TIMED GENERAL INSTRUMENT INTERFACE SPECIFICATION

Section 6.0
Navigation and Attitude Control Interface Section
Signature Page

TECHNICAL CONTENT APPROVAL (PAGE 1 OF 1)

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TIMED GENERAL INSTRUMENT INTERFACE SPECIFICATION

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REVISION APPROVAL (PAGE 1 OF 5)

TIMED Spacecraft Approval Page

Rev #	Date	D. Kusnierkiewicz	K. Heffernan	W. Radford	W. Devereux
A					
B					
C					
D					
E					
F					
G					
H					
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Rev #	Date	A. El-Dinary			
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GUVI Instrument Approval Page

Rev #	Date	B. Ogorzalek			
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SABER Instrument Approval Page

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6. NAVIGATION AND ATTITUDE CONTROL

6.1 NAVIGATION ACCURACY

6.1.1 Position Knowledge

Orbital position will be known onboard the spacecraft to an accuracy of 300 meters (3σ) along each axis. Orbital position information will be made available on the MIL-STD-1553b bus once per second and in the stored spacecraft housekeeping telemetry.

6.1.2 Velocity Knowledge

Spacecraft velocity will be known to an accuracy of 0.25 meters per second (3σ) along each axis. Velocity information will be made available on the MIL-STD-1553b bus once per second and in the stored housekeeping telemetry.

6.1.3 Position and Velocity Reference

Position will be provided in the Earth-Centered Earth-Fixed (ECEF) frame in geodetic coordinates (degrees latitude, degrees longitude, and meters altitude) referenced to the WGS-84 reference ellipsoid. Velocity will be provided as the derivative of ECEF position; it will be expressed as a three-element cartesian vector (in meters/second) relative to the locally-level (east, north, up) reference frame defined by the current position of the spacecraft. Both position and velocity will be provided at a 1 Hz rate and will be valid at the next 1-PPS epoch.

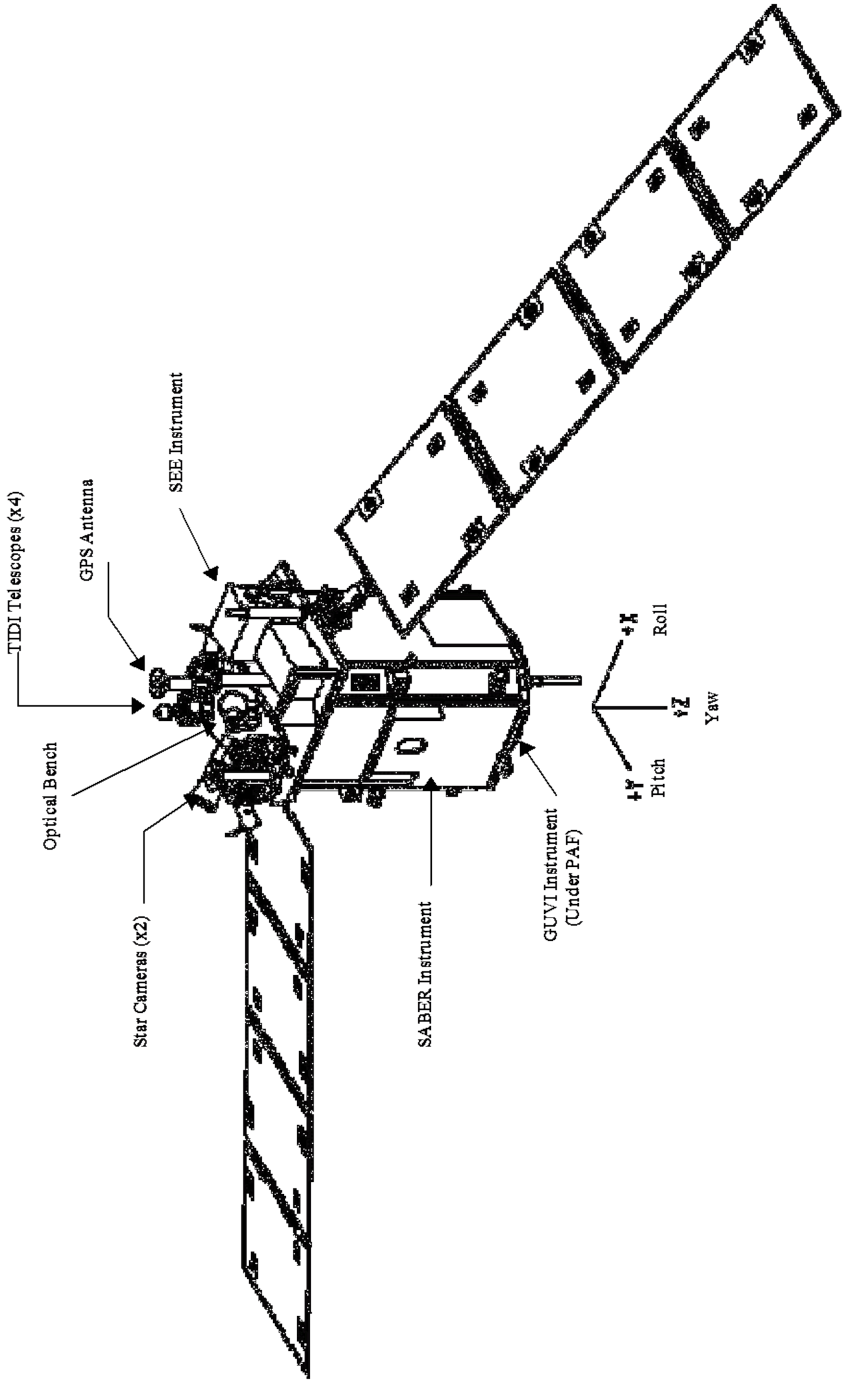
6.1.4 Sun Vector

The Attitude System will provide the unit vector to the center of the sun at a 1 Hz rate to the spacecraft. The vector will be expressed in cartesian coordinates in the nominal spacecraft body frame (sec. 6.2.1) and time tagged with sufficient accuracy to maintain the angle accuracy specified below (sec. 6.1.5).

6.1.5 Sun Angle Accuracy

The sun angle will be calculated on board the spacecraft to an accuracy of 0.06° (3σ) for each axis with respect to the spacecraft's reference coordinate system.

Fig. 6.2.1-1. Definition of TIMED Spacecraft Coordinate System



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6.2 ATTITUDE CONTROL AND DETERMINATION

6.2.1 Attitude Coordinates

The nominal spacecraft body frame axes (X,Y,Z) are defined as illustrated in Figure 6.2.1-1. This is a right-hand system with roll defined about X, pitch about Y, and yaw about Z. The specific spacecraft body frame will be defined by an optical cube mounted on the optical bench. All scientific and attitude instruments will be aligned relative to this cube.

The specific inertial frame for attitude reference will be the J2000 reference frame. Spacecraft attitude will be represented as roll, pitch, and yaw about the spacecraft coordinates. The attitude angles and body rates will be valid at the time tag provided in the spacecraft status message.

6.2.2 Pointing Direction

TIMED is a three-axis stabilized, nadir-pointing spacecraft. During normal operation, the spacecraft +X axis lies in the orbit plane and generally points either in the ram or wake direction. The +Y axis of the spacecraft will be normal to the orbit plane, defined by the cross-product of the nadir and velocity vectors, and on the opposite side of the orbit plane from the sun. The +Z axis will be pointed in the nadir direction. Operationally, the spacecraft will perform a 180-degree yaw maneuver approximately every 60 days to keep the sun >90° from the cold (+Y) side of the spacecraft.

In the event of the loss of data from both star trackers, the attitude system will enter a "sun-safe" mode which will result in an uploadable vector between the - Z and - Y axes being pointed toward the sun. The instruments will not be powered during “sun-safe” modes. During spacecraft maneuvering to the “sun-safe” mode, the sun will not be in the FOV of any instrument for greater than TBD seconds.

6.2.3 Attitude Control Capability

In the normal operational mode, the TIMED Attitude Control System (ACS) will orient the spacecraft axes (defined in 6.2.1) to the desired attitude to within 0.5° (3σ) each axis. The attitude system shall be capable of accepting an offset to adjust the attitude relative to the nominal attitude defined in sec. 6.2.2.

6.2.4 Attitude Determination Capability

The attitude system will provide the attitude knowledge to within 0.03° (3σ) for each of three axes at the optical alignment cube on the Master Star Tracker. Attitude information will be provided once per second and with a maximum latency of 3.9 seconds on the MIL-STD-1553b bus and in the stored spacecraft housekeeping telemetry.

6.2.5 Attitude Stability and Jitter

Attitude stability is defined as angular motion about the commanded state at frequencies within the ACS's closed-loop bandwidth. Attitude jitter is defined as angular motion at frequencies above the ACS's control bandwidth.

Tables 6.2.5-1 and 6.2.5-2, and figure 6.2.5-1 summarize the attitude stability and jitter requirements of each of the TIMED instruments. The stability and jitter requirement for the spacecraft is derived from these instrument requirements, and is plotted as a function of frequency as the heavy solid line in the figure. As shown, the requirements of the SABER instrument dominate. The plot includes linear and sinusoidal extrapolations of the basic SABER angular rate specification (0.0075 deg/sec), and depicts the attitude control requirement of 0.5° (3 σ) in each axis at low frequencies. Performance will be maintained below the solid line through a combination of ACS control, structural rigidity, and limiting of disturbances.

Stability motion can be controlled by the ACS. APL is responsible for meeting the stability requirements at all times with the following exception: solar panel movements (at the occurrence rate of once per day), spacecraft yaw maneuvers (once per sixty days) and during non-recurring transient events (e.g., door and cover openings). Impending solar panel movements will be announced on the MIL-STD-1553b bus 15 seconds before the event. Impending yaw maneuvers will be announced on the MIL-STD-1553b bus 60 seconds before the event.

Jitter motion cannot be controlled by the ACS. It must be held within the prescribed limits by limiting all torque and force sources such as mirror movements, compressor activity, filter wheel movements, rotating platforms, etc. and/or by damping of the structure. A structural model will be developed that includes the spacecraft, instruments and all disturbance torques and forces in an attempt to quantify the spacecraft's jitter performance. At that time, APL shall decide whether to limit the disturbance torques and forces in order to meet the jitter specification.

TABLE 6.2.5-1

TIMED ATTITUDE STABILITY REQUIREMENT

Time Period (seconds)	Angular Motion (3σ, degrees)	Axis*	Instrument Driving Specification
15	0.1 (zero-to-peak)	All	GUVI
	Figure 6.2.5-1		SABER
60	2 (zero-to-peak)	All	SEE
-	-	-	TIDI

* The pitch stability specifications are relative to the 1 revolution per orbit spacecraft pitch motion.

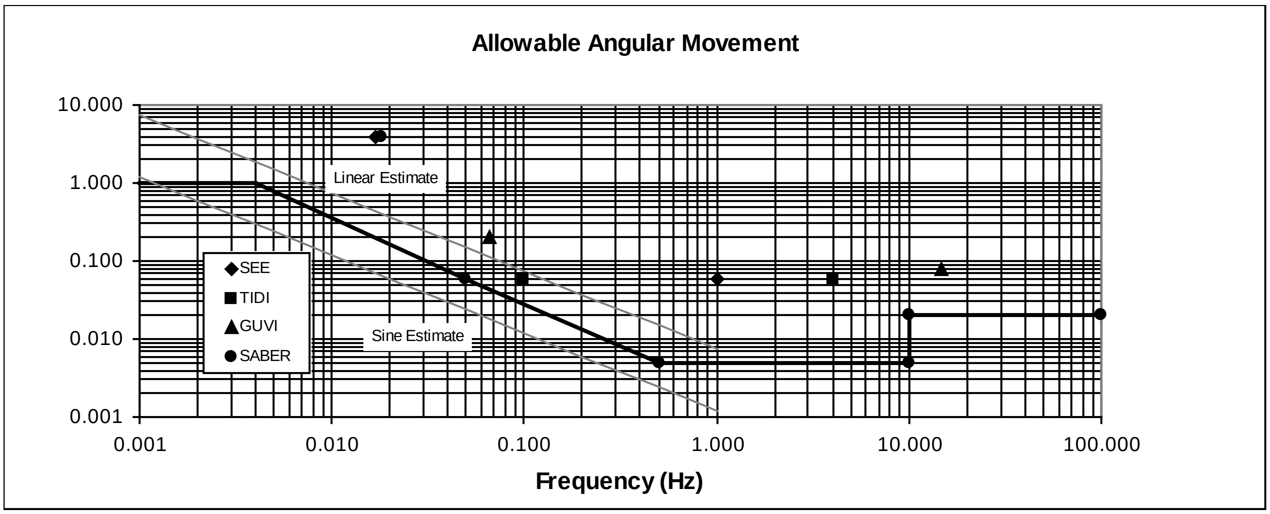
TABLE 6.2.5-2

TIMED ATTITUDE JITTER REQUIREMENT

Time Period (seconds)	Angular Motion (3σ, degrees)	Axis*	Instrument Driving Specification
0.068	0.04 (zero-to-peak)	Pitch, Roll	GUVI
	Figure 6.2.5-1		SABER
1	0.03 (zero-to-peak)	All	SEE
0.25	0.03 (zero-to-peak)	All	TIDI
10	0.03 (zero-to-peak)	All	TIDI

FIGURE 6.2.5-1

TIMED ALLOWABLE ANGULAR MOVEMENT



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6.2.6 Pointing Mode Definitions

6.2.6.1 Normal Operational Mode

Normal Operation Mode is defined as the condition when the TIMED spacecraft Guidance and Control System operating within performance limits. During this mode, the “S/C Attitude Nadir Pointing” mode flag and the “S/C Attitude Sun Safe” mode flag in the spacecraft status message will both be set to “0.” The instruments will be powered during Normal Operation.

6.2.6.2 Nadir Pointing Mode

Nadir Pointing Mode is defined as the condition when the TIMED spacecraft Guidance and Controy System is operating with degraded performance. During this mode, the “S/C Attitude Nadir Pointing” mode flag in the spacecraft status message will be set to “1.” The instruments will remain powered during Nadir Pointing Mode.

6.2.6.3 Sun-Safe Mode

Sun-Safe Mode is defined as the condition when the TIMED spacecraft is Guidance and Control System is performing out of specification. During this mode, the “S/C Attitude Sun Safe” mode flag in the spacecraft status message will be set to “1.” The instruments will be powered off 10 seconds after setting this mode flag.

A Sun-Safe mode vector will point the -Y axis ±10° to the sun. This vector will be uploaded following initial acquisition of the spacecraft.

6.2.6.4 Mode Transition Thresholds

The transition from Normal Operation Mode to Nadir Pointing Mode nominally will occur when the spacecraft attitude is greater than 0.5° (absolute) in any single axis. The transition from Nadir Pointing Mode to Sun-Safe Mode will occur when the spacecraft attitude is greater than 5.0° (absolute) in any single axis. These thresholds will be uploadable parameters which can be changed after launch.

6.2.7 Yaw Maneuver

Yaw maneuvers will be constrained to take place during eclipse. The yaw maneuver rotation direction will prevent the SABER boresight from being pointed in the ram direction. The maneuvers will be scheduled to minimize the time that the sun is on the +Y (cold) side of the spacecraft. As a result, the maneuvers will be scheduled to take place within 2 orbits of ß=0° and will not be scheduled prior to that time. In the case of an anomoly, every effort will be made to ensure that the maneuver takes place at 0° < ß < 4° (i.e. sun on the +Y side prior to the move).

6.2.8 Spacecraft Direction

The ram direction bit in the spacecraft status message indicates which direction the X-axis points in the ram direction. If this bit is set, the +X-axis is pointing in the ram direction. If this bit is clear, the -X-axis is pointing in the ram direction. This bit is set after the yaw maneuver is completed and the spacecraft attitude errors are within specification. The following sequence summarizes the events of a yaw maneuver:

1. Set "yaw maneuver" bit 60 seconds prior to maneuver
2. Clear "attitude valid" bit just prior to maneuver
3. Roll, pitch, yaw set to 0
4. Perform maneuver
5. Wait for attitude errors to settle within spec
6. Change ram direction bit
7. Report roll, pitch and yaw
8. Set attitude valid bit
9. Clear "yaw maneuver" bit

The GPS position is transformed to a local vertical geocentric frame with the +Z-axis pointing toward the center of the Earth. Roll, pitch and yaw are error angles about the X-axis, Z-axis, and Y-axis respectively.

6.3 POINTING ACCURACY

6.3.1 Pointing Knowledge

The pointing of each instrument will be defined at the boresight for that instrument. The pointing knowledge accuracy will be defined as the accuracy from the spacecraft master reference cube to the instrument boresight and will include errors due to thermal distortion, 1-G effects, launch shifts, and alignment measurement errors. Table 6.3.1-1 summarizes the pointing knowledge requirements from the spacecraft master cube to the instrument boresight for each instrument.

The pointing knowledge accuracy will be allotted between the spacecraft side of the mounting interface and the instrument side of the mounting interface. The spacecraft side is defined from the spacecraft master cube to the foot of the instrument while the instrument side is defined from the foot of the instrument to the instrument boresight. The break-down of the spacecraft side accuracy and instrument side accuracy will be described in the respective instrument SIIS.

TABLE 6.3.1-1

TIMED ATTITUDE POINTING KNOWLEDGE ACCURACY REQUIREMENTS

Pointing Knowledge Accuracy (3σ, degrees)	Axis	Instrument Driving Specification
0.25	All	GUVI
0.1	All	SABER
0.05	All	SEE
0.05	All	TIDI