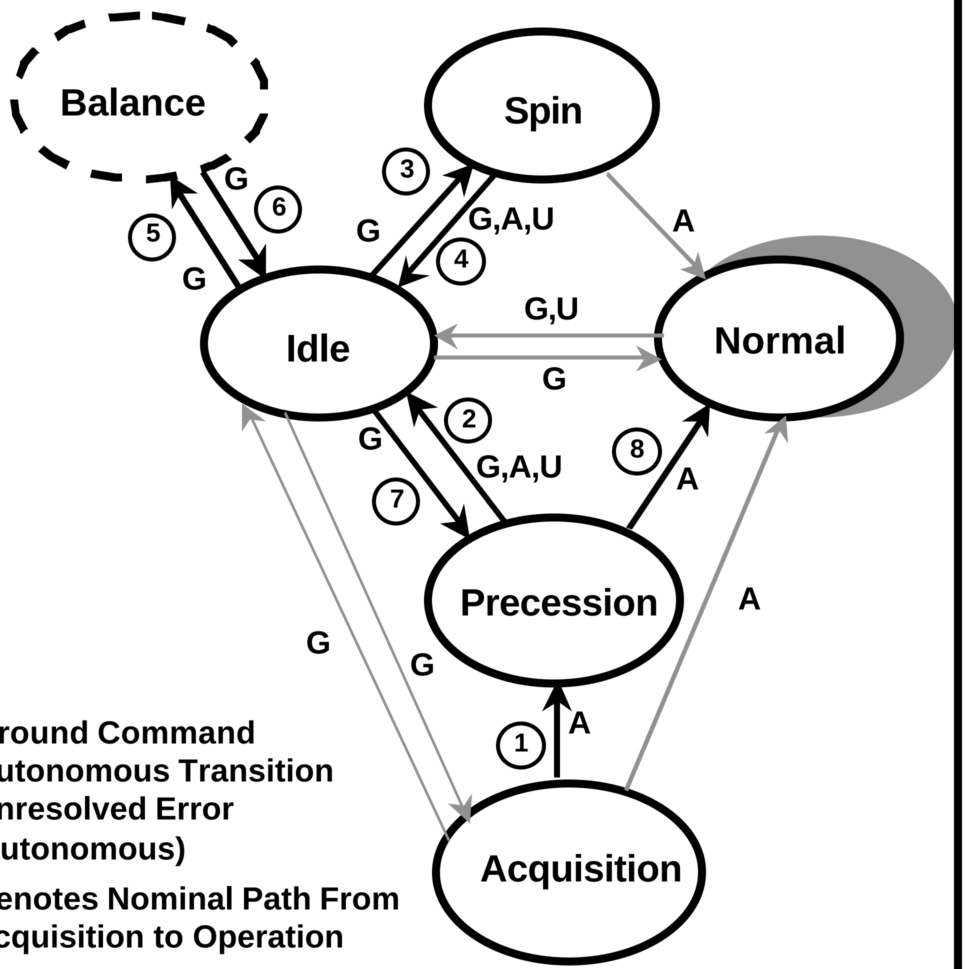
ACS PHASING AND ORIENTATION



ACS FLIGHT SOFTWARE ARCHITECTURE



ACS MODES AND MODE DEFINITION



G - Ground Command
A - Autonomous Transition
U - Unresolved Error (Autonomous)
(#) - Denotes Nominal Path From Acquisition to Operation

Acquisition (Wake Up) Mode
Establishes Desired Spin Rate and Damps Transverse Rates

Precession Mode
Establishes Sun-pointing Orientation

Normal Mode
Maintains Sun-pointing Orientation and Nominal Spin Rate; Encompasses Fine Precession, Nutation, and Spin Rate Control

Spin Mode
Establishes Desired Spin Rate

Idle Mode
Disables Control Until Ground Intervention

Balance Operations
Balances Spacecraft Using IADs to Obtain Pure Spin About Imager Axis

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ACS MODES TRANSITION LOGIC

High Energy Solar Spectroscopic Imager (HESSI)

	Acquisition	Precession	Normal	Spin	Idle
Acquisition		Time since LV release > 2.5 hours	$\beta < 5.0$ deg AND $\Omega > 0.12$ rpm	None	Ground Command
Precession	None		$\beta < 0.2$ deg AND $14.5 < \Omega < 15.5$rpm	None	Ground Command OR { $\beta < 5$ deg AND NOT $14.5 < \Omega < 15.5$ rpm }
Normal	None	None		None	Ground Command OR $\beta > 0.5$ deg OR NOT $13.5 < \Omega < 16.5$ rpm
Spin	None	None	$14.5 < \Omega < 15.5$rpm AND $\beta < 0.2$ deg		Ground Command OR { $14.5 < \Omega < 15.5$ rpm AND NOT $\beta < 0.2$ deg }
Idle	Ground Cmd	Ground Cmd	Ground Cmd	Ground Cmd	

Note 1: Autonomous Mode Transitions can Only Occur When the Sun Is in Presence
Note 2: Persistence Checks are Performed for All Autonomous Mode Transitions
Note 3: b = Angle Between Spin Axis and Sun
w = Measured Spin Rate

ACS HARDWARE UTILIZATION

	Acquisition	Precession	Spin	Normal	Idle	Balance
Spin-Axis TQR	Y	Y	N	Y (pointing)	On Request	N
Transverse TQR	Y	N	Y	Y (spin rate)	On Request	N
CSS	N	Y	N	N	On Request	N
FSS	N	Y	Y	Y	On Request	Y
MAG	Y	Y	Y	Y	On Request	N
IAD	N	N	N	N	N	Y
SAS	N	N	N	N	On Request	Y

Notes:

1. All sensors sampled at 8 Hz PACI rate
2. When FSS Sun Presence Indicator is high, FSS output supersedes CSS output
3. MAG Processing Includes Compensation for Torqrod-Generated Magnetic Field
    - Initial Compensation Matrix Generated from Ground Test
    - Matrix Obtained by Energizing One Torqrod at a Time and Measuring Field Change
4. For Normal Mode Spin Rate Control is Limited to 10 A-m^2
5. SAS is Utilized as Primary Balancing Sensor
6. SAS can Not Be Used for ACS control

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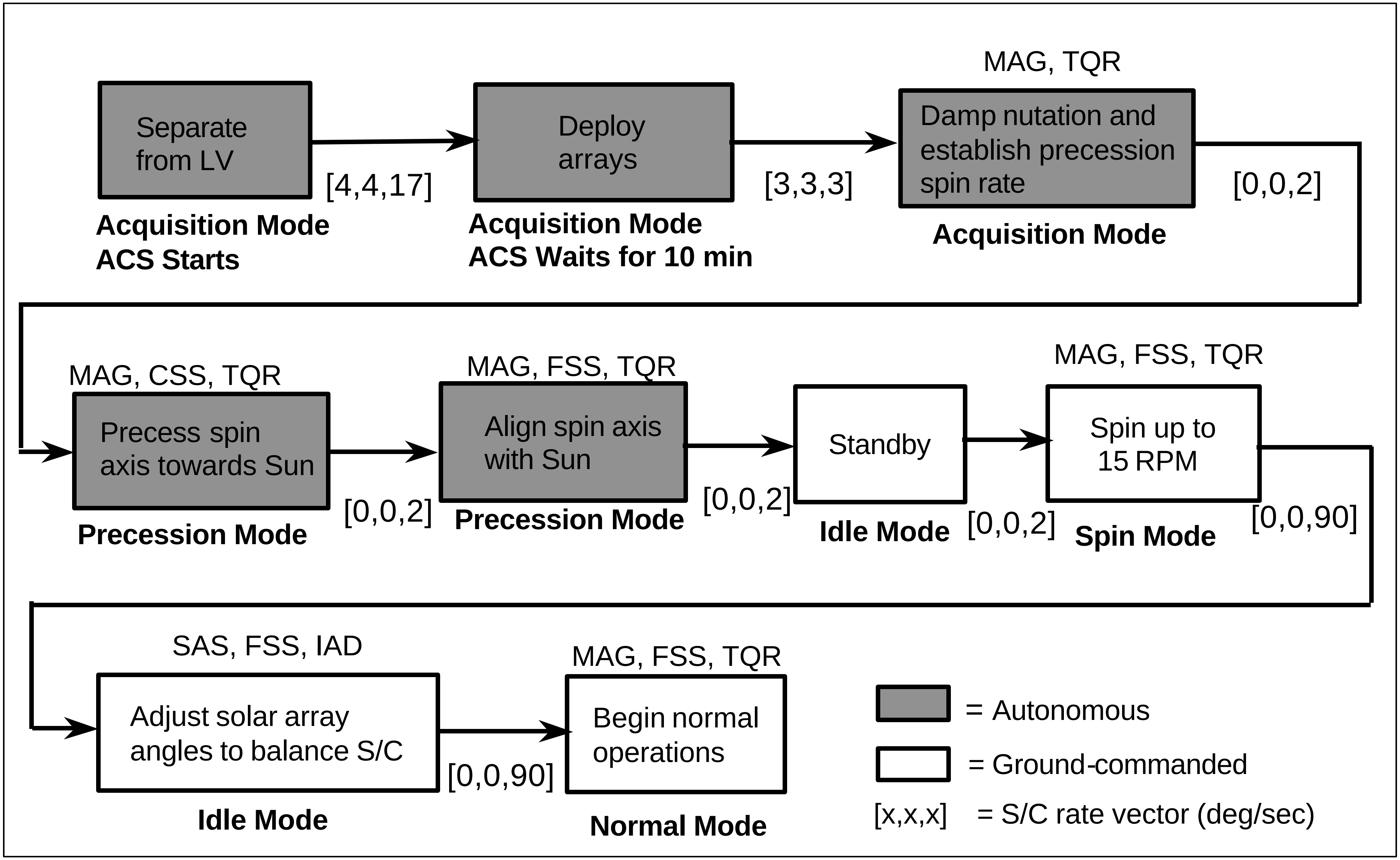
EVENT SEQUENCE TO NORMAL OPERATIONS

High Energy Solar Spectroscopic Imager (HESSI)



Nominal LV Tip-off Conditions:

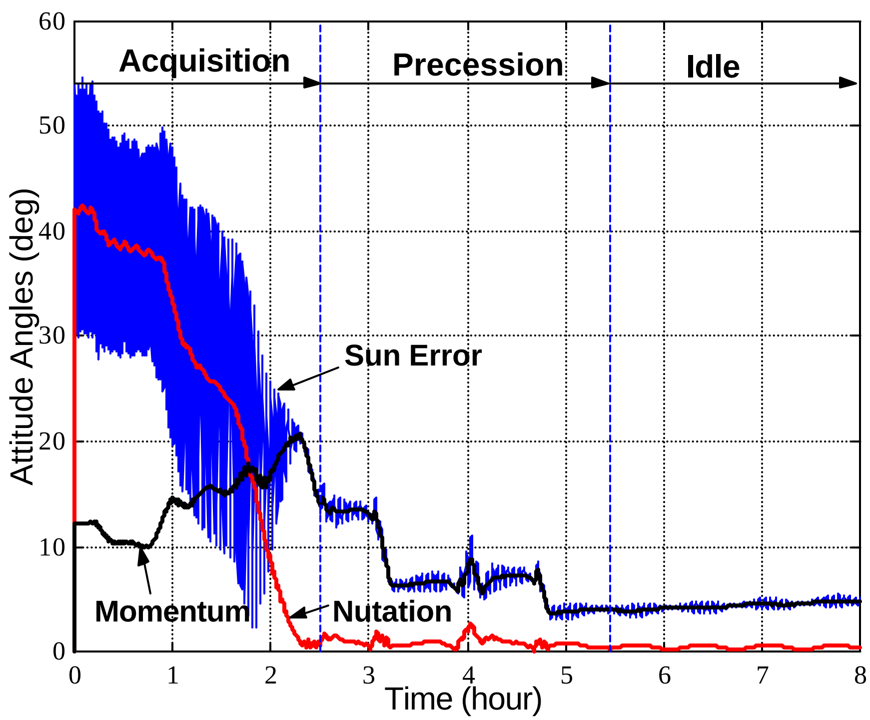
- Momentum Vector within 10 deg of Sun
- 4 deg/sec Transverse Rate
- 17 deg/sec Spin Rate

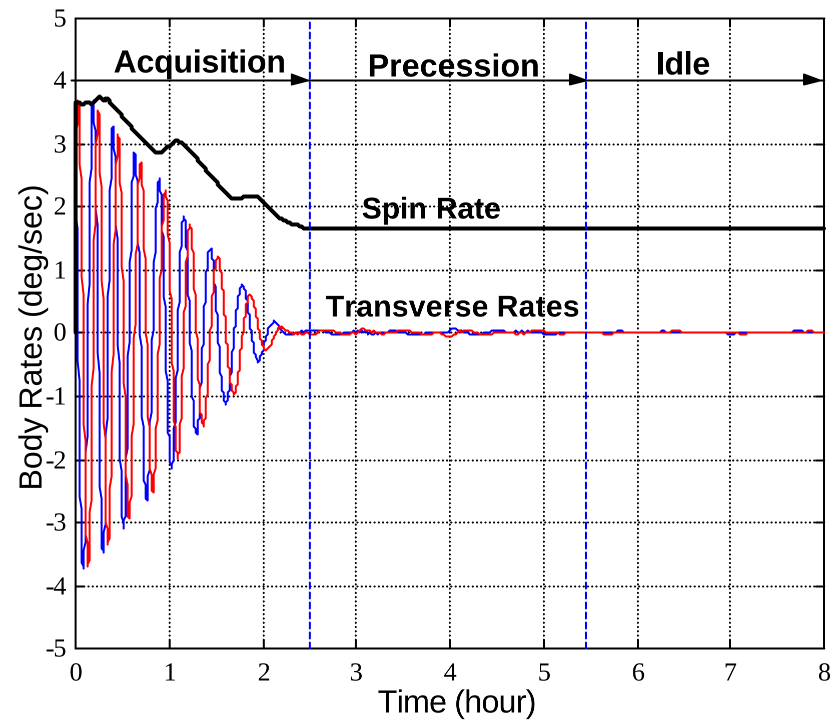
30-second Array Deployment with 2-second Delay between Arrays Adds 2° of Additional Nutation

Initial 2.5 hour Acquisition Mode Establishes Spin Rate and Damps Transverse Rates (B-dot)

FSS Utilized When Sun Cone Angle is within 32 Degrees

30-minute Eclipse Once per Orbit with Precession Control Disabled





WORST ATTITUDE SUN ACQUISITION

Worst LV Tip-off Conditions:

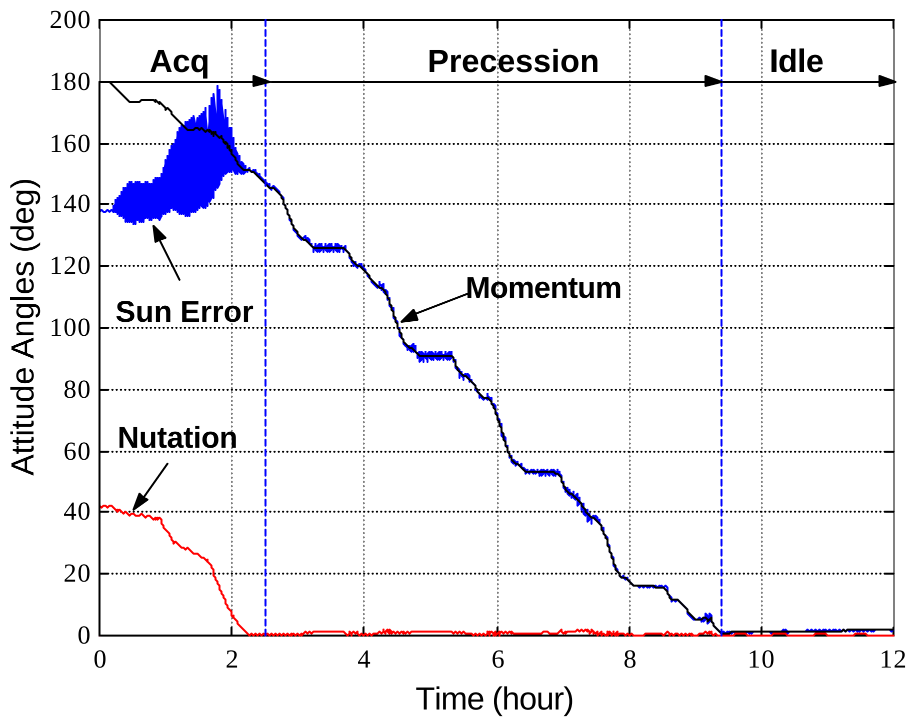
- Momentum Vector within 180 deg of Sun
- 4 deg/sec Transverse Rate
- 17 deg/sec Spin Rate

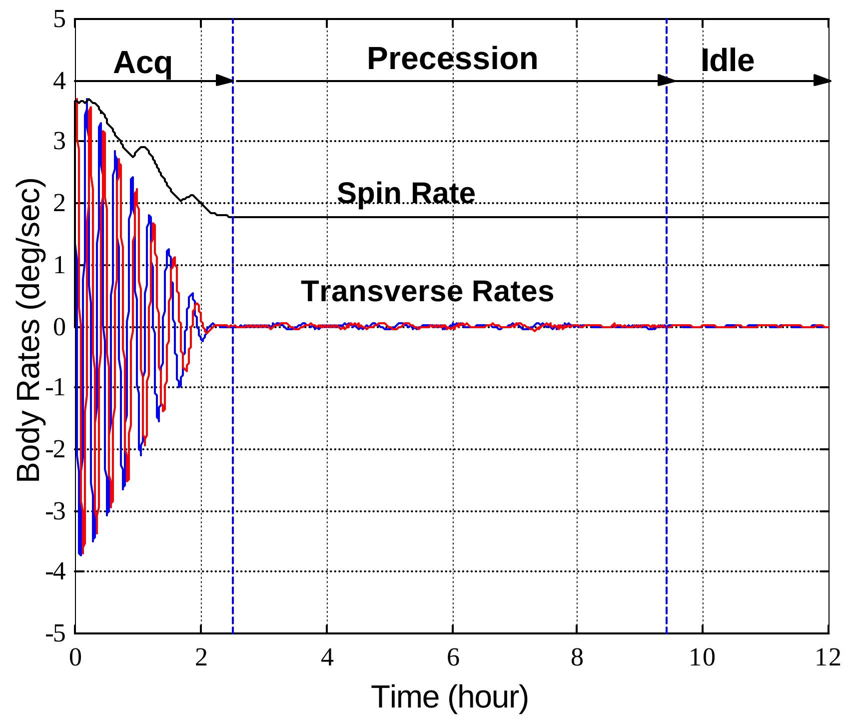
30-second Array Deployment with 2-second Delay between Arrays Adds 2° of Additional Nutation

Initial 2.5 hour Acquisition Mode Establishes Spin Rate and Damps Transverse Rates

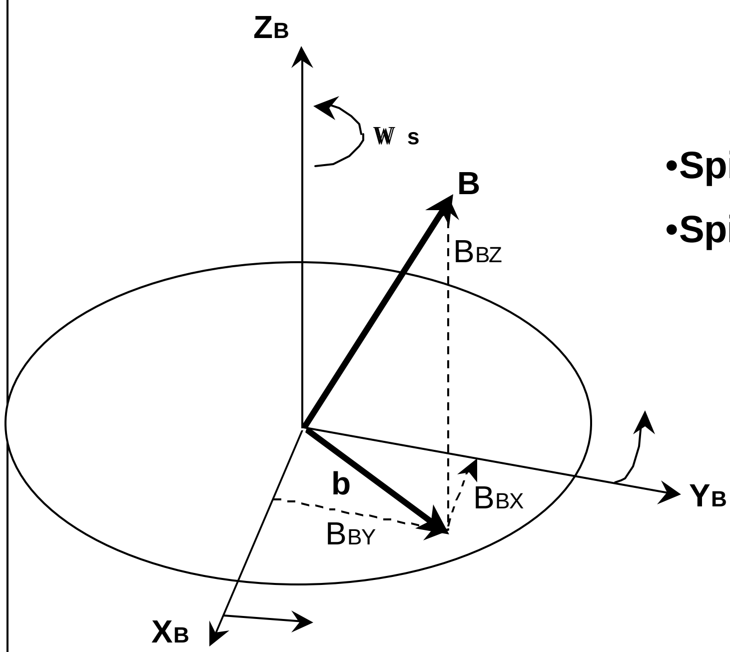
FSS Utilized When Sun Cone Angle is within 32 Degrees

30-minute Eclipse Once per Orbit with Precession Control Disabled





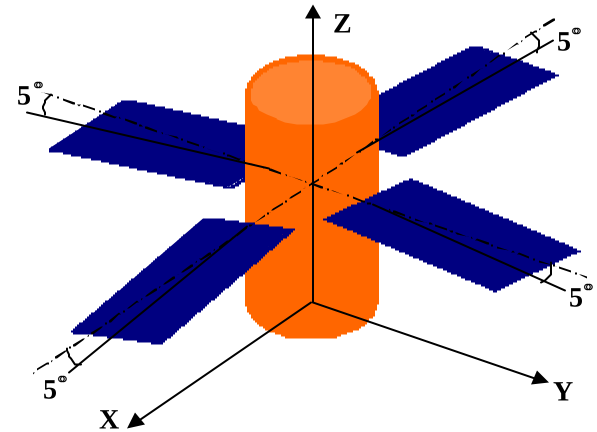
SPIN RATE ESTIMATION



- **b is the Projection of B onto the Spin Plane**
- **b is Periodic in the Body x and y Axes at Spin Period**
- **Absolute Spin Rate can be Determined by**
  - Record **b** Crossing Time Period Δt at X Axis
  - Record **b** Crossing Time Period Δt at Y Axis
  - Spin Rate Estimate at One Axis = $2\pi/\Delta t$
  - Average X and Y Spin Rate Estimates
- **Spin Rate Estimate is Updated Whenever a New Crossing Occurs**
- **Spin Rate Estimation Errors**:
  - Bigger Errors Tend to Occur at Low Spin Rates
  - Error Varies with Orbit/Magnetic Field Positions
  - Errors due to Nutation Motion

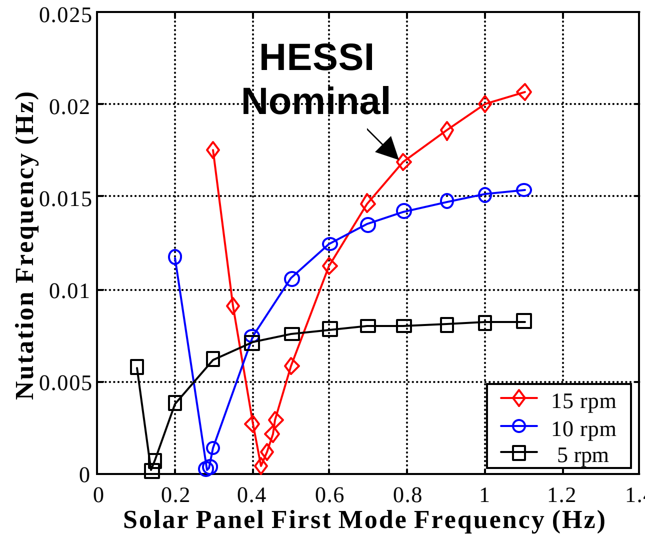
SOLAR ARRAY FREQUENCE ANALYSIS RESULTS

Dynamics Model Assumptions:
- One Rigid Central Body with Zero Cross Product MOI
- 4 Rigid Panels Symmetrically Located
- Spring-damper Joints
  - 1% Damping Ratio
- 4 Solar Panels at Nominal 5° Angle

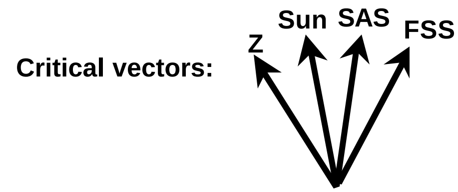


Analysis Results:
- HESSI 1st Mode Frequency 0.79 Hz per Structural Analysis
- For Nominal 15 rpm Spin:
  - Unstable for <= 0.43Hz 1st Mode Frequency
  - Min Nutation Frequency Occurs at 0.43Hz
- HESSI Stiffness > 3 times of Unstable Stiffness
- For 10 rpm
  - Unstable for <= 0.29Hz S/A 1st Mode Frequencies
- For 5 rpm
  - Unstable for <= 0.14Hz S/A 1st Mode Frequencies

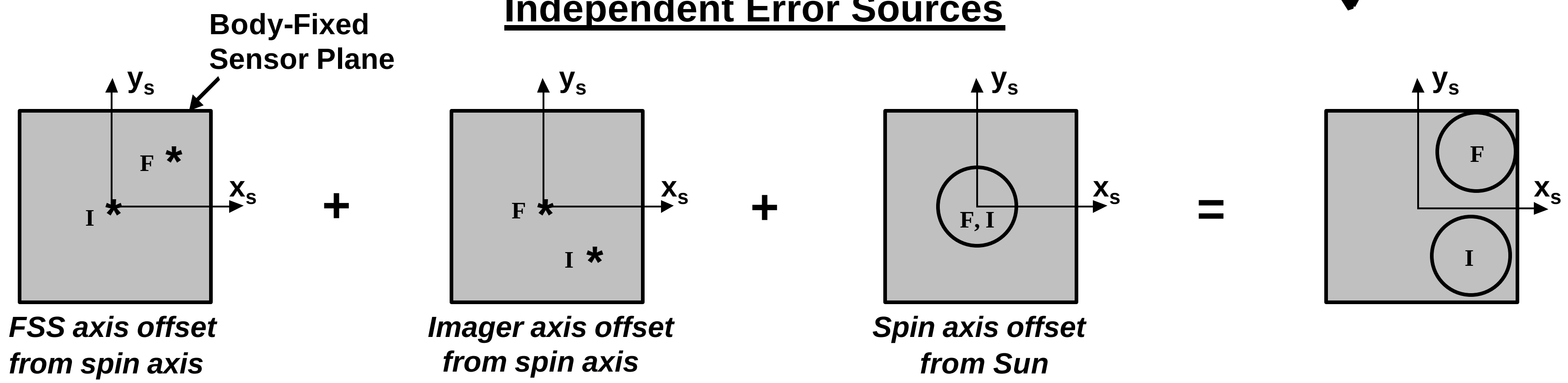
Nutation Freq vs. S/A 1st Mode Freq



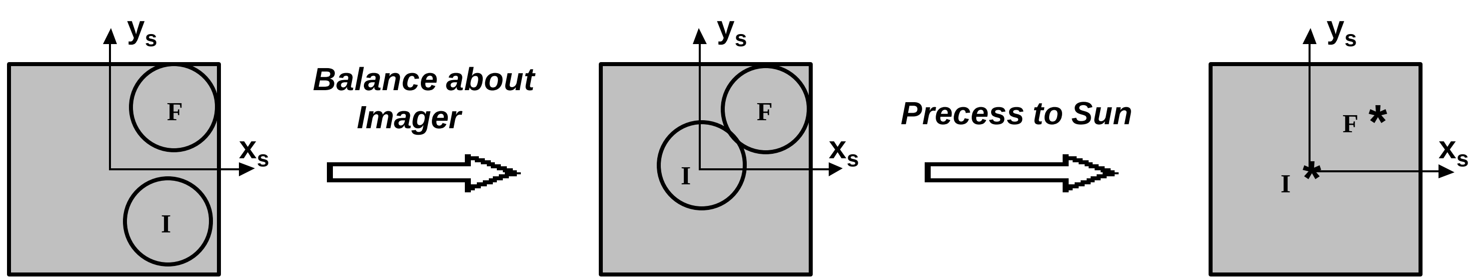
ON-ORBIT BALANCE - CONCEPT



Independent Error Sources



Spacecraft Balance & Precession



F = Output in FSS Sensor Plane
I = Output in Imager Sensor Plane

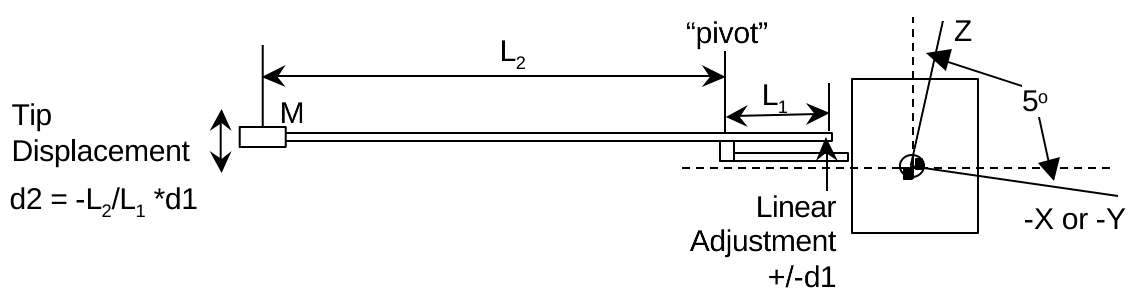
ON-ORBIT BALANCE - CAPABILITY

Objective

- Provide On-orbit Adjustment to Compensate for Offset Between Principal Spin Axis and SAS Boresight Axis

Key Issues

- Adjustment Sensitivity
  - 0.00043 cm Linear Adjustment Resolution Equates to 0.0022^{o} Spin Axis Angle Resolution
- A 1^{o} Spin Axis Capture Range Equates to
  - 455 Steps
  - 0.55 deg Array Deflection
  - Linear Adjustment of 0.2 cm
  - Net Tip Deflection of 2.2 cm
- Full Travel Range is 2.54 cm Equating to 12 Degrees of Spin Axis Range
- Estimates Show That Approximately 5% of the Rigid Body Deflection is Lost to Centrifugal Force



ACS HARDWARE

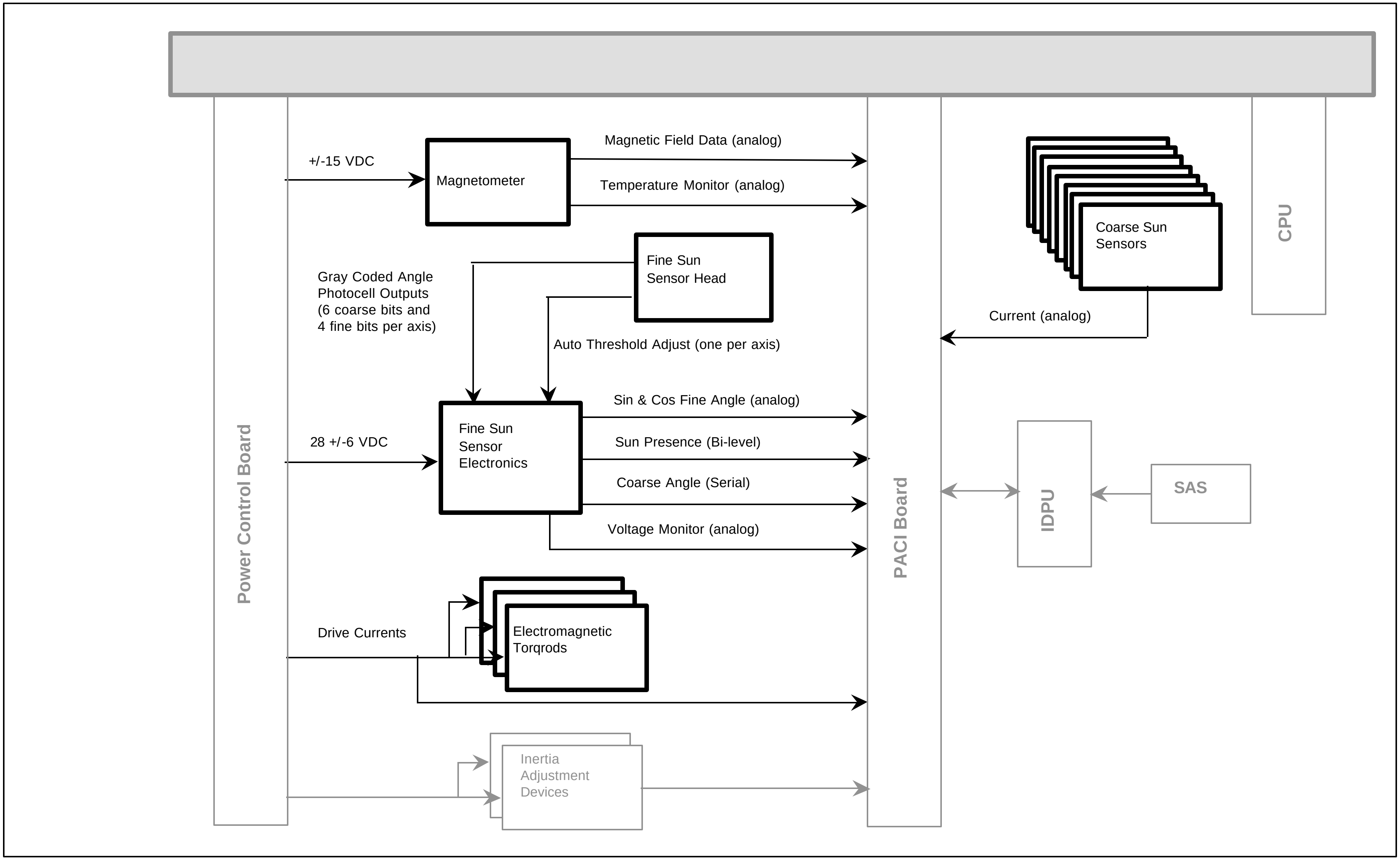
ACS Interface Block Diagram

Hardware Performance and Technical Data

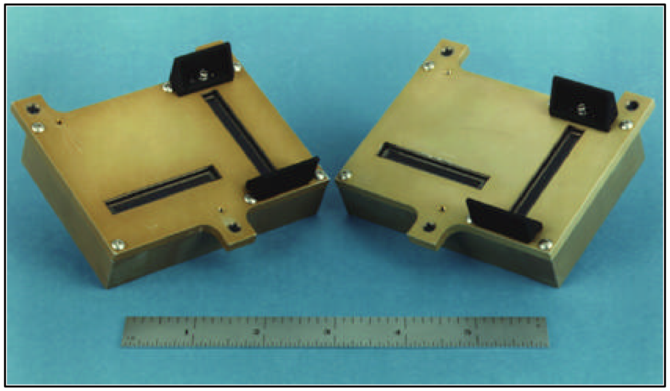
FOVs of FSS and CSS

Torque Rod Compensation Matrix

ACS INTERFACE BLOCK DIAGRAM



FINE SUN SENSOR HEAD



Supplier: Adcole

Supplier Part Number: Model 41660

Quantity: 1

Mass: 0.29 kg

Size: 9.6 x 9.7 x 3.6 cm

Power: n/a

Performance:

- Operational Field of View: ± 32^{o} cone
- Sun Presence Field of View: ± 31.5^{o} ± 0.5^{o}
- Measurement Resolution:
  0.005^{o} for 8-bit D/A Converter, Dictated by since/cosine Signals
- Measurement Accuracy:
  0.05^{o} (3σ) in ± 10^{o} Half Cone
  0.1^{o} (3σ) Outside Half Cone

Detector layout:

- 6 Gray-Coded Coarse Bits
- 4 Fine Bits

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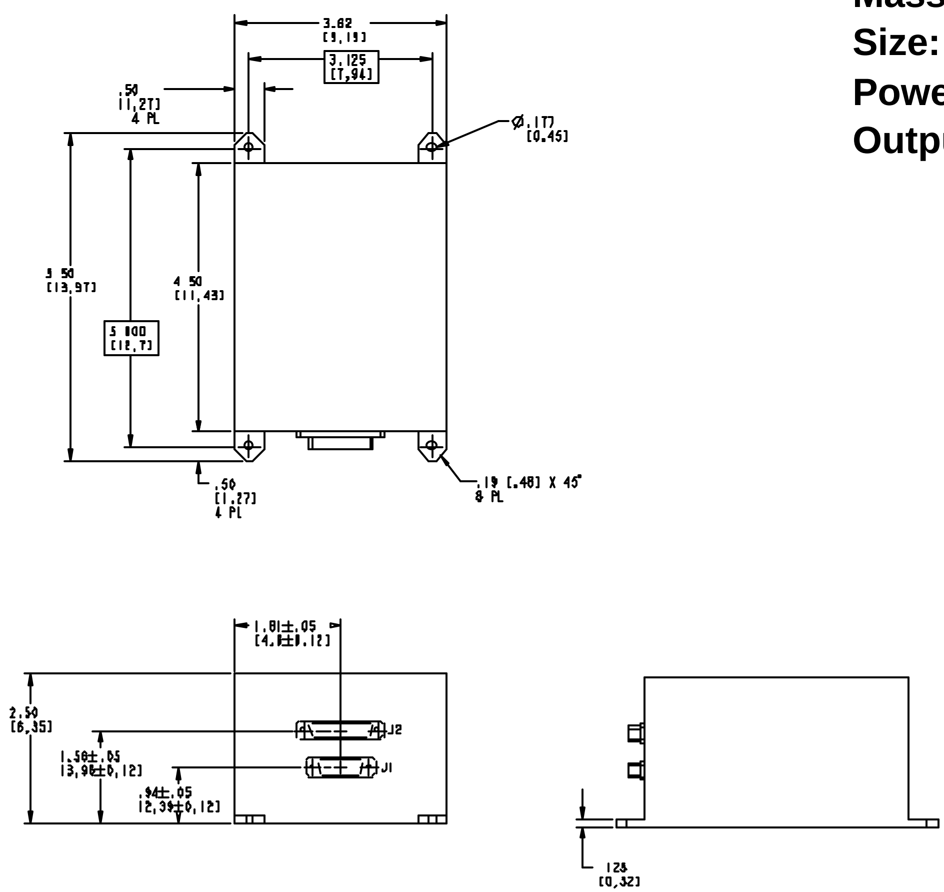
FINE SUN SENSOR ELECTRONICS

High Energy Solar Spectroscopic Imager (HESSI)



Supplier: **Adcole**

Supplier Part Number: Model 44000

Quantity: **1**

Mass: **0.64 kg**

Size: **14.0 x 9.2 x 6.4 cm**

Power: **2.8 W**

Output Signals:

- 10-Bit Serial Coarse Angle Data Per Axis
  - •Bit 1 - Axis Identification Bit
  - •Bits 2 - 4 - Zero Bits
  - •Bits 5 - 10 - 6-Bit Gray Coded Coarse Angle
- 4 Fine Bits Analog Fine Angle Data (sine & cosine)
- Axes Separated by 10 msec
- Bi-Level Sun Presence Indicator
- Analog State-of-Health Signal

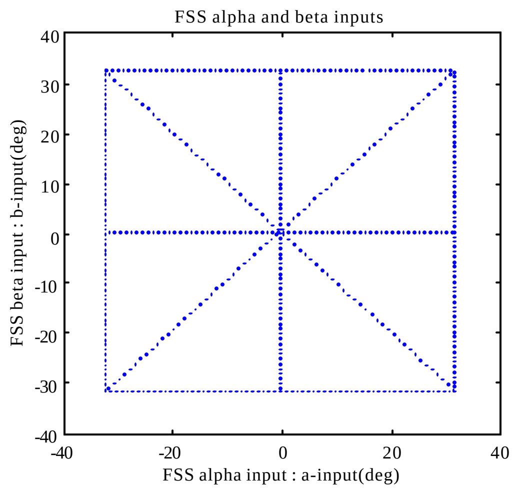
Sensor Data Processing

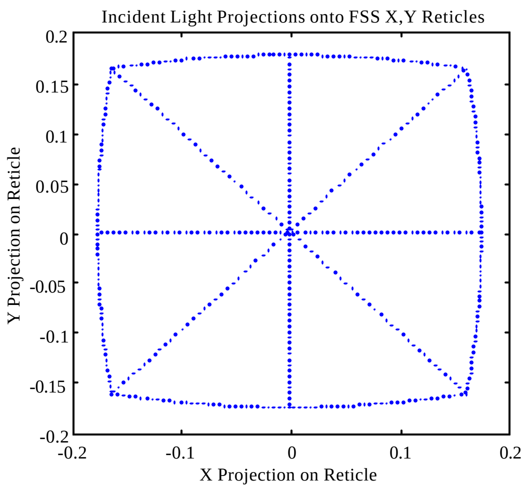
Inputs:

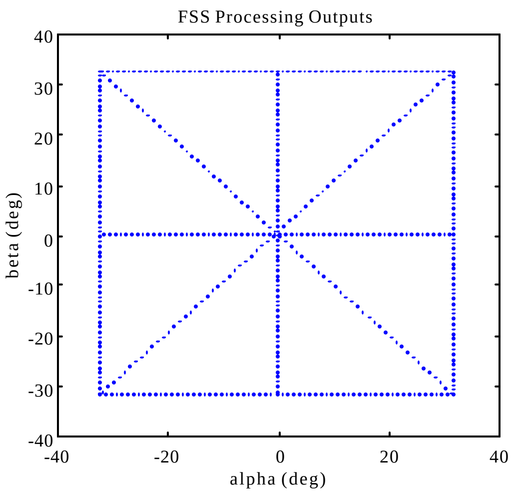
α and β Specified by an Input Pattern. Model Converts This Pattern to Interface Type Signals (Gray Coded Coarse Angle Data Plus sin and cos Fine Angle Data)

Outputs:

Processing Software Recovers the Original α and β Angles







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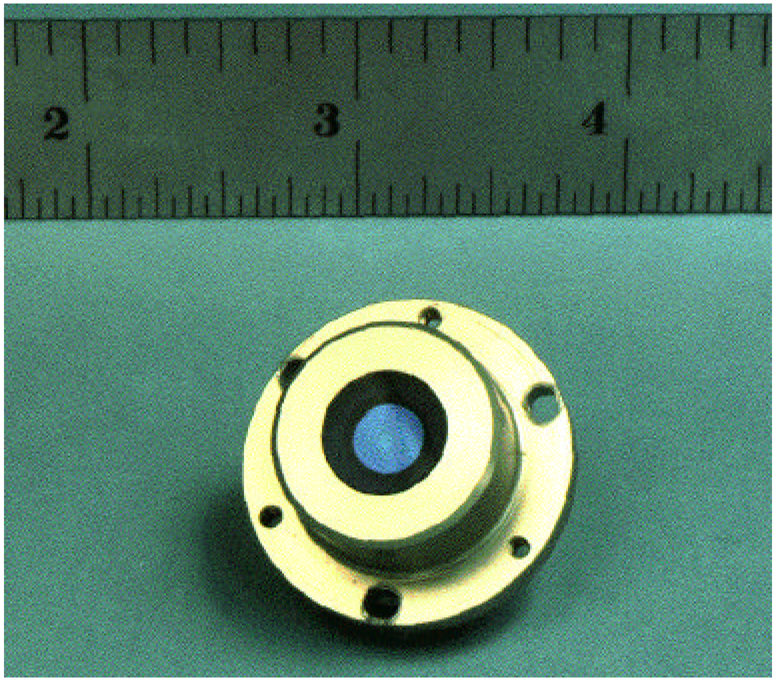
COARSE SUN SENSOR

High Energy Solar Spectroscopic Imager (HESSI)

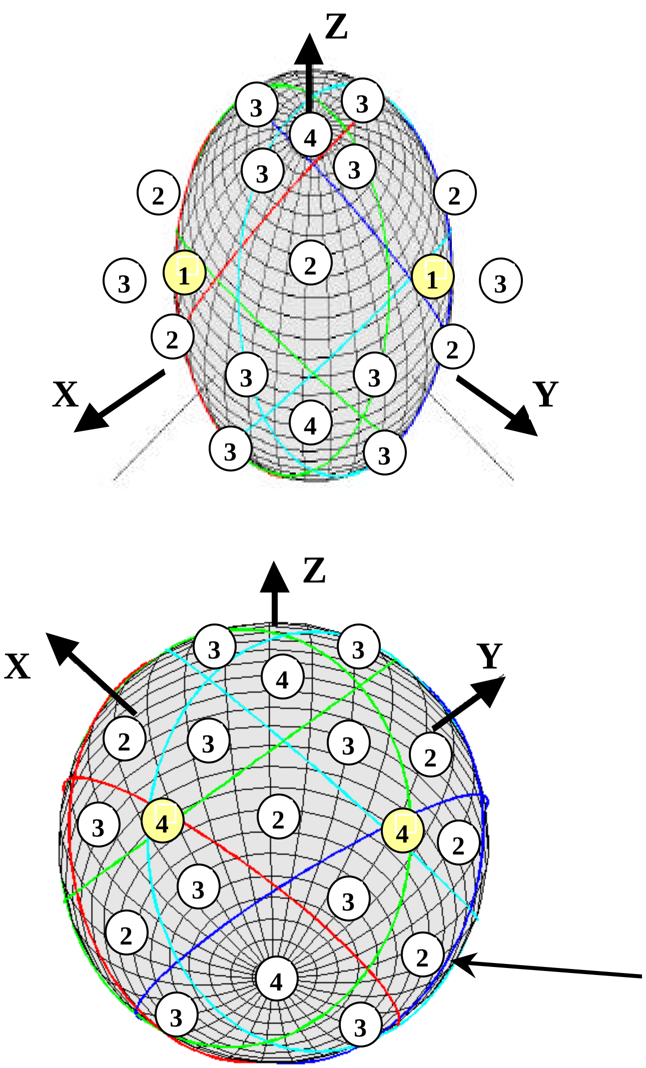


Supplier: **Adcole**
Supplier Part Number: Model 29450
Quantity: **8**
Mass: **0.011 kg**
Size: **2.8 dia x 1.2 cm**
Power: **n/a**
Measurand: **Cosine of Angle Between Cell Normal and Sun**
Performance:

- Operational Field of View: ± 80^o Cone
- Sun Presence Field of View: ± 90^o Cone
- Peak Cell Current Output: 1.317 milli-Amps

Interface: **Analog Output with a Two-Wire (+,-) Interface to PACI**

CSS COVERAGE



HESSI CSS Configuration:

- Nominal Solar Wing Positions are 5 deg Tilting Down
- Two Cells Per Wing with Cell Normal Pointing ±35 deg Relative to Wing Panel

Shown for Nominal Solar Wing Positions:

- Coverage for Each CSS Limited to ±70^o Cone Angle (34% of Full Sun) to Minimize Earth Albedo Effect
- Albedo Ranges from 27% (Summer) to 37% (Winter) at Peak Latitudes with an Orbit Average of 25%

Note:

- Four Small Regions with One Cell Coverage Caused by Solar Panel 5 deg Tilt Below Horizontal Plane

+X panel sensors (green)
-X panel sensors (blue)
+Y panel sensors (cyan)
-Y panel sensors (red)

Numbers represent sensor coverage in each region

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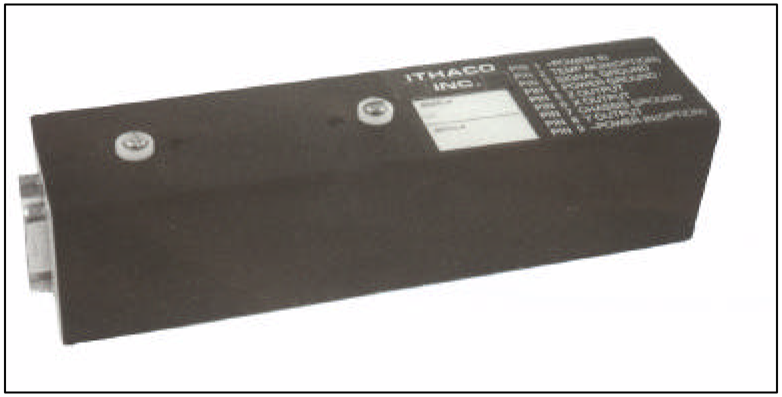
THREE-AXIS MAGNETOMETER

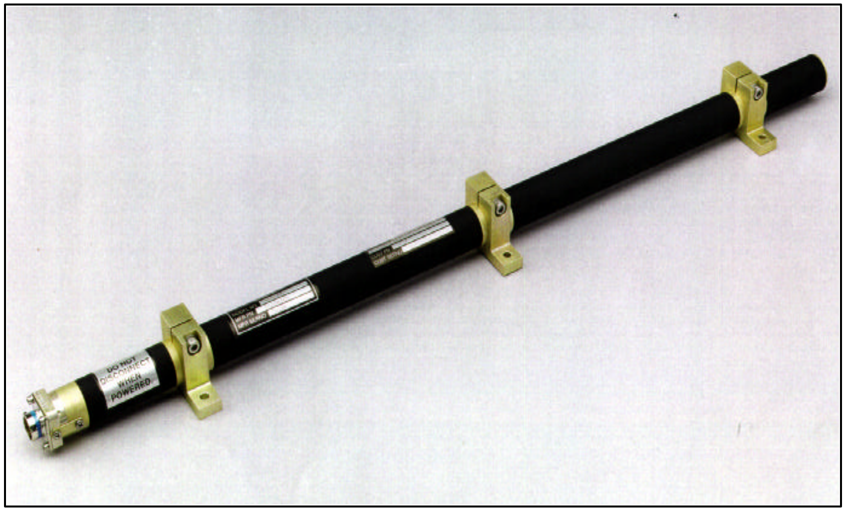
High Energy Solar Spectroscopic Imager (HESSI)



Supplier: Ithaco
Supplier Part Number: IM-103
Quantity: 1
Mass: 0.231 kg
Size: 15.5 x 4.2 x 3.8 cm
Power: 0.95 W
Magnetic Field Range: ± 600 mG in Three Axes
Measurement Accuracy: 4 mG (3s)
Scale Factor: 8.3333 V/G
Bandwidth: >100 Hz
Outputs:

- Three Voltages Proportional to B field
- One Voltage Proportional to Temperature

TORQUE RODS



Supplier: Ithaco
Supplier Part Number: TR60CFR
Quantity: 3
Mass: 1.7 kg
Size: 2.8 dia x 63.8 cm
Power (Standby): 0 W
Power (Orbit Average): 0.2 W
Power (Operating): 1.3 W
Linear moment output: 60 Amp-m^2
Scale factor: 0.25 Amp-m^2/milli-Amp
Coil resistance: 40 Ohms
Coil inductance: 2.5 Henries
Time constant: 62.5 msec

TQROD FIELD STRENGTH - ANALYTICAL RESULTS

For a Single 60 Am^2 torqrod, fully energized, the Field Strength is Shown.

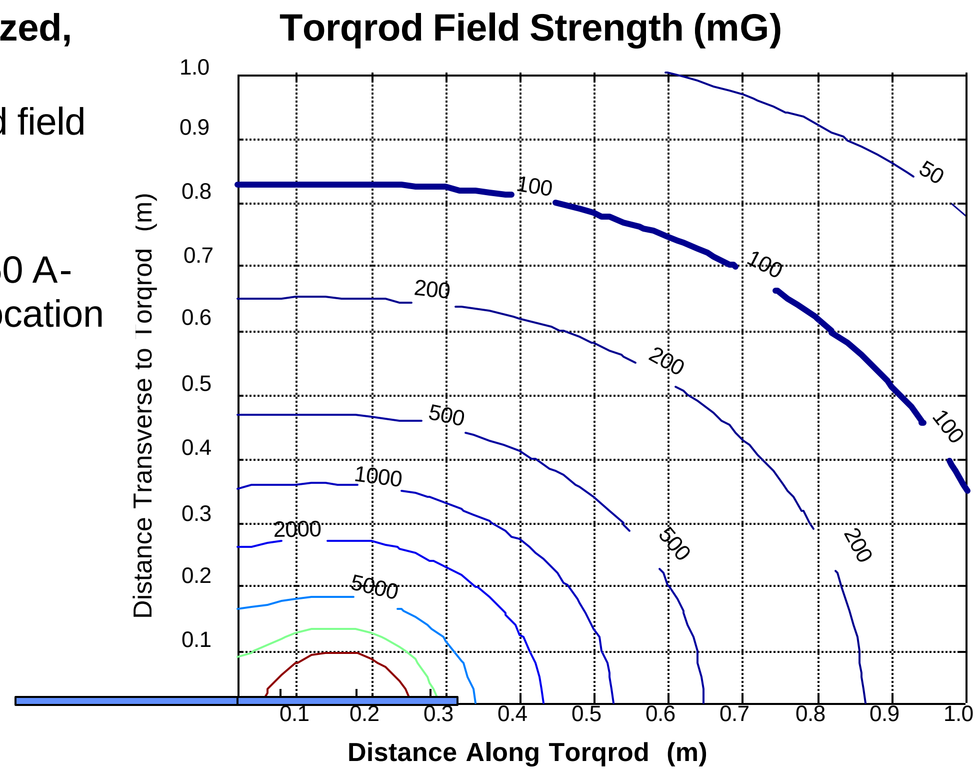
•Residual fields are ~1% of the last energized field

For HESSI Configuration

When Three Torque Rods are Energized to 60 A-m^2, the Magnetic Field Strength at MAG Location is Calculated as

$$\mathbf{B} = \begin{bmatrix} 41.6 \\ 21.2 \\ -18.3 \end{bmatrix} \text{milliGauss}$$

Torque Rod Compensation Matrix Limits This Torque Rod Magnetic Field Effect On the MAG Output.

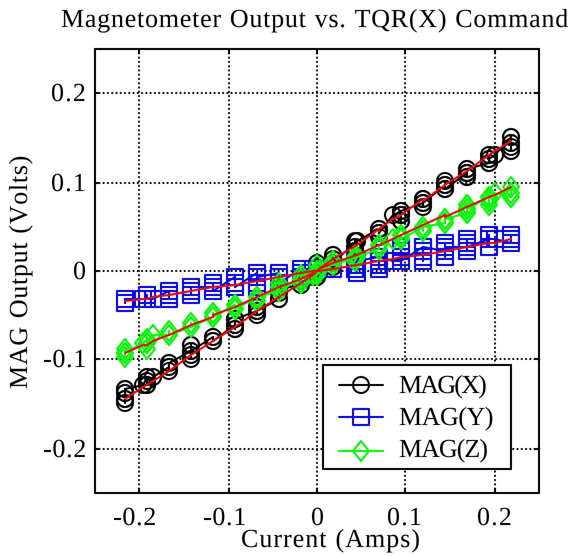


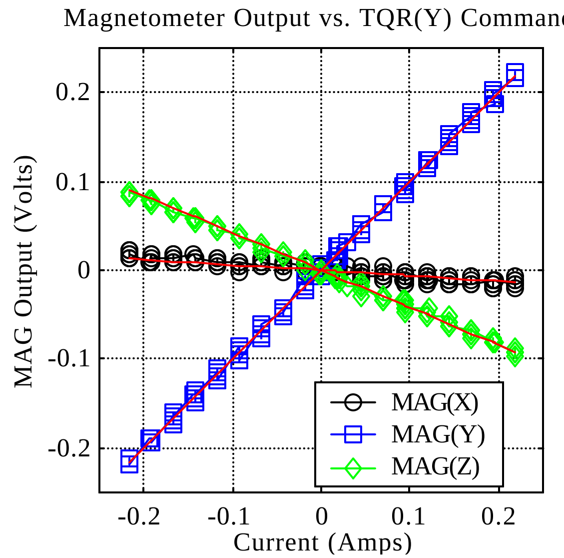
TORQUE ROD COMPENSATION MATRIX - FROM TESTING

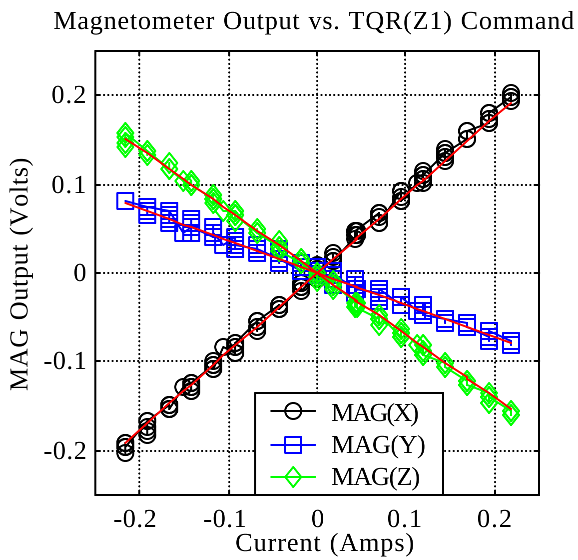
Torque Rod Compensation Matrix is Obtained by Applying A Series of Current to Each Torque Rod and Measuring Magnetometer Outputs.

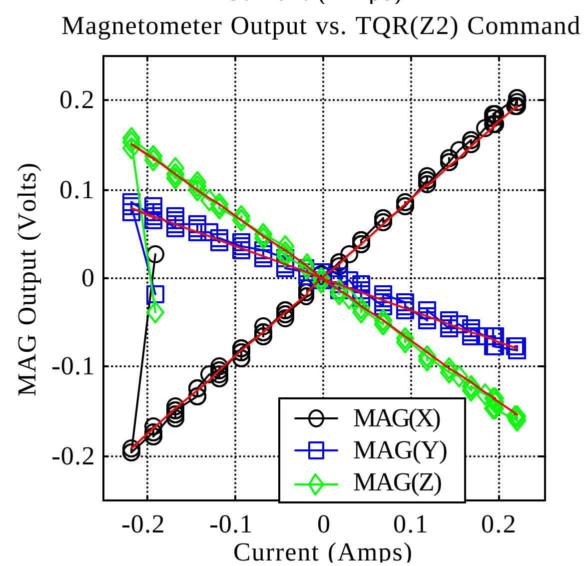
More Than Four Tests Performed so far Result in the Same Compensation Matrix Used in ACS FSW:

$$\begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} = \begin{bmatrix} 0.6713 & -0.0614 & 0.8819 \\ 0.1619 & 1.0262 & -0.3627 \\ 0.4246 & -0.4165 & -0.6973 \end{bmatrix} \begin{bmatrix} I_x \\ I_y \\ I_z \end{bmatrix}$$









ACS SOFTWARE

ACS Operation Modes

ACS FSW Diagrams

ACS Mode Selection

ACS FSW Input/Output Modules and Variables

Input Processing

Mode Control Logic and Hot Bench Performance Results

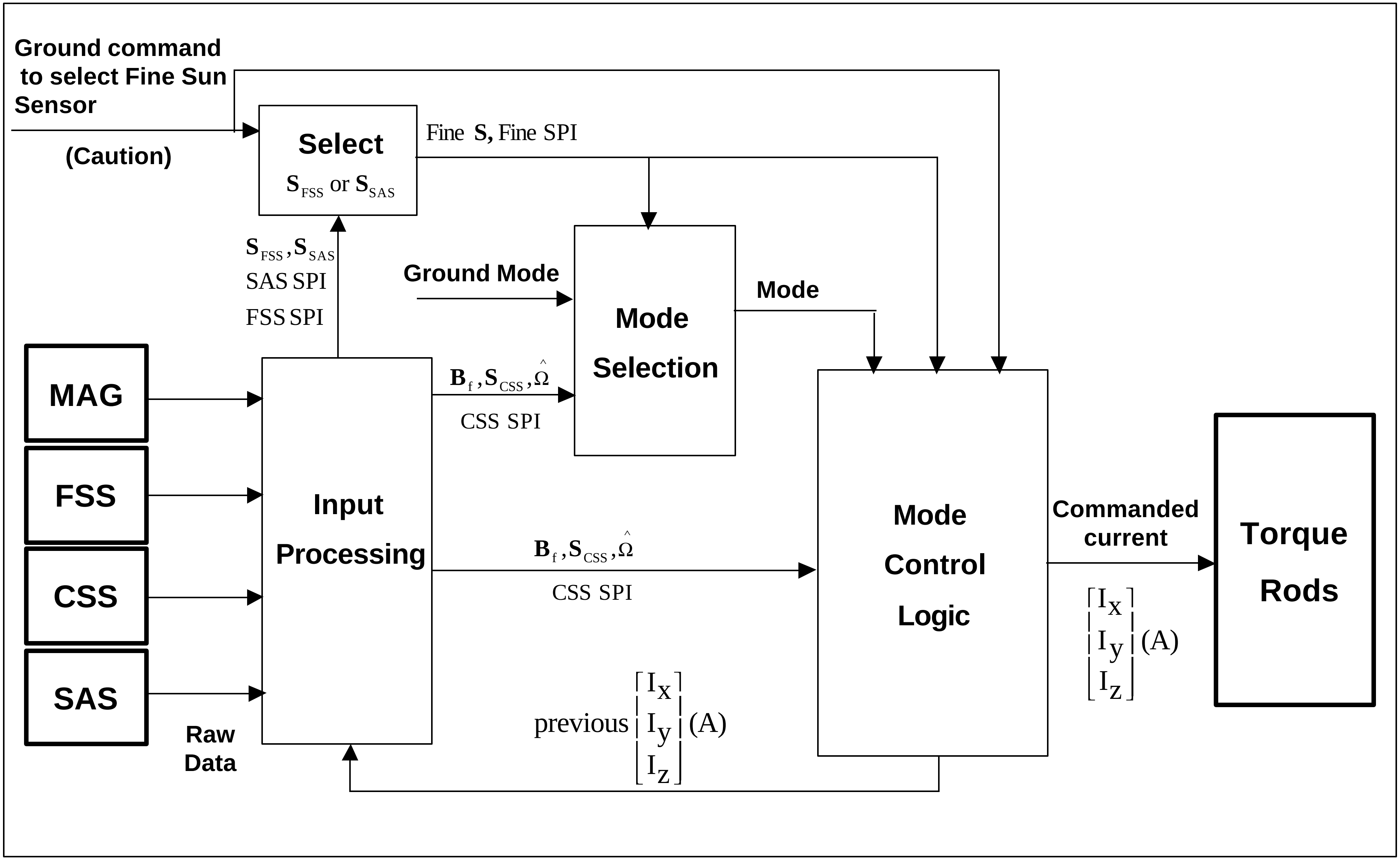
ACS Commands and Parameters

ACS OPERATING MODES

Operating Mode	Purpose	Sensor Used	Actuator Used
1. Acquisition	Damps Transverse Rates and Establishes a Desired Low Spin Rate	MAG	All Three TQRs
2. Precession	Points Spin Axis to Sun and Reduces Nutation	CSS, FSS, MAG	ZTQR
3. Normal	Maintains Sun-Pointing Orientation and Nominal Spin Rate; Encompasses Fine Precession, Nutation, and Spin Rate Control	FSS, MAG	All Three TQRs
4. Spin	Establishes Desired Spin Rate	FSS, MAG	All Three TQRs
5. Idle	Disables Control Until Ground Intervention		
Balance	Balances Spacecraft Using IADs to Obtain Pure Spin About Imager Axis	FSS, SAS	IAD

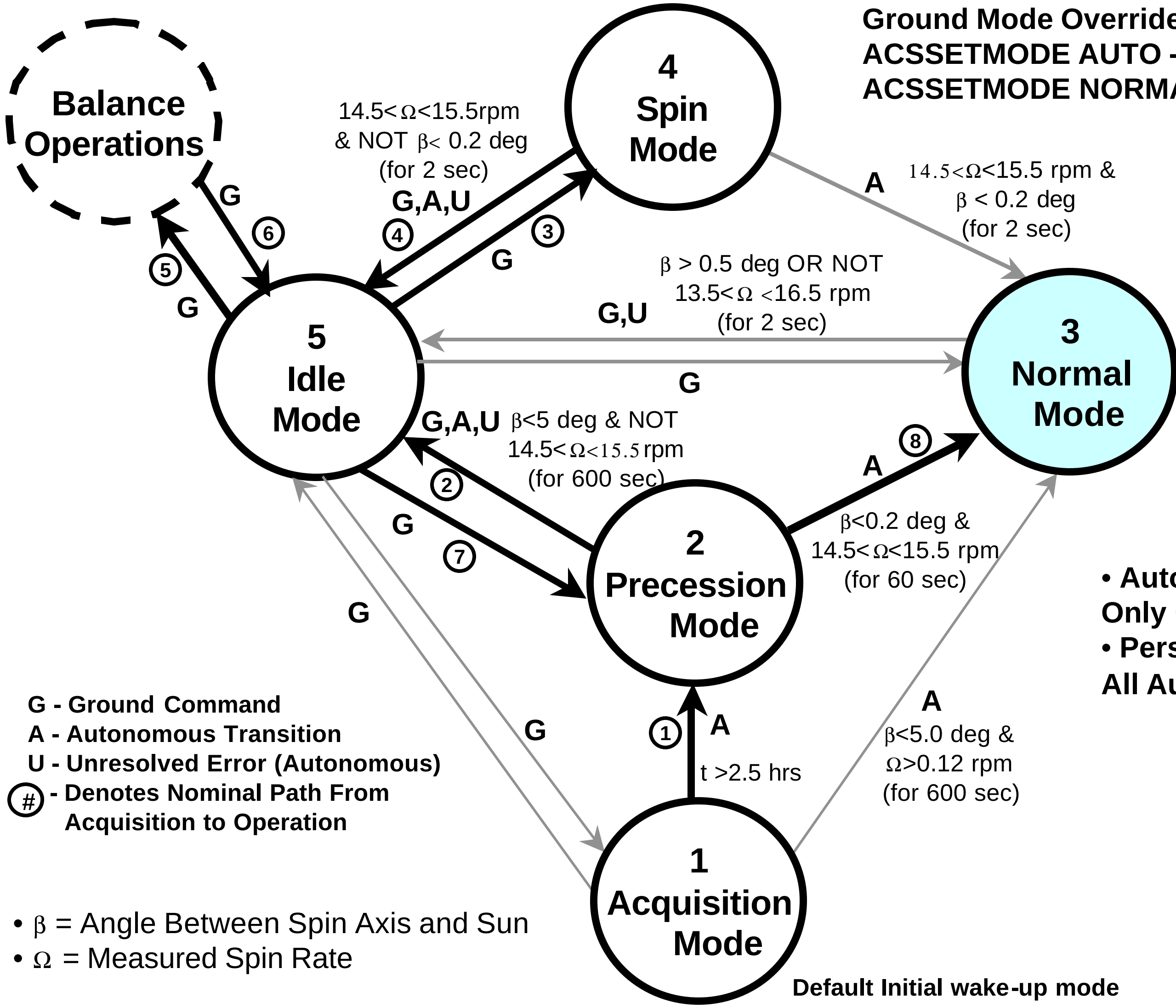
ACS FSW TOP LEVEL DIAGRAM

High Energy Solar Spectroscopic Imager (HESSI)



MODE SELECTION

Ground Mode Overrides Autonomously Selected Mode
ACSSETMODE AUTO - Allows Autonomous Mode Selection
ACSSETMODE NORMAL - Ground Forces to Normal Mode

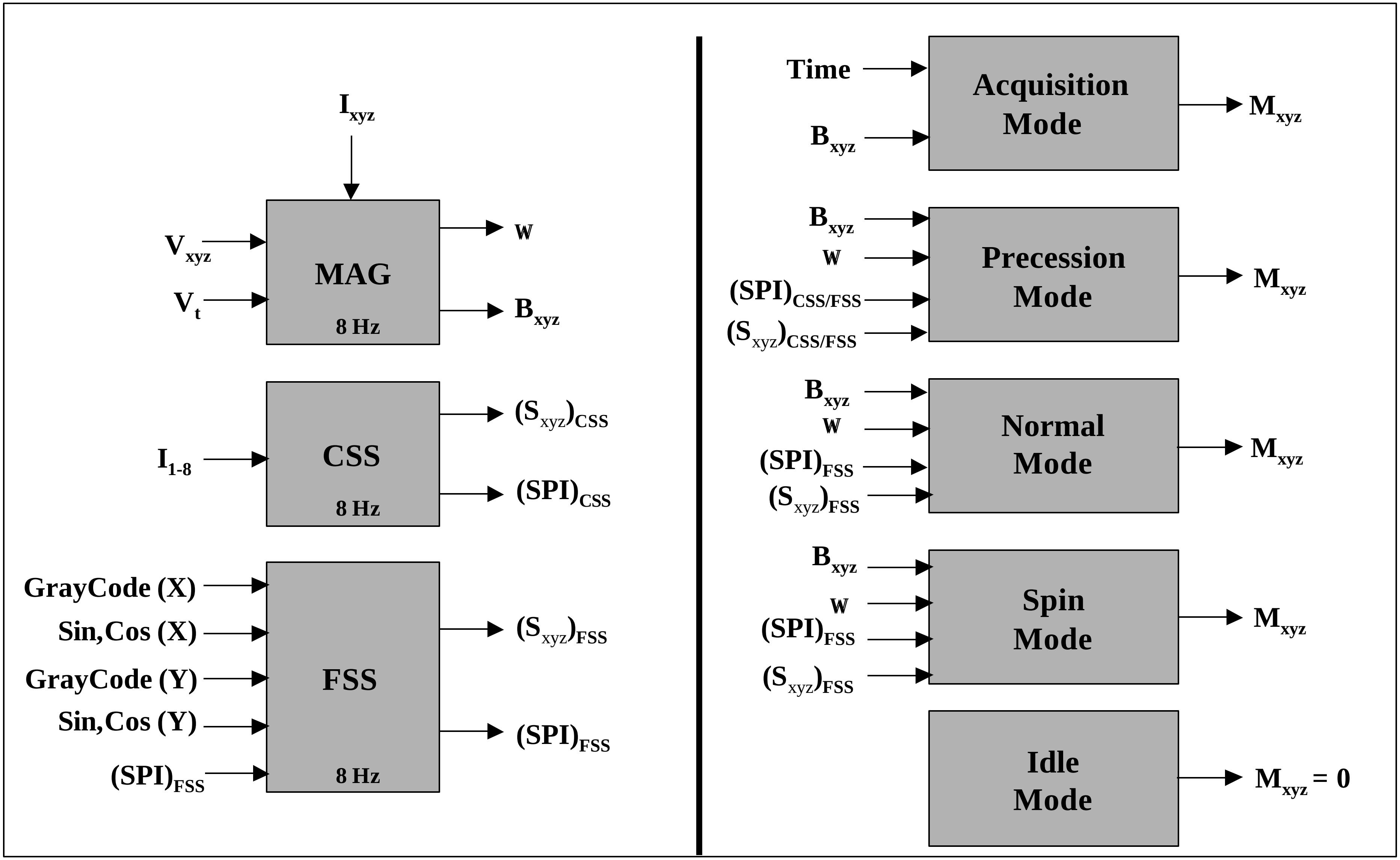


- **Autonomous Mode Transitions Can Only Occur When the Sun is in View**
- **Persistence Checks Are Performed for All Autonomous Mode Transitions**

G - Ground Command
A - Autonomous Transition
U - Unresolved Error (Autonomous)
(#) - Denotes Nominal Path From Acquisition to Operation

- β = Angle Between Spin Axis and Sun
- Ω = Measured Spin Rate

ACS FSW INPUT/OUTPUT MODULES



ACS FSW INPUT VARIABLES

ACS FSW Input Variables From CDHS - 38 Parameters

#	Variable	Type	Description	Range
1	MAG1	Float	MAG x output	± 5 volts
2	MAG2	Float	MAG y output	± 5 volts
3	MAG3	Float	MAG z output	± 5 volts
4	CSS1	Float	CSS 1 (CX11) output	0 – 0.0013 amps
5	CSS2	Float	CSS 2 (CX10) output	0 – 0.0013 amps
6	CSS3	Float	CSS 3 (CX01) output	0 – 0.0013 amps
7	CSS4	Float	CSS 4 (CX00) output	0 – 0.0013 amps
8	CSS5	Float	CSS 5 (CY11) output	0 – 0.0013 amps
9	CSS6	Float	CSS 6 (CY10) output	0 – 0.0013 amps
10	CSS7	Float	CSS 7 (CY01) output	0 – 0.0013 amps
11	CSS8	Float	CSS 8 (CY00) output	0 – 0.0013 amps
12	coarse_xg	Integer	FSS x-axis coarse data (Gray code)	0 – 64 (equivalent decimal)
13	coarse_yg	Integer	FSS y-axis coarse data (Gray code)	0 – 64 (equivalent decimal)
14	sinx	Float	FSS x-axis sin of angle	± 5 volts
15	cosx	Float	FSS x-axis cos of angle	± 5 volts
16	siny	Float	FSS y-axis sin of angle	± 5 volts
17	cosy	Float	FSS y-axis cos of angle	± 5 volts
18	FSS_SPI	Integer	FSS Sun Presence Indicator	0, 1
19	xcounts1	Integer	SAS x count 1	±128
20	xcounts2	Integer	SAS x count 2	±128
21	xcounts3	Integer	SAS x count 3	±128
22	xcounts4	Integer	SAS x count 4	±128
23	xcounts5	Integer	SAS x count 5	±128
24	xcounts6	Integer	SAS x count 6	±128
25	xcounts7	Integer	SAS x count 7	±128
26	xcounts8	Integer	SAS x count 8	±128
27	ycounts1	Integer	SAS y count 1	±128
28	ycounts2	Integer	SAS y count 2	±128
29	ycounts3	Integer	SAS y count 3	±128
30	ycounts4	Integer	SAS y count 4	±128
31	ycounts5	Integer	SAS y count 5	±128
32	ycounts6	Integer	SAS y count 6	±128
33	ycounts7	Integer	SAS y count 7	±128
34	ycounts8	Integer	SAS y count 8	±128
35	SAS_time	Float	SAS time tag	0 – 1e+8 seconds
36	SC_time	Float	Spacecraft time	0 – 1e+8 seconds
37	ground_mode	Integer	Ground command mode	1-5
38	Sun_sensor_toggle	Integer	Sun sensor toggle switch (0=FSS,1=CSS)	0,1

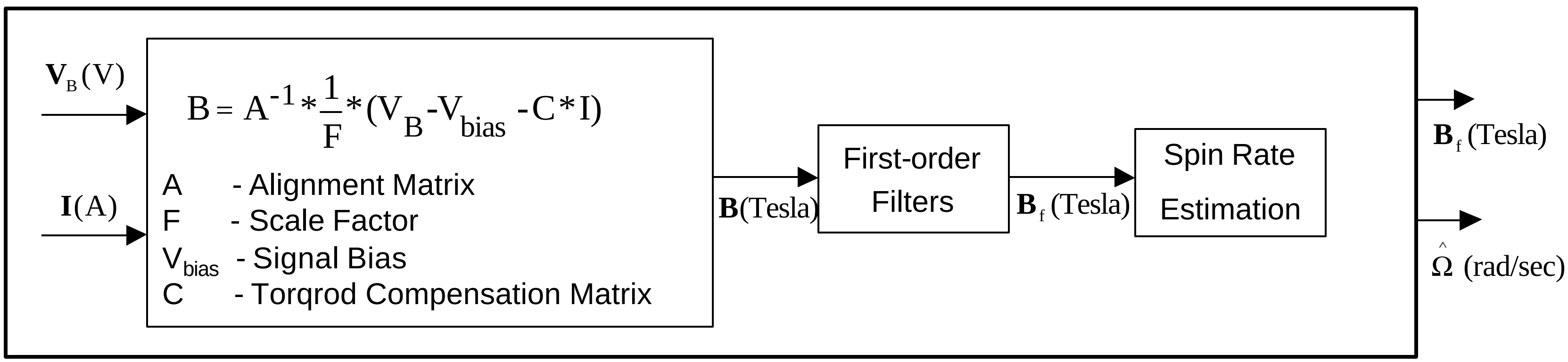
ACS FSW OUTPUT VARIABLES

ACS Telemetry Variables
- 22 Parameters
- 1 flag

#	Variable	Type	Description	Range
1	Ix	Float	Current to TQRX	± 0.25 amp
2	Iy	Float	Current to TQRY	± 0.25 amp
3	Iz	Float	Current to TQRZ	± 0.25 amp
4	spin_rate	Float	Spin rate estimate	± 2 rad/sec
5	mode	Integer	SC operation Mode	1 – 5
6	MAGx	Float	Magnetic field along x-axis	± 0.0001 tesla
7	MAGy	Float	Magnetic field along y-axis	± 0.0001 tesla
8	MAGz	Float	Magnetic field along z-axis	± 0.0001 tesla
9	CSSx	Float	CSS Sun vector along x-axis	± 1
10	CSSy	Float	CSS Sun vector along y-axis	± 1
11	CSSz	Float	CSS Sun vector along z-axis	± 1
12	FSSx	Float	FSS Sun vector along x-axis	± 1
13	FSSy	Float	FSS Sun vector along y-axis	± 1
14	FSSz	Float	FSS Sun vector along z-axis	± 1
15	CSS_SPI	Integer	CSS Sun Presence Indicator	0, 1
16	wx	Float	Transverse rate estimate along x-axis	± 0.1 rad/sec
17	wy	Float	Transverse rate estimate along y-axis	± 0.1 rad/sec
18	to_idle_flag	Integer	Flag describing transition to Idle Mode	0 – 5
19	SASx	Float	SAS Sun vector along x-axis	± 1
20	SASy	Float	SAS Sun vector along y-axis	± 1
21	SASz	Float	SAS Sun vector along z-axis	± 1
22	SAS_SPI	Integer	SAS Sun Presence Indicator	0, 1
23	Css_unusual_flag	Integer	CSS Unusual Setting Indicator	0, 1

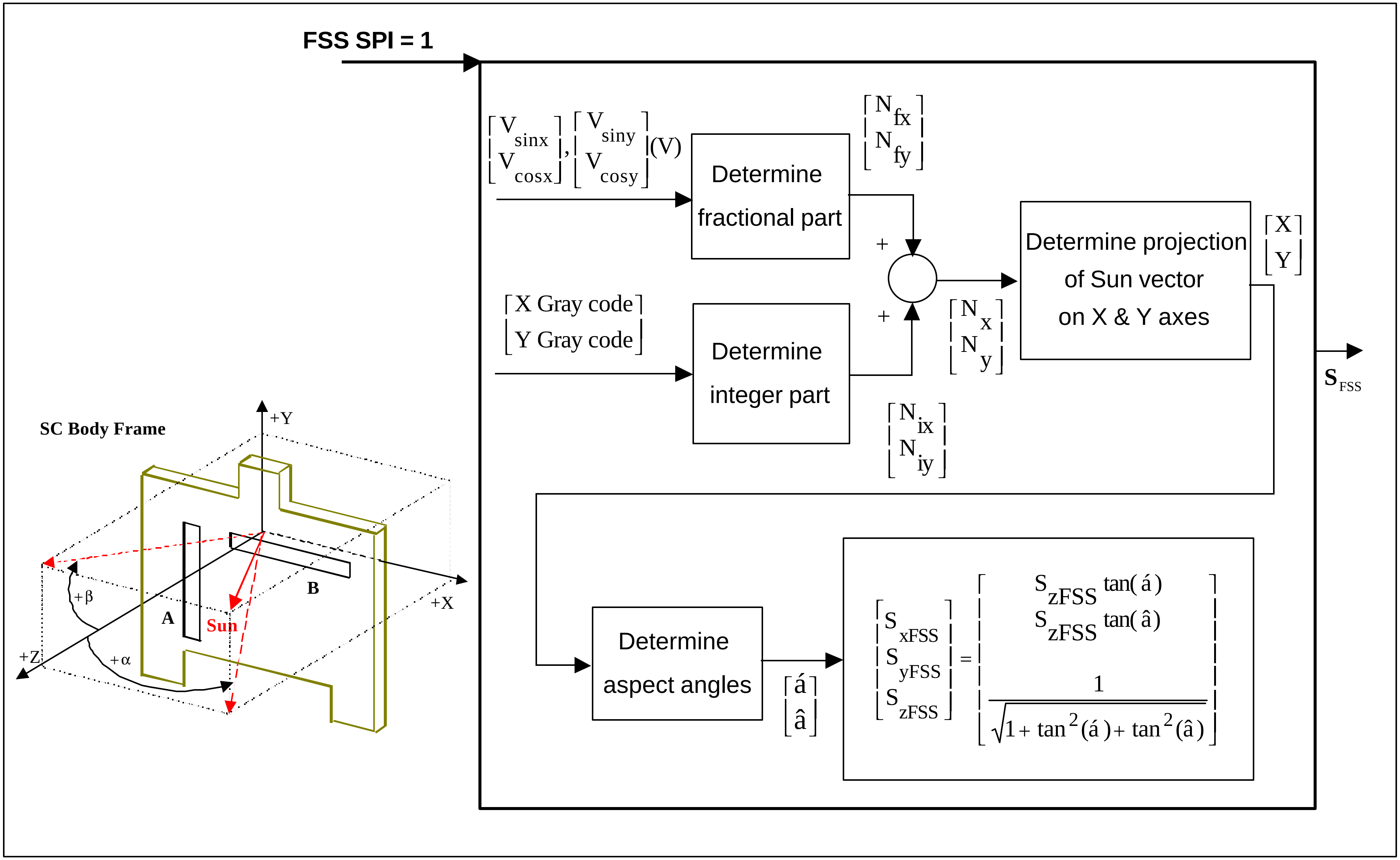
to_idle_flag	Description
0	No transition to Idle
1	Not used
2	Precession to Idle: $\beta < 5$ deg AND NOT $14.5 < \Omega < 15.5$ rpm
3	Normal to Idle: $\beta > 0.5$ deg
4	Normal to Idle: NOT $13.5 < \Omega < 16.5$ rpm
5	Spin to Idle: $14.5 < \Omega < 15.5$ rpm AND NOT $\beta < 0.2$ deg

INPUT PROCESSING - MAG PROCESSING

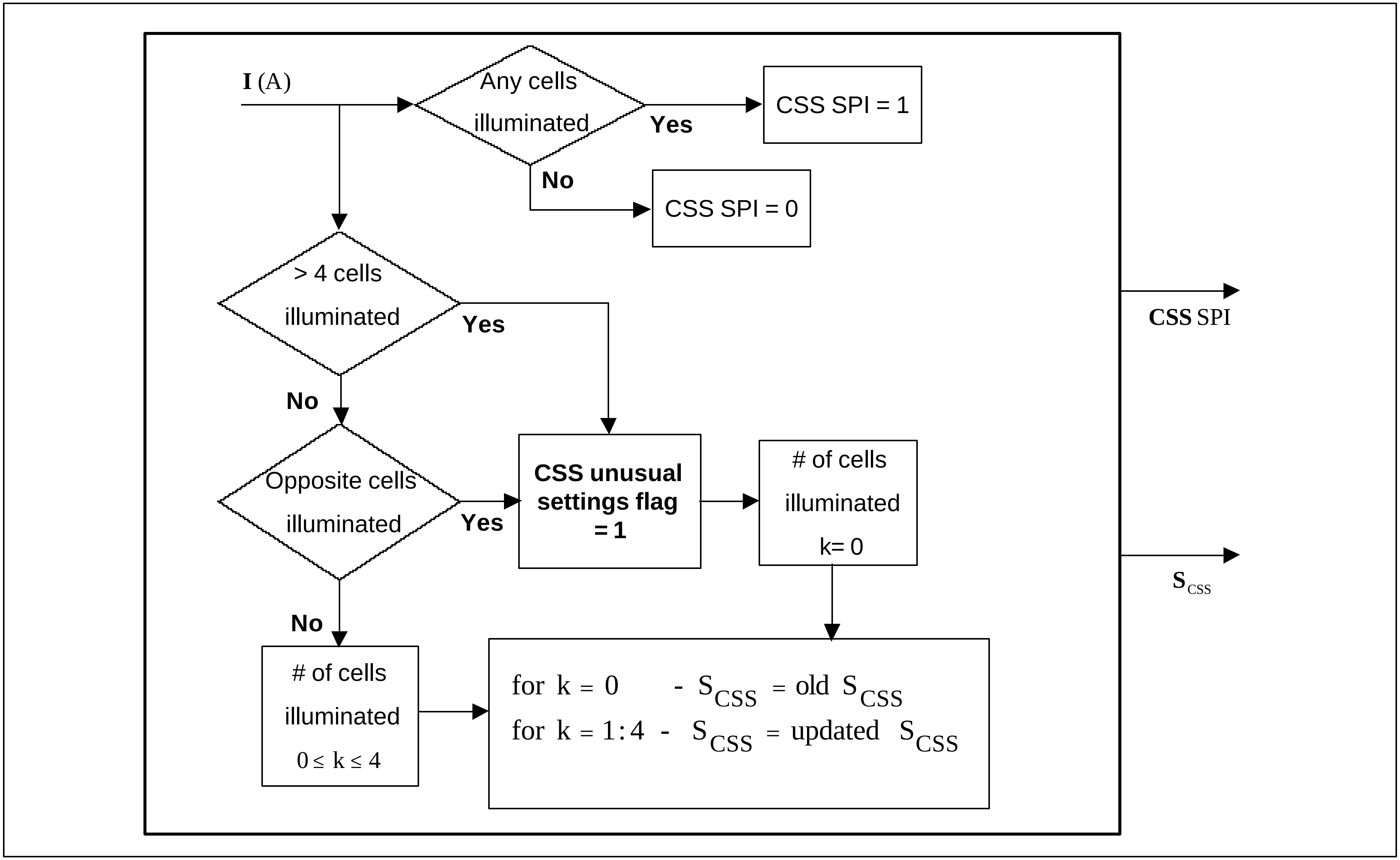


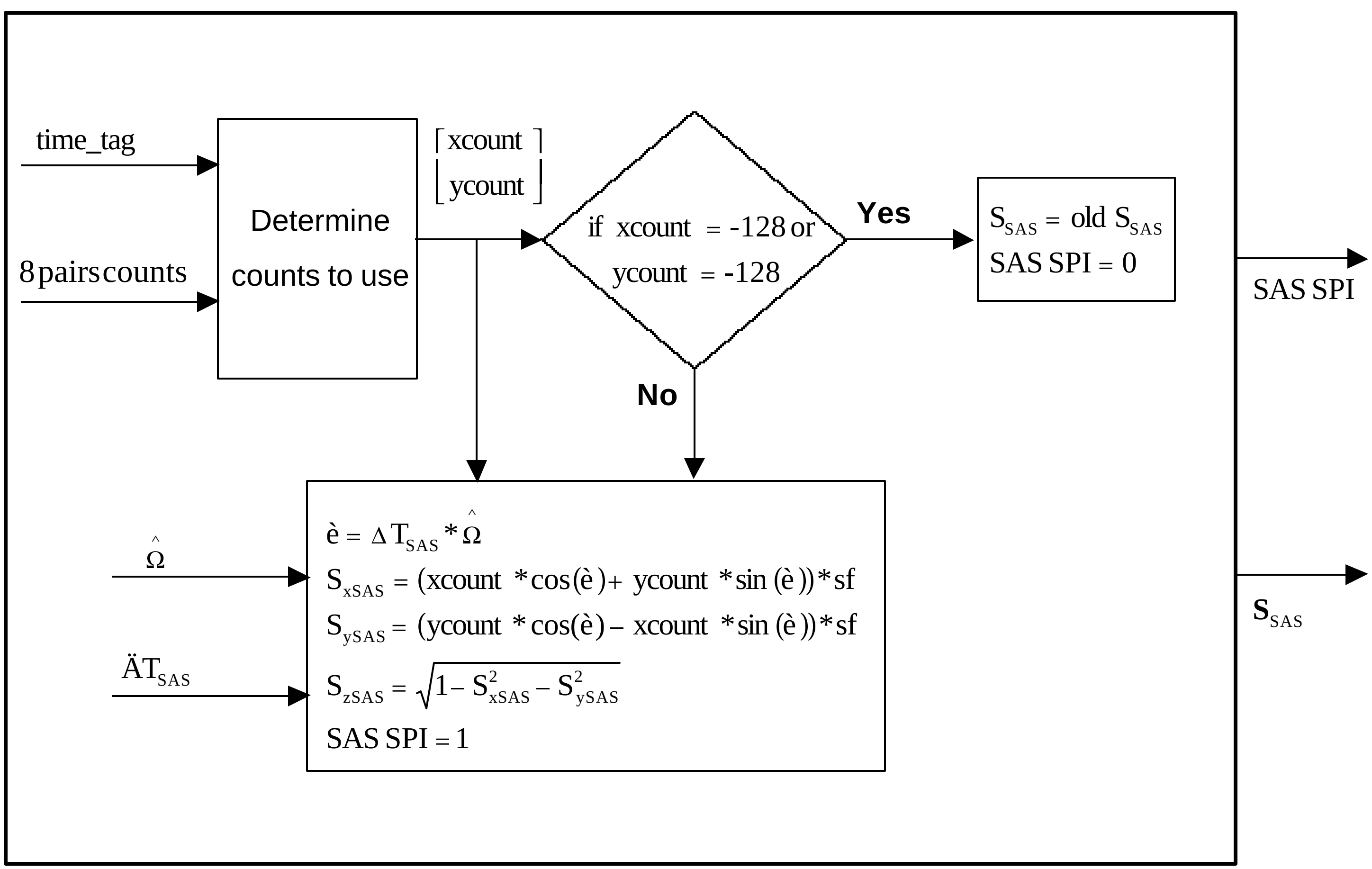
Note: 1 Gauss = 10^{-4} Tesla

INPUT PROCESSING - FSS PROCESSING

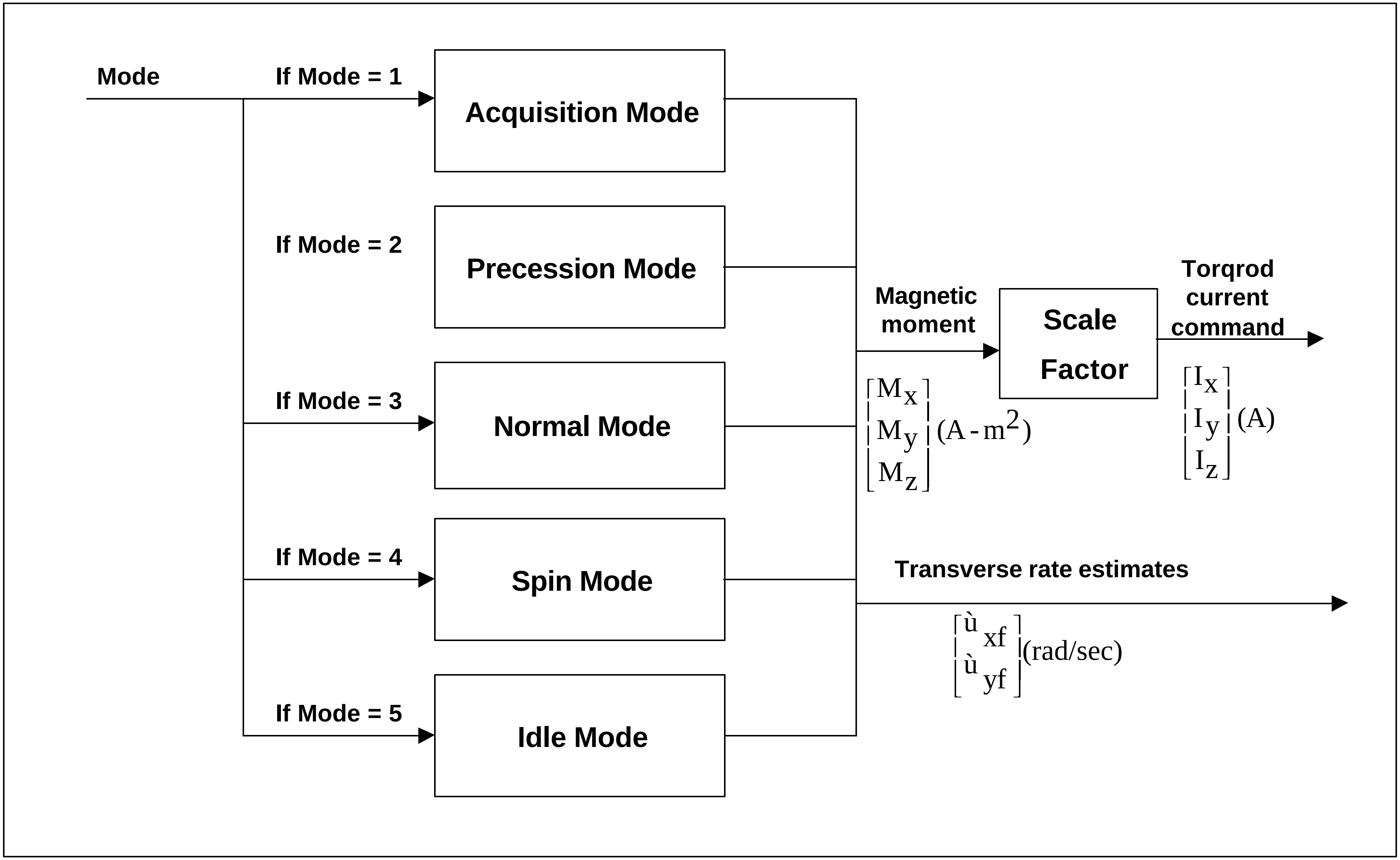


INPUT PROCESSING - CSS PROCESSING




time_tag
8 pairs counts
Determine counts to use
xcount
ycount
if xcount = -128 or ycount = -128
Yes
No
S_SAS = old S_SAS
SAS SPI = 0
SAS SPI
Ω̂
ÄT_SAS
è = ΔT_SAS * Ω̂
S_xSAS = (xcount * cos(è) + ycount * sin(è)) * sf
S_ySAS = (ycount * cos(è) – xcount * sin(è)) * sf
S_zSAS = √(1 – S²_xSAS – S²_ySAS)
SAS SPI = 1
S_SAS

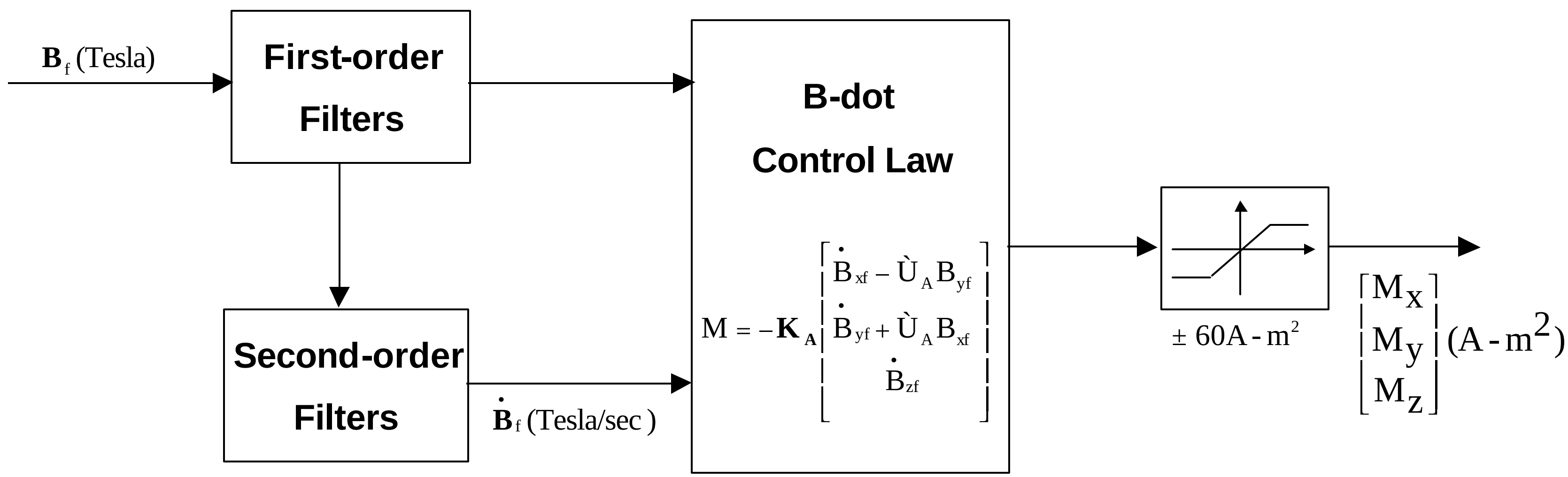
MODE CONTROL LOGIC - TOP LEVEL



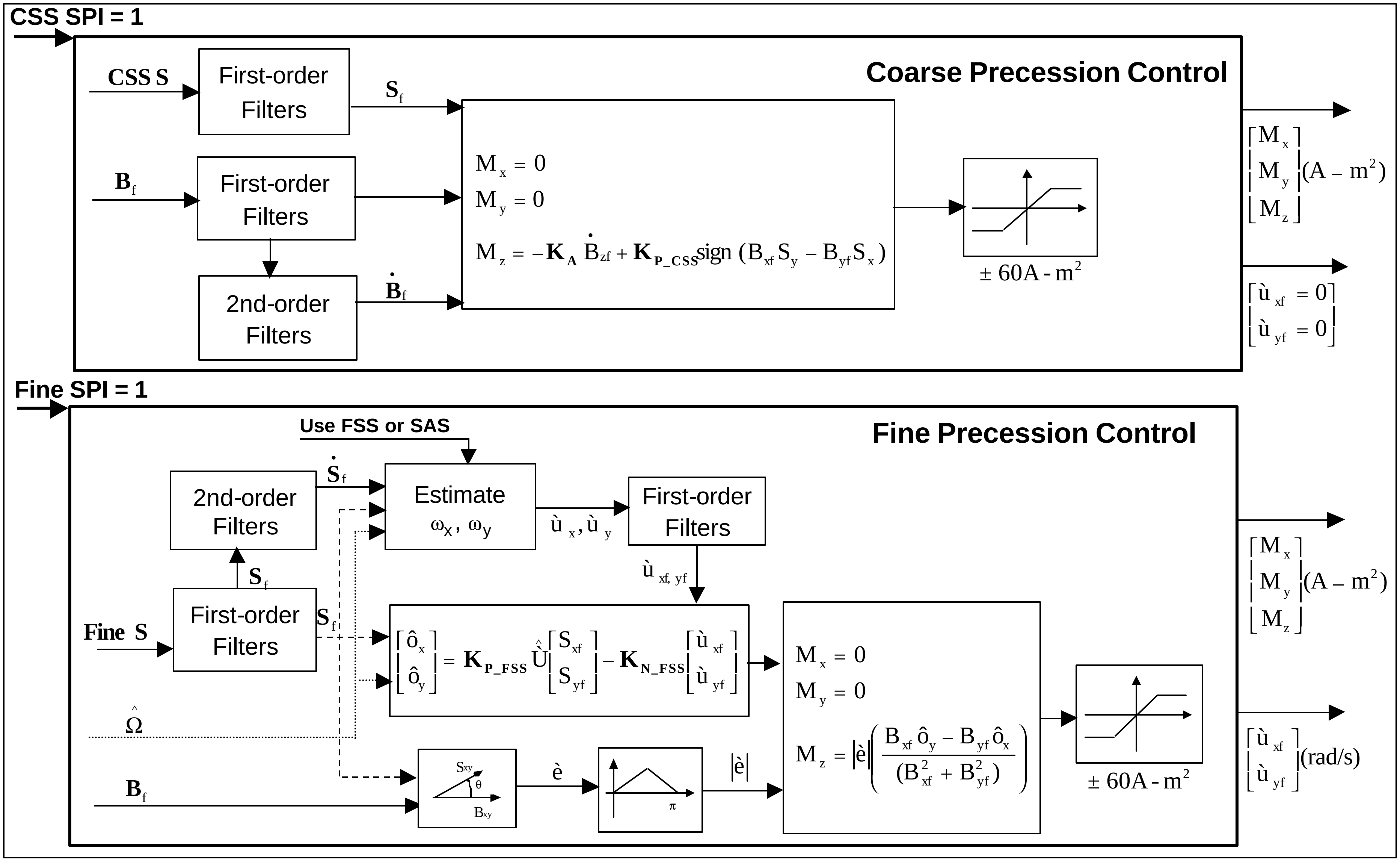
SPECTRUMASTRO

MODE CONTROL LOGIC - ACQUISITION MODE

High Energy Solar Spectroscopic Imager (HESSI)



MODE CONTROL LOGIC - PRECESSION MODE



HOT BENCH TEST RESULTS FOR NOMINAL INITIAL ACQUISITION

SPECTRUMASTRO

High Energy Solar Spectroscopic Imager (HESSI)

Nominal Initial Conditions:

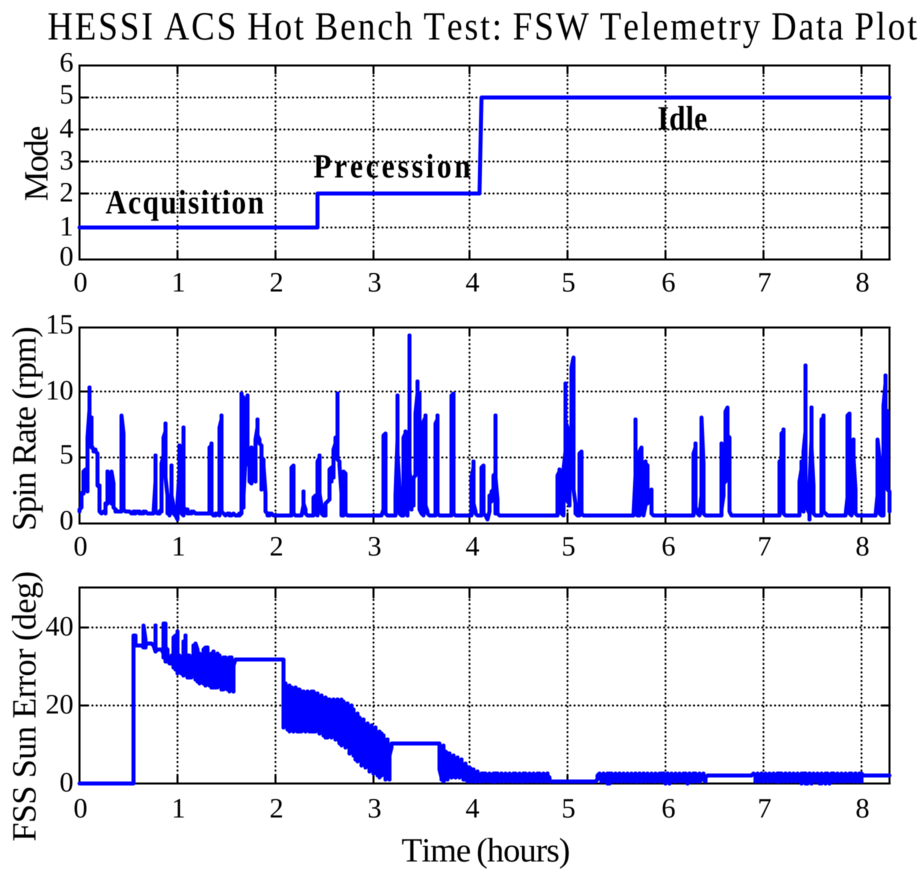
- At Tip-off:
  - Body Rates (4, 4, 17) deg/sec
  - Momentum Vector 5 deg from Sun
- After Solar Array Deployment:
  - Body Rates (2.6, 2.6, 3.2) deg/sec
  - Momentum Vector 7 deg from Sun

Event Sequence:

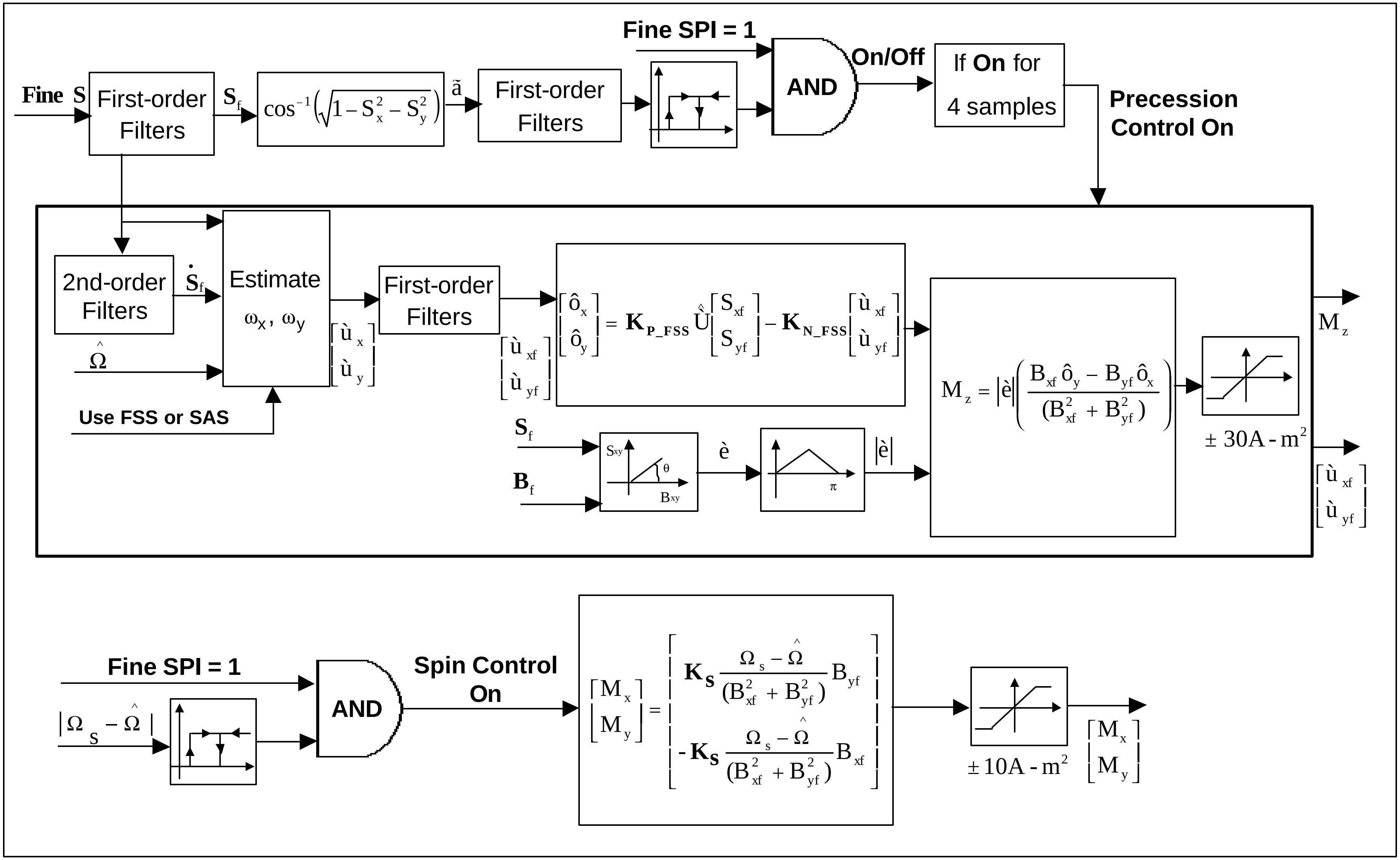
- Immediately Following CPU Boot-Up ACS Begins Operation in Acquisition Mode
- Torque Rods Inactive for Initial 10 minutes to Allow for Proper Solar Array Deployment
- After 2.5 Hours, ACS Transitions to Precession Mode
- If Sun Error < 5 deg and Spin Rate > 0.12rpm within 2.5 hours, ACS will Transitions to Normal Mode then to Idle Mode (see Mode Transition Logic)
- Once the Sun is within 5 deg of Z-axis, ACS Transitions to Idle Mode.

Note:

- Assume Eclipses Occur during the First 30 Minutes of Each 97 Min Orbit. Torque Rods are Disabled while in Eclipse
- Spin Rate Estimation is Poor for Low Spin Rates



MODE CONTROL LOGIC - NORMAL MODE



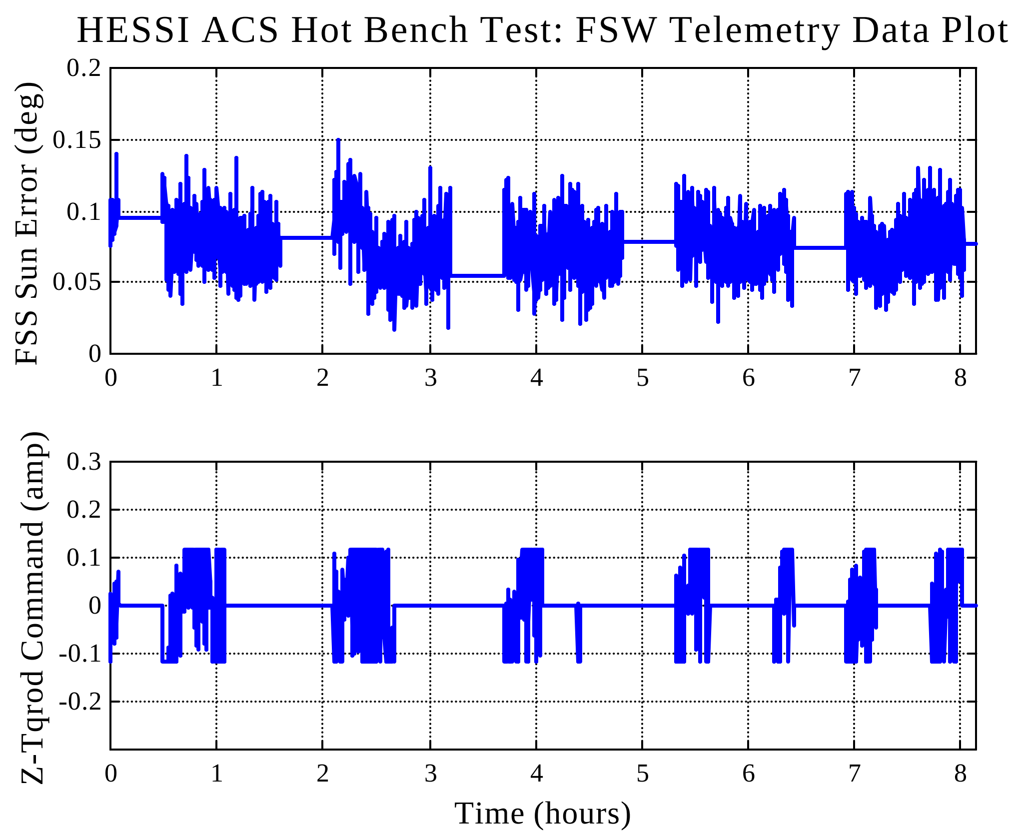
SPECTRUMASTRO

HOT BENCH TEST RESULTS FOR NORMAL MODE - LOW DUTY CYCLE

High Energy Solar Spectroscopic Imager (HESSI)

Normal Mission Mode Performance:

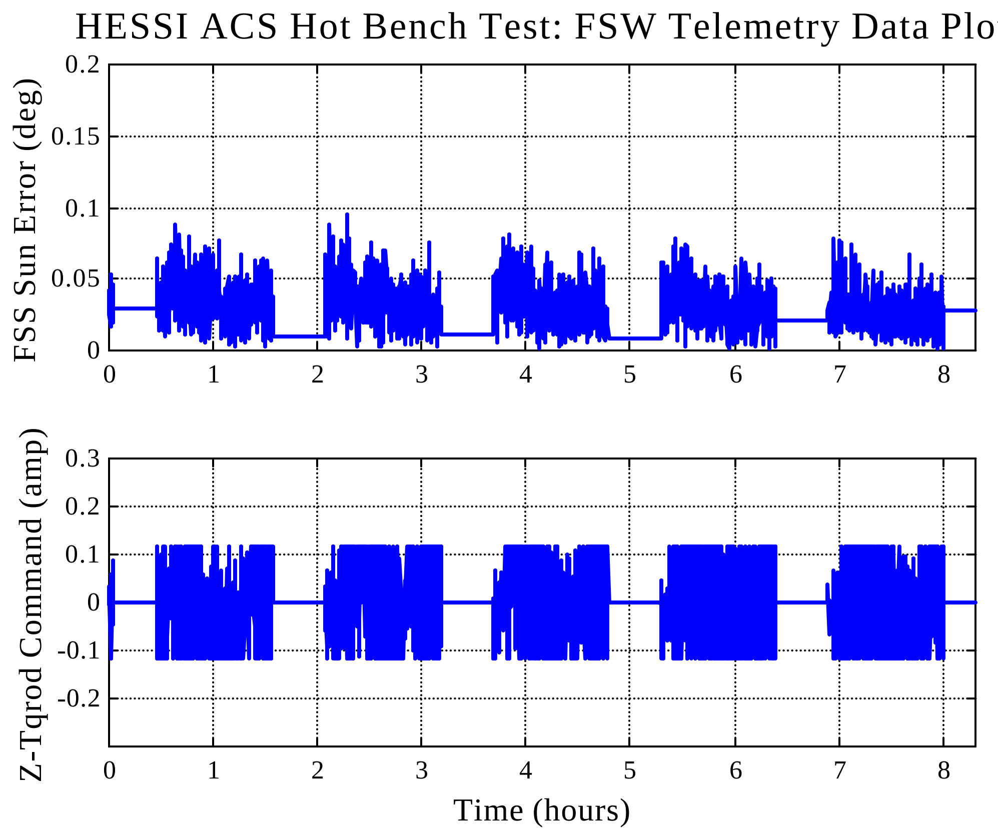
- Low Torqrod Duty Cycle
  - Min Hysteresis Bound 0.05 deg
  - Max Hysteresis Bounds 0.1 deg
- Sun Error <0.15 deg
- 50% Z-Torque Rod Duty-Cycle During Sun Viewing



HOT BENCH TEST RESULTS FOR NORMAL MODE - HIGH DUTY CYCLE

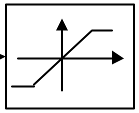
Normal Mission Mode Performance:

- High Torqrod Duty Cycle
  - Min Hysteresis Bound 0.0 deg
  - Max Hysteresis Bounds 0.1 deg
- Sun Pointing Error is Reduced by Half
- 100% Z-Torque Rod Duty-Cycle During Sun Viewing



MODE CONTROL LOGIC - SPIN MODE

$$\begin{bmatrix} M_x \\ M_y \end{bmatrix} = \begin{bmatrix} K_S \dfrac{\Omega_s - \hat{\Omega}}{(B_{xf}^2 + B_{yf}^2)} B_{yf} \\ -K_S \dfrac{\Omega_s - \hat{\Omega}}{(B_{xf}^2 + B_{yf}^2)} B_{xf} \end{bmatrix}$$



$\pm\, 60 A - m^2$

M_z= Fine Precession Control as in Precession Mode

$$\begin{bmatrix} M_x \\ M_y \\ M_z \end{bmatrix}$$

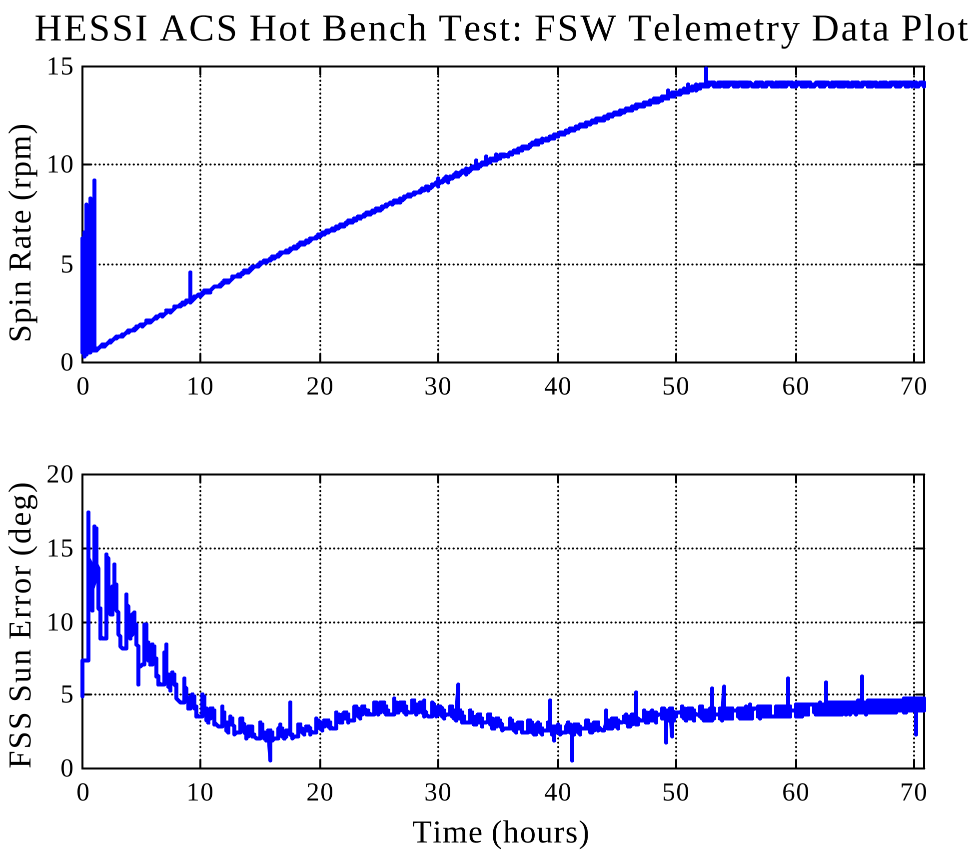
HOT BENCH TEST RESULTS FOR SPIN MODE

Spin Up Performance:

- SC Spins Up from 0.25 rpm to 14.5 rpm in 50 Hours
- Sun Error is Controlled During Spin-Up

Comments:

- Several Smaller Steps of Spin-Up may Be Desirable During On-Orbit Operation to Reduce the Peak Sun Error



MODE CONTROL LOGIC - IDLE MODE

$$\begin{bmatrix} M_x \\ M_y \\ M_z \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} M_x \\ M_y \\ M_z \end{bmatrix}$$

ACS COMMANDS

ACS FSW Related Commands:

ACSSETMODE AUTO - Allows Autonomous Mode Selection
ACQUISITION - To Damp Out Transverse Rates and Establish Desired Low Spin Rate
PRECESSION - To Establish Sun Pointing Orientation
NORMAL - To Maintain Nominal Spin Rate and Sun Pointing
SPIN - To Establish Desired Spin Rate
IDLE - To Disable Control Until Ground Intervention

ACSSUNSENSOR FSS - Select FSS as the Fine Sun Sensor for ACS Controls
SAS - Select SAS as the Fine Sun Sensor for ACS Controls
Strongly Recommended: Consult Spectrum ACS Engineers Prior to Selecting SAS for ACS Control.

SPECTRUMASTRO

ACS COMMAND PARAMETERS 1-30

High Energy Solar Spectroscopic Imager (HESSI)

Present Default ACS Parameter Table
- 153 Parameters

Note: The Default Values of Some Parameters may Need to be Changed.

Torqrod compensation matrix components (parameters 8–16)

ACS controls parameters (parameters 17–30)

#	Parameter	Type	Default Value	Description	Range
1	mode_command	Integer	1	Initial Mode setting	1-5
2	css_thresh	Float	0.0005 amp	CSS threshold	0 – 0.001
3	fss_bias_x	Float	0	FSS bias along x-axis	± 1
4	fss_bias_y	Float	0	FSS bias along y-axis	± 1
5	mag_bias_x	Float	0 tesla	MAG bias along x-axis	± 0.0001
6	mag_bias_y	Float	0 tesla	MAG bias along y-axis	± 0.0001
7	sas_delay	Float	2.5 sec	SAS data delay	0 – 5.0
8	tqr_comp11	Float	0.671259 volts/amp	Torqrod compensation matrix component	± 20
9	tqr_comp12	Float	-0.06135 volts/amp	Torqrod compensation matrix component	± 20
10	tqr_comp13	Float	0.881908 volts/amp	Torqrod compensation matrix component	± 20
11	tqr_comp21	Float	0.161945 volts/amp	Torqrod compensation matrix component	± 20
12	tqr_comp22	Float	1.026166 volts/amp	Torqrod compensation matrix component	± 20
13	tqr_comp23	Float	-0.36266 volts/amp	Torqrod compensation matrix component	± 20
14	tqr_comp31	Float	0.424606 volts/amp	Torqrod compensation matrix component	± 20
15	tqr_comp32	Float	-0.41646 volts/amp	Torqrod compensation matrix component	± 20
16	tqr_comp33	Float	-0.69728 volts/amp	Torqrod compensation matrix component	± 20
17	tqr_sat_high	Float	60 amp-m^2	Torqrod high saturation level	0 – 100
18	tqr_sat_point_low	Float	30 amp-m^2	Torqrod low saturation level in pointing	0 – 100
19	tqr_sat_spin_low	Float	10 amp-m^2	Torqrod low saturation level in spin	0 – 100
20	acq_spin_com	Float	0.035 rad/sec	Commanded spin rate during Acquisition	0 – 0.1
21	norm_spin_com	Float	1.57 rad/sec	Commanded spin rate during Normal operation	0 – 2
22	acq_gain	Double	1e+11 amp-m^2-sec/tesla	Acquisition control gain	0 – 1e+11
23	coarse_prec_gain	Float	1e+4 amp-m^2	Coarse Precession control gain	0 – 1e+6
24	fine_prec_gain	Float	1.5 N-m-sec	Fine Precession control gain	0 – 5
25	fine_nut_gain	Float	4.5 N-m-sec	Fine nutation control gain	0 – 20
26	spin_gain	Float	1 amp-m^2-sec/tesla	Spin control gain	0 – 10
27	point_high	Float	0.001745 rad	High setting for pointing hysteresis logic	0 – 0.004
28	point_low	Float	0.0008725 rad	Low setting for pointing hysteresis logic	0 – 0.002
29	point_check*	Integer	1	Initial state of pointing hysteresis logic	0, 1
30	delta_spin_high	Float	0.1 rad/sec	High setting for spin hysteresis logic	0 – 0.4

ACS COMMAND PARAMETERS 31-60

Group	#	Parameter	Type	Value	Description	Range
ACS controls parameters	31	delta_spin_low	Float	0.05 rad/sec	Low setting for spin hysteresis logic	0 – 0.2
	32	spin_check*	Integer	1	Initial state of spin hysteresis logic	0, 1
	33	point_acq2norm	Float	0.0873 rad	Transition pointing error from Acquisition to Normal	0 – 0.2
	34	point_prec2norm	Float	0.0035 rad	Transition pointing error from Precession to Normal	0 – 0.01
	35	point_norm2idle	Float	0.0088 rad	Transition pointing error from Normal to Idle	0 – 0.01
	36	point_spin2norm	Float	0.0035 rad	Transition pointing error from Spin to Normal	0 – 0.01
	37	rate_acq2norm	Float	0.0126 rad/sec	Transition rate from Acquisition to Normal	0 – 0.1
	38	drate_prec2norm	Float	0.05 rad/sec	Transition rate error from Precession to Normal	0 – 0.5
	39	drate_norm2idle	Float	0.15 rad/sec	Transition rate error from Normal to Idle	0 – 0.5
	40	drate_spin2norm	Float	0.05 rad/sec	Transition rate error from Spin to Normal	0 – 0.5
Persistence check parameters	41	time_acq2norm	Float	600 sec	Transition time from Acquisition to Normal	0 – 1800
	42	time_acq2prec	Float	9000 sec	Transition time from Acquisition to Precession	0 – 18000
	43	time_prec2norm	Float	60	Transition time from Precession to Normal	0 – 600
	44	time_prec2idle	Float	600 sec	Transition time from Precession to Idle	0 – 1800
	45	time_norm2idle_ang	Float	2 sec	Transition time from Normal to Idle due to pointing error	0 – 600
	46	time_norm2idle_rate	Float	2 sec	Transition time from Normal to Idle due to rate error	0 – 600
	47	time_spin2norm	Float	2 sec	Transition time from Spin to Normal	0 – 600
	48	time_spin2idle	Float	2 sec	Transition time from Spin to Idle	0 – 600
	49	time_init2tqr	Float	600 sec	Initial Torqrod waiting time	0 – 1800
	50	point_err_chk	Float	4 cycles	Persistent pointing error check time in Normal mode	0 – 600
	51	time_bootwait	Float	120 sec	Initial mode transition wait time	0 – 1800
Solar array settings and CSS	52	sa_x1_ang	Float	5 deg	+X solar panel rotation angle	0 – 10
	53	sa_y1_ang	Float	5 deg	+Y solar panel rotation angle	0 – 10
	54	sa_x0_ang	Float	5 deg	-X solar panel rotation angle	0 – 10
	55	sa_y0_ang	Float	5 deg	-Y solar panel rotation angle	0 – 10
	56	sa_normal_ang	Float	35 deg	Angle between CSS normal vector and solar panel	0 – 90
	57	css_sf_amp	Float	0.0013 amp	CSS scale factor	0 – 0.002
	58	switch_css_fss	Integer	0	Switch between CSS and FSS 0 – use FSS, 1 – use CSS	0,1
	59	west_dct_limit	Float	1.5 sec	B field multiple zero crossing check time	0 – 200
	60	west_dw_limit	Float	2 rad/sec	Spin rate estimation upper limit	0 – 2

ACS COMMAND PARAMETERS 61-90

Misalignment matrix components

Filter gains

61	tqr_sf_m2I	Float	-0.00382 $1/m^2$	Torque rod scale factor	-0.007 - 0
62	mag_sig_biasx	Float	-0.0210 volts	MAG signal X-axis bias	± 0.2
63	mag_sig_biasy	Float	-0.0222 volts	MAG signal Y-axis bias	± 0.2
64	mag_sig_biasz	Float	-0.0078 volts	MAG signal Z-axis bias	± 0.2
65	mag_sig_invsfx	Float	1.228894e-5 tesla/volts	MAG signal X-axis scale factor inverse	0 – 1e-4
66	mag_sig_invsfy	Float	1.198365e-5 tesla/volts	MAG signal Y-axis scale factor inverse	0 – 1e-4
67	mag_sig_invsfz	Float	1.206855e-5 tesla/volts	MAG signal Z-axis scale factor inverse	0 – 1e-4
68	mag_sig_mis11	Float	1.00038	Inverse MAG misalignment matrix component	0 – 2
69	mag_sig_mis12	Float	0.01063	Inverse MAG misalignment matrix component	± 0.2
70	mag_sig_mis13	Float	-0.02069	Inverse MAG misalignment matrix component	± 0.2
71	mag_sig_mis21	Float	0.01699	Inverse MAG misalignment matrix component	± 0.2
72	mag_sig_mis22	Float	1.00029	Inverse MAG misalignment matrix component	0 – 2
73	mag_sig_mis23	Float	-0.00372	Inverse MAG misalignment matrix component	± 0.2
74	mag_sig_mis31	Float	-0.00820	Inverse MAG misalignment matrix component	± 0.2
75	mag_sig_mis32	Float	0.01281	Inverse MAG misalignment matrix component	± 0.2
76	mag_sig_mis33	Float	0.99990	Inverse MAG misalignment matrix component	0 – 2
77	fss_mis11	Float	1	FSS misalignment matrix component	± 2
78	fss_mis12	Float	0	FSS misalignment matrix component	± 0. 2
79	fss_mis13	Float	0	FSS misalignment matrix component	± 0. 2
80	fss_mis21	Float	0	FSS misalignment matrix component	± 0. 2
81	fss_mis22	Float	1	FSS misalignment matrix component	± 2
82	fss_mis23	Float	0	FSS misalignment matrix component	± 0. 2
83	fss_mis31	Float	0	FSS misalignment matrix component	± 0. 2
84	fss_mis32	Float	0	FSS misalignment matrix component	± 0. 2
85	fss_mis33	Float	1	FSS misalignment matrix component	± 2
86	mag_bias_z	Float	0 tesla	MAG bias along z-axis	± 0.0001
87	b_filter_zerox	Float	0	MAGx filter zero	0 – 0.9999
88	b_filter_polex	Float	0.9681	MAGx filter pole	0 – 0.9999
89	b_filter_gainx	Float	0.03195	MAGx filter gain	0 - 2
90	b_filter_zeroy	Float	0	MAGy filter zero	0 – 0.9999

ACS COMMAND PARAMETERS 91-120

Filter gains

91	b_filter_poley	Float	0.9681	MAGy filter pole	0 – 0.9999
92	b_filter_gainy	Float	0.03195	MAGy filter gain	0 - 2
93	b_filter_zeroz	Float	0	MAGz filter zero	0 – 0.9999
94	b_filter_polez	Float	0.9681	MAGz filter pole	0 – 0.9999
95	b_filter_gainz	Float	0.03195	MAGz filter gain	0 - 2
96	b_der_z1x	Float	-1.3333	MAGx 2nd order derivative coefficient z1	± 5
97	b_der_z2x	Float	0.3333	MAGx 2nd order derivative coefficient z2	± 5
98	b_der_p1x	Float	0	MAGx 2nd order derivative coefficient p1	± 5
99	b_der_p2x	Float	0	MAGx 2nd order derivative coefficient p2	± 5
100	b_der_kx	Float	12	MAGx 2nd order derivative gain k	± 50
101	b_der_z1y	Float	-1.3333	MAGy 2nd order derivative coefficient z1	± 5
102	b_der_z2y	Float	0.3333	MAGy 2nd order derivative coefficient z2	± 5
103	b_der_p1y	Float	0	MAGy 2nd order derivative coefficient p1	± 5
104	b_der_p2y	Float	0	MAGy 2nd order derivative coefficient p2	± 5
105	b_der_ky	Float	12	MAGy 2nd order derivative gain k	± 50
106	b_der_z1z	Float	-1.3333	MAGz 2nd order derivative coefficient z1	± 5
107	b_der_z2z	Float	0.3333	MAGz 2nd order derivative coefficient z2	± 5
108	b_der_p1z	Float	0	MAGz 2nd order derivative coefficient p1	± 5
109	b_der_p2z	Float	0	MAGz 2nd order derivative coefficient p2	± 5
110	b_der_kz	Float	12	MAGz 2nd order derivative gain k	± 50
111	fss_filter_zerox	Float	0	FSSx filter zero	0 – 0.9999
112	fss_filter_polex	Float	0.3333	FSSx filter pole	0 – 0.9999
113	fss_filter_gainx	Float	0.6667	FSSx filter gain	0 - 2
114	fss_filter_zeroy	Float	0	FSSy filter zero	0 – 0.9999
115	fss_filter_poley	Float	0.3333	FSSy filter pole	0 – 0.9999
116	fss_filter_gainy	Float	0.6667	FSSy filter gain	0 - 2
117	point_filter_zero	Float	0	Pointing_error filter zero	0 – 0.9999
118	point_filter_pole	Float	0.83333	Pointing_error filter pole	0 – 0.9999
119	point_filter_gain	Float	0.1667	Pointing_error filter gain	0 - 2
120	fss_der_z1x	Float	-1.3333	FSSx 2nd order derivative coefficient z1	± 5

ACS COMMAND PARAMETERS 121-153

Filter gains

121	fss_der_z2x	Float	0.3333	FSSx 2^{nd} order derivative coefficient z2	± 5
122	fss_der_p1x	Float	0	FSSx 2^{nd} order derivative coefficient p1	± 5
123	fss_der_p2x	Float	0	FSSx 2^{nd} order derivative coefficient p2	± 5
124	fss_der_kx	Float	12	FSSx 2^{nd} order derivative gain k	± 50
125	fss_der_z1y	Float	-1.3333	FSSy 2^{nd} order derivative coefficient z1	± 5
126	fss_der_z2y	Float	0.3333	FSSy 2^{nd} order derivative coefficient z2	± 5
127	fss_der_p1y	Float	0	FSSy 2^{nd} order derivative coefficient p1	± 5
128	fss_der_p2y	Float	0	FSSy 2^{nd} order derivative coefficient p2	± 5
129	fss_der_ky	Float	12	FSSy 2^{nd} order derivative gain k	± 50
130	w_filter_zerox	Float	0	Transverse rate wx filter zero	0 – 0.9999
131	w_filter_polex	Float	0.83333	Transverse rate wx filter pole	0 – 0.9999
132	w_filter_gainx	Float	0.1667	Transverse rate wx filter gain	0 - 2
133	w_filter_zeroy	Float	0	Transverse rate wy filter zero	0 – 0.9999
134	w_filter_poley	Float	0.83333	Transverse rate wy filter pole	0 – 0.9999
135	w_filter_gainy	Float	0.1667	Transverse rate wy filter gain	0 - 2
136	css_filter_zerox	Float	0	CSSx filter zero	0 – 0.9999
137	css_filter_polex	Float	0.9681	CSSx filter pole	0 – 0.9999
138	css_filter_gainx	Float	0.03195	CSSx filter gain	0 - 2
139	css_filter_zeroy	Float	0	CSSy filter zero	0 – 0.9999
140	css_filter_poley	Float	0.9681	CSSy filter pole	0 – 0.9999
141	css_filter_gainy	Float	0.03195	CSSy filter gain	0 - 2
142	mag_filter_zerox	Float	0	MAG processing MAGx filter zero	0 – 0.9999
143	mag_filter_polex	Float	0.5	MAG processing MAGx filter pole	0 – 0.9999
144	mag_filter_gainx	Float	0.5	MAG processing MAGx filter gain	0 - 2
145	mag_filter_zeroy	Float	0	MAG processing MAGy filter zero	0 – 0.9999
146	mag_filter_poley	Float	0.5	MAG processing MAGy filter pole	0 – 0.9999
147	mag_filter_gainy	Float	0.5	MAG processing MAGy filter gain	0 - 2
148	mag_filter_zeroz	Float	0	MAG processing MAGz filter zero	0 – 0.9999
149	mag_filter_polez	Float	0.5	MAG processing MAGz filter pole	0 – 0.9999
150	mag_filter_gainz	Float	0.5	MAG processing MAGz filter gain	0 - 2
151	west_filter_zero	Float	0	Spin rate estimation filter zero	0 – 0.9999
152	west_filter_pole	Float	0.9901	Spin rate estimation filter pole	0 – 0.9999
153	west_filter_gain	Float	0.009901	Spin rate estimation filter gain	0 - 2

ACS OPERATIONS

Normal Operations

Screens

Safe Mode

Anomalies and Contingencies

Under voltage

NORMAL OPERATIONS

During Normal Mission Operation:

- Mode: Normal
- FSS Sun Pointing Error < 0.2 deg
- Spin Rate Estimation: 15 ± 0.5 rpm
- Magnetic Field Vector Updating Constantly
- Z-Torque Rod Firing for Precession
- X, Y-axis Torque Rod Firing for Spin Rate Regulation

During Initial Acquisition Phase:

- Initial Mode After Separation Should Be Acquisition
- After 2.5 Hours, the SC Should Transition to Precession Mode
- When CSS Sees the Sun (SPI is High), CSS Error Should be Decreasing
- FSS Error Should be Updating whenever FSS Sees the Sun and CSS/FSS Error <= 32 deg
- Magnetometer Measurement Should be Updating Constantly
- X, Y and Z Torque Rods Should be Activated in Acquisition Mode All the Times
- Z Torque Rod Should Be Activated in Precession Mode When SC is In the Sun

SCREEN - PACI PAGE

SPECTRUMASTRO

High Energy Solar Spectroscopic Imager (HESSI)

Analog Inputs:

- FSS Analog: (-5 ~ 5 Volts)
- MAG: (-5 ~ 5) Volts
- MAG Temperature: (-40 ~ 90°C) (0 ~ 5V)
- FSS SOH: (0 ~ 5 Volts)
- 4 Torqrod Currents: (-0.2292 ~ 0.2292 A)

Temperature Sensors AD590s: (deg C)

- FSE
- 2 IAD
- 4 Torque rods
- 4 S/A Wings

IAD Positions:

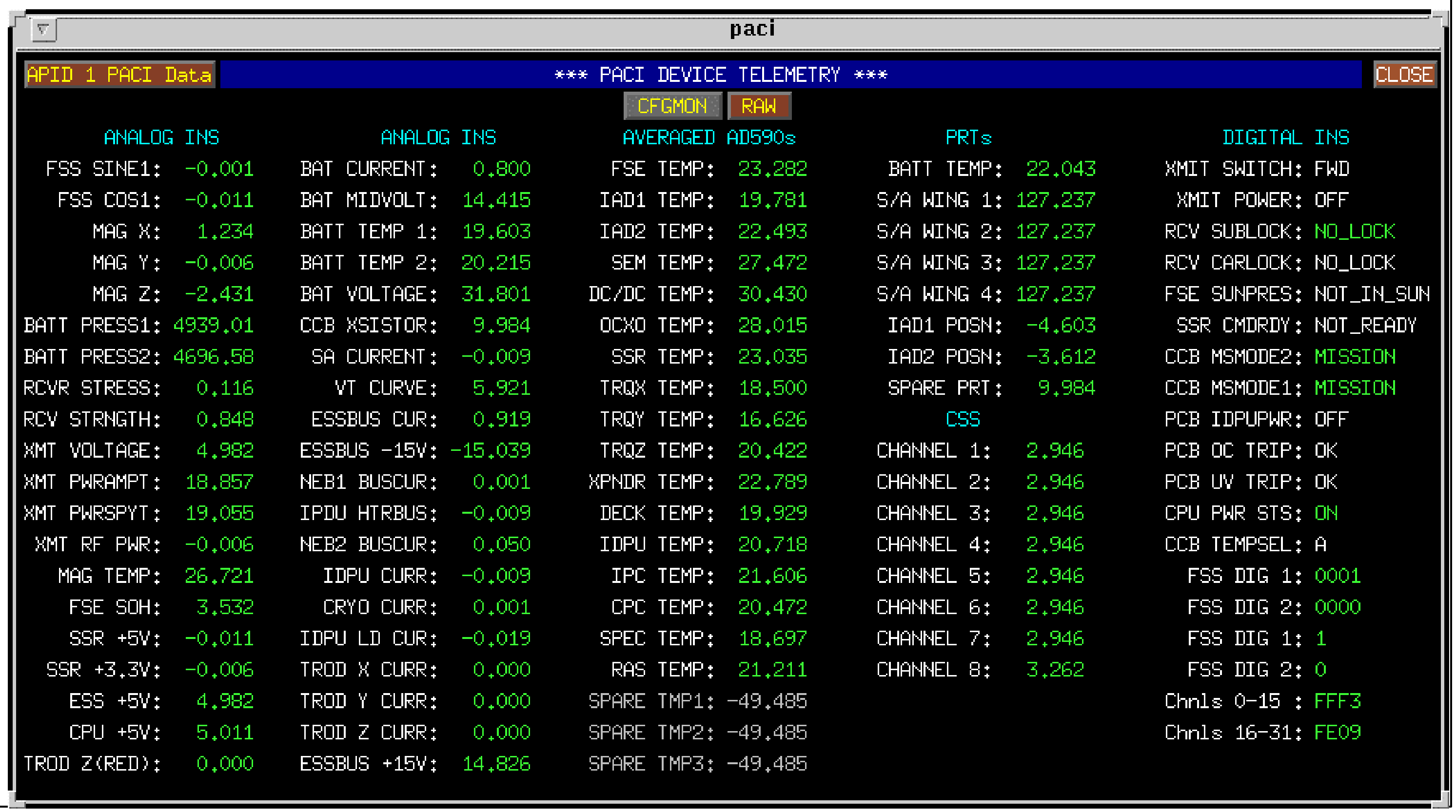
- (-10 ~ 3 Volts)

CSS Current Inputs:

- 8 Channel (0 ~ 1300μA)

Digital Inputs:

- FSS Sun Presence: (0,1)
- FSS Coarse Gray-Code Bits: (0000 ~ 1111)
- FSS Coarse Bit Decimal Values: (0 ~ 63)
- FSS Coarse Bit Hex Values: (0000 ~ FFFF)



SCREEN - ACS MAIN PAGE

ACS Information:
- Mode Command Status: Commanded or Auto
- Current ACS Mode:
- Idle Mode Transition Indicator (0 ~ 5)
- ACS Primary Control Sun Sensor in Use
- Actual and Commanded Torque Rod Currents (Amp)
- Magnetic Field (Gauss)
- FSS, CSS, SAS
    - Sun Vector
    - Pointing Error Calculation (deg)
    - Sun Presence Indicator
- Transverse Rate Estimations (rad/sec)
- Spin Rate Estimation (rpm)

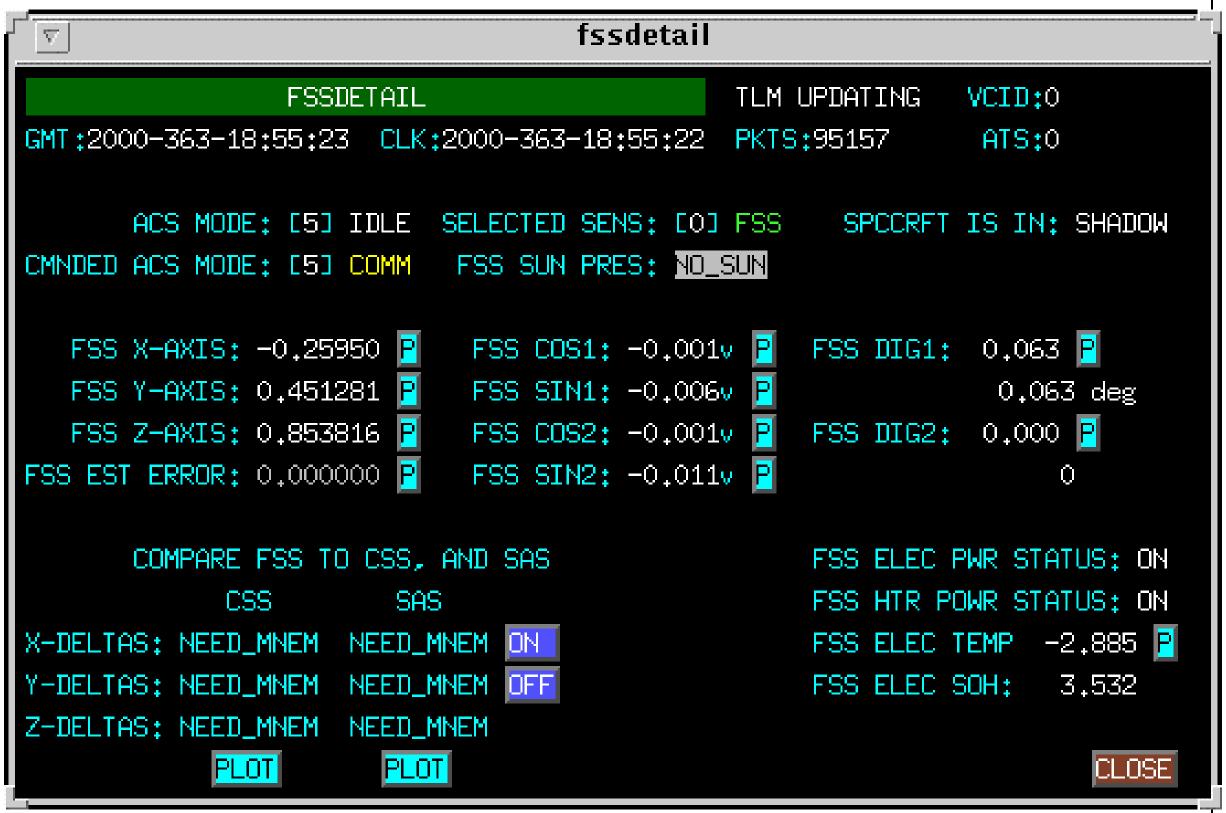
Others:
- Telemetry Command Status
- Sun Pointing Error Fault Monitor (0, 1):
    - Disabled by Default
    - Must be Enabled from Ground
    - When Set to 1:
        - Torqrods Powered Down
        - No Commands Sent to ACS
- IAD Selection
- IAD Rotation Direction

SCREEN - FSS DETAILS PAGE

High Energy Solar Spectroscopic Imager (HESSI)

Displays Detailed Fine Sun Sensor Information:

- Current ACS Mode
- Mode Command Status: Commanded or Auto
- ACS Primary Control Sun Sensor in Use
- FSS Sun Presence: 1=SUN, 0=NO_SUN
- FSS Sun Vector
- FSS Pointing Error Calculation (deg)
- For X and Y Axes:
  - sine/cosine Signal (Volts)
  - Coarse Bits
  - Pointing Error Estimation (deg)
- FSS Electronics Outputs
  - Power Status
  - FSE Temperature
  - State of Health (SOH)
    - 3.5 V Nominal



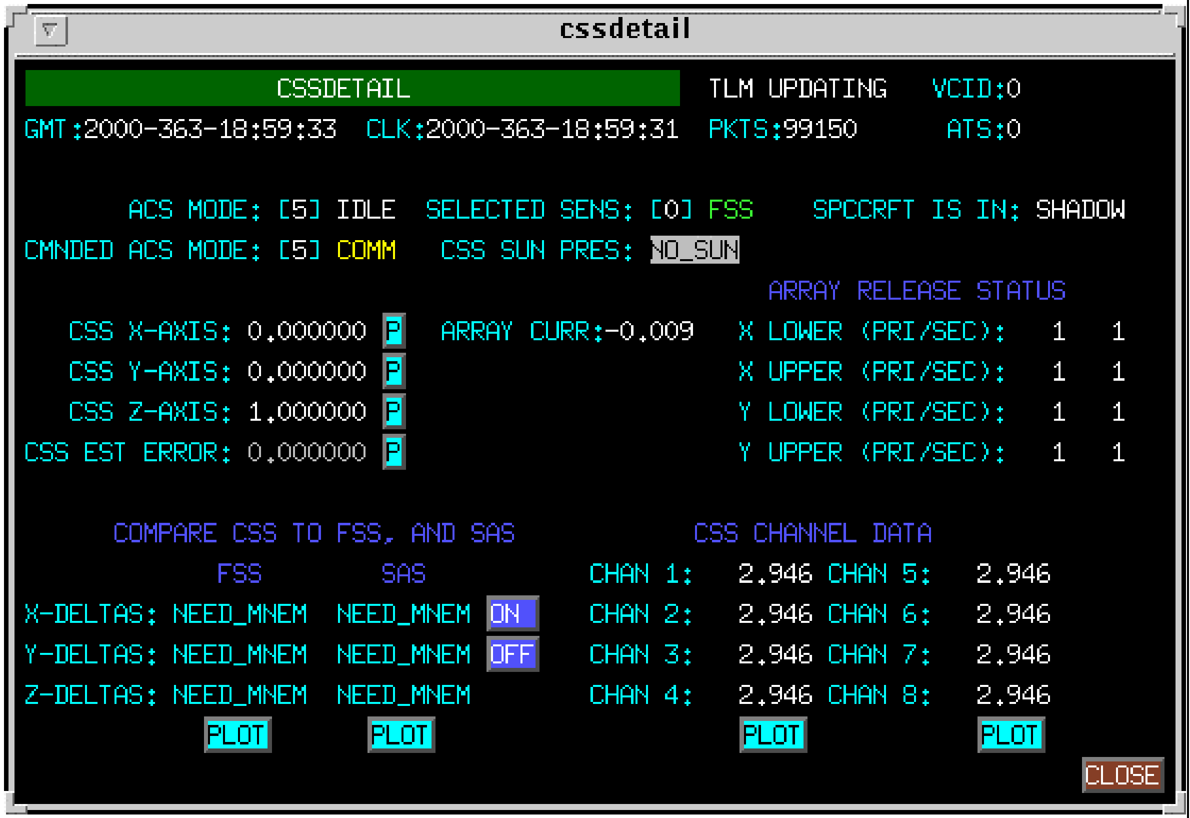
SPECTRUMASTRO

SCREEN - CSS DETAILS PAGE

High Energy Solar Spectroscopic Imager (HESSI)

Displays Detailed Coarse Sun Sensor Information:
- Current ACS Mode
- Mode Command Status: Commanded or Auto
- ACS Primary Control Sun Sensor in Use
- CSS Sun Presence
- CSS Sun Vector
- CSS Pointing Error Calculation
- 8 CSS Channel Current Outputs:
    - (0 ~1300μA)

Solar Array Release Status:
- X-axis Lower Pri/Sec Release
- X-axis Upper Pri/Sec Release
- Y-axis Lower Pri/Sec Release
- Y-axis Upper Pri/Sec Release



To be Added

SAFE MODE

Idle Mode is Considered a Safe Mode for HESSI:

- All Torque Rods Are Disabled
- Sun Pointing Error shall Accumulate Approximately 1 deg/Day During Idle Mode

A Flag Indicates the Possible Causes for Autonomous Transition to Idle Mode:

to_idle_flag =	0	- No Transition to Idle Mode
	1	- Not used
	2	- Precession to Idle : β<5 deg AND NOT 14.5<Ω<15.5rpm
	3	- Normal to Idle: β > 0.5 deg
	4	- Normal to Idle: NOT 13.5<Ω<16.5rpm
	5	- Spin to Idle: 14.5<Ω<15.5rpm AND NOT β<0.2 deg

Autonomous Transitions 3 and 4 Indicate Possible Anomalies During Normal Mode:

- Pointing Error is out of Acceptable Range, or
- Spin Rate Falls Out of the Operating Range

ANOMALY 1 - STOWED SOLAR ARRAYS

SPECTRUMASTRO

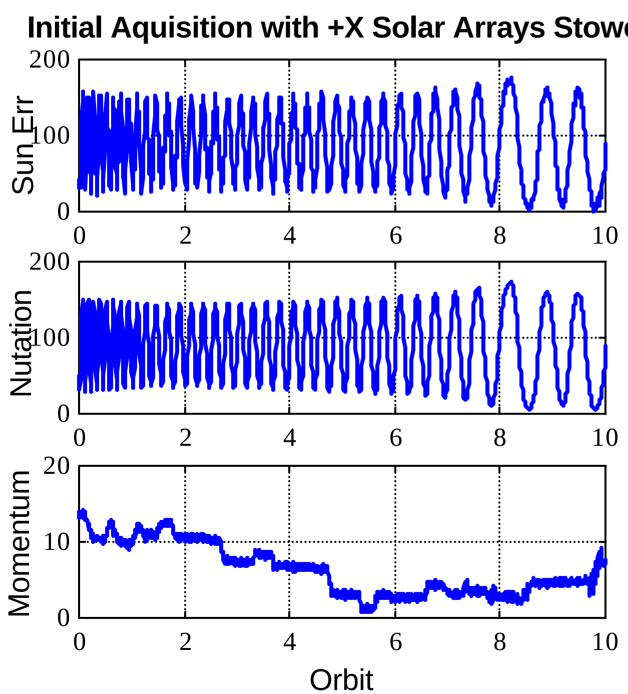
High Energy Solar Spectroscopic Imager (HESSI)

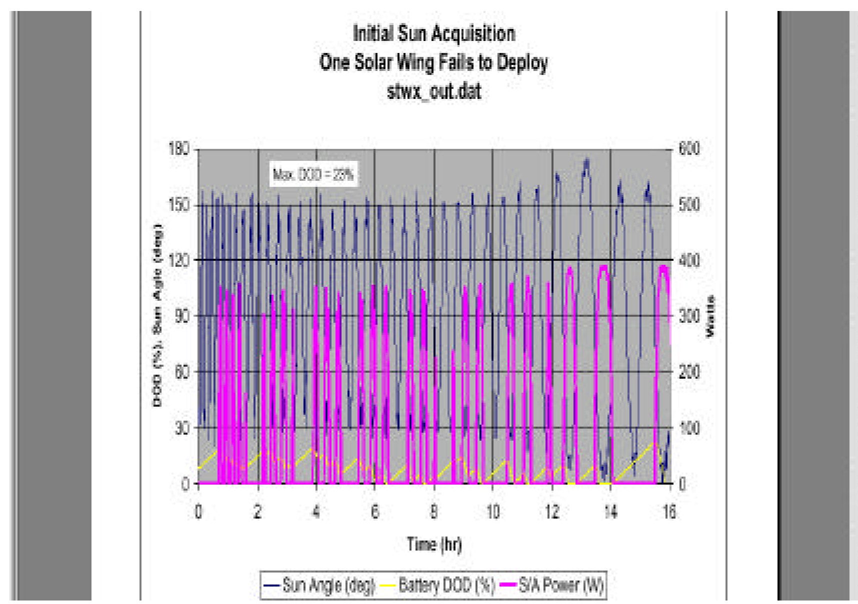
+X Solar Array Not Deployed:

- Shown for 10 Orbits of Simulation for Initial Acquisition Phase with a Nominal LV Tip-off Conditions
- Other 3 Solar Arrays will be Able to Generate Sufficient Power - Maximum DOD=23%

Contingence:

- Deploy Stowed Solar Array from Ground

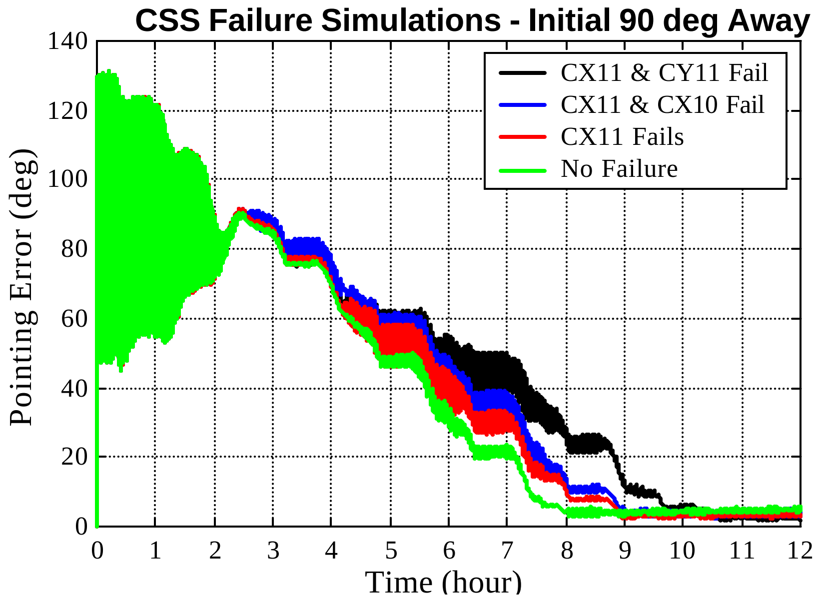




ANOMALY 2 - CSS Cell FAILURE

One or Two CSS Cells Fail During Initial Acquisition Phase:

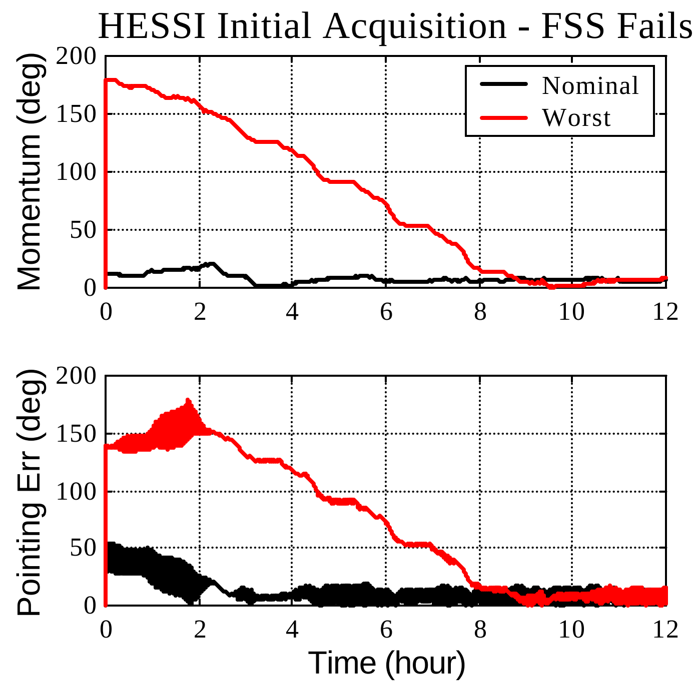
- Assume No Current Output from Failed Cells
- Assume Nominal Tip-Off Rates (4, 4, 17) deg/sec
- Assume Tip-Off Orientation: 90 deg from the Sun
- SC Should be able to Acquire the Sun for up to Two Cell Failure Cases
- May Need to Modify ACS FSW to Discontinue the Use of Bad CSS Channels



SPECTRUMASTRO

ANOMALY 3 - FSS FAILURE

High Energy Solar Spectroscopic Imager (HESSI)



FSS Fails During Initial Acquisition Phase:

• CSS should be able to Save the Spacecraft by Pointing Z-axis toward the Sun

• CSS is Designed for Pointing SC to Sun Coarsely, therefore, Precession Performance using CSS is Not as Good as Using FSS

• SC will Stay in Precession Mode without Ground Interference

Contingence:

• Switch CSS in Place of FSS (in Future Version of ACS FSW)

FSS Fails During Normal Mission Operation:

• CSS can't Meet Mission Pointing Requirement of 0.2 deg Because of its Low Accuracy (1~2 deg)

Contingence:

• Using CSS + SAS for Possible Limited Mission Capability (May be in Future Version of ACS FSW)

MAG Failure

- No Magnetic Field Measurement from MAG

Contingence:

- None

UNDER VOLTAGE

Under-voltage trip levels

- UV1 Level is 26.85V Nominal and 24.86V Degraded Mode
- UV2 Level is 26.33V Nominal and 24.15V Degraded Mode
- UV3 Level is 25.70V Nominal and 23.54V Degraded Mode

Under-voltage trip action

- UV1 Causes IDPU Safe Mode Signal to Be Sent
- UV2 Turns off Torque Rods, FSS, Magnetometer and CPU
- UV3 Turns off All Switches. Transmitter and Receiver Will Still Work. Ground Command to Turn On CPU