SOFTWARE REQUIREMENTS SPECIFICATION

FOR THE

GLOBAL ULTRAVIOLET IMAGER

(GUVI)

FLIGHT INSTRUMENT

7366-9040

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Technical Content Approvals

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Table of Contents

1. Introduction

1.1 Scope

This specification defines the software requirements for the Global Ultraviolet Imager (GUVI) flight instrument. The software requirements are derived from the requirements defined in the GUVI Technical Requirements Specification. This document describes only the GUVI flight software requirements. The GUVI ground segment software requirements are defined in the GUVI POC Software Requirements Specification.

GUVI is an instrument on the Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics (TIMED) spacecraft. GUVI consists of a cross-track scanning imaging spectrograph that operates in the far ultraviolet region. The GUVI instrument produces horizon to horizon line scan images at five simultaneous far ultraviolet wavelengths. GUVI obtains airglow measurements on a global basis. These measurements will be used by the GUVI ground segment to determine electron density profiles, total electron content, and the global distribution of auroras.

1.2 Identification

The GUVI flight instrument computer program is named GUVI Flight Software. The GUVI Flight Software consists of two components, (1) Detector Processor Software, and (2) Telemetry Processor Software.

1.3 Functional summary

The GUVI flight instrument consists of two major subsystems: the scanning imaging spectrograph (SIS) and the electronics control unit (ECU). The scanning imaging spectrograph subsystem includes the spectrograph optics housing and electronics package, and the detector tubes, high voltage power supplies, and focal plane electronics. The electronics control unit contains the processor, interface, and power switching circuitry required by the GUVI instrument.

The ECU controls instrument operation, collects, processes, and formats detector data, and accepts and executes instrument commands. The ECU consists of the telemetry processor, the detector processor, the interface unit, and the power switching unit. The detector processor and telemetry processor are microprocessor based units, and they execute the software specified in this document.

The detector processor software module computes the position of each photon event in the spectrograph and bins the events from each measurement frame into spatial and spectral pixels. The detector processor module receives photon event data from the spectrograph detector, and transfers the binned spectrograph data to the telemetry processor.

The telemetry processor software module provides the control and telemetry functions for the GUVI instrument. The module accepts commands from the TIMED spacecraft and controls the operation of the various GUVI detectors, power supplies, and mechanisms. The module inputs and formats data from the spectrograph detectors along with general housekeeping information, and sends the data to the spacecraft data handling subsystem for transmission to ground stations.

2. Applicable Documents

The following documents form a part of this specification to the extent specified herein.

TIMED Component Environmental Specification, 7363-9010

TIMED General Instrument Interface Specification, 7363-9050

GUVI Technical Requirements Specification, 7366-9001

GUVI Product Assurance Implementation Plan, 7366-9190

GUVI Software Quality Assurance Plan, 7366-9003

GUVI Payload Operations Center Software Requirements Specification, 7366-9200

GUVI Subsystem Interface Control Document, 7366-9020

GUVI Flight Software Development Plan, 7366-9002

Space Department Software Quality Assurance Guidelines, SDO-9989, September 1992

3. Interface Requirements

3.1 Interface Description

The GUVI Flight Software interfaces with all GUVI subsystems and the TIMED spacecraft. Detector data are collected from the spectrograph subsystem. The spectrograph subsystem consists of the Scanning Imaging Spectrograph (SIS) and a redundant pair of ultraviolet detectors. The GUVI low voltage power switching unit and TIMED spacecraft interface circuitry are located in the electronics control unit. The GUVI main power switch is controlled by the spacecraft and not the GUVI Flight Software.

3.2 Inputs from the TIMED Spacecraft

Inputs from the TIMED spacecraft will consist of commands, broadcast messages, and software uploads. All inputs are received from the spacecraft command and data handling subsystem over a MIL-STD-1553 bus interface. GUVI command messages are used to set the operating state of the instrument. Broadcast messages contain information about the spacecraft attitude and operational status.

The spacecraft command subsystem does not provide time delayed commands to the instruments. Therefore, the GUVI instrument will have the capability to store spacecraft commands and execute the command at the proper time. The average command rate for the GUVI instrument is assumed to be 400 bytes per week. The software upload capability will be used to change the operational code. The maximum software upload will be 64 kilobytes.

3.3 Outputs to the TIMED Spacecraft

Outputs to the TIMED spacecraft will consist of instrument telemetry data and an instrument mode word. The data are transmitted to the spacecraft command and data handling subsystem over a MIL-STD-1553 bus interface. The GUVI telemetry data contain the formatted detector data along with instrument housekeeping data. The telemetry data message length varies with the GUVI operating mode. The instrument mode word is a 64 bit word that indicates the operating state of the instrument.

3.4 Inputs from the Spectrograph Subsystem

3.4.1 Scanning Imaging Spectrograph Interface

The GUVI Flight Software inputs housekeeping data from the Scanning Imaging Spectrograph (SIS). The housekeeping data consist of scan mirror position, spectrograph slit position, pop up mirror position, cover open and closed telltales, scan motor current, scan mirror temperature, and spectrograph temperature. The current and temperature data are read as unsigned integers from the interface circuit.

3.4.2 Detector Interface

The GUVI Flight Software inputs event data, input and output count rates, and housekeeping data from the spectrograph detectors. Only one detector is in use at a time. The event data are the digitized pulse height values from the detector anodes for each photon event. The housekeeping data include the detector high voltage monitor and temperature monitors, and are read as unsigned integers from the interface circuit. The event data and count rates are read by the detector processor software module, while the housekeeping data are read by the telemetry processor software module.

3.5 Outputs to Spectrograph Subsystem

3.5.1 Scanning Imaging Spectrograph Interface

The GUVI Flight Software outputs control data to the Scanning Imaging Spectrograph (SIS). The control data consist of scan motor drive pulses, scan mirror heater on, slit motor drive, and pop up motor drive. All control data except the scan motor drive pulses are activated only in response to commands.

3.5.2 Detector Interface

The GUVI Flight Software outputs control data to the spectrograph detector. The control data include a high voltage power supply control word to adjust the high voltage level, a detector configuration word, and primary and secondary detector power control. The high voltage control word is converted to an analog signal and sent to the high voltage power supply. The configuration word sets control parameters in the detector electronics. The detector power control data toggles relays in the power switching unit which turns power on or off to the detectors.

3.6 Inputs from the Power Switching Unit

The GUVI Flight Software inputs housekeeping data from the power switching unit. The housekeeping data include the status of the power switching relays and current monitors.

3.7 Detector Processor to Telemetry Processor Interface

The telemetry processor will output a control word to the detector processor to request a single word of either binned detector data, pulse height data, or dark count data. The telemetry processor will use the same interface to command the detector processor to begin a new function, and to define the spatial and spectral bins.

The detector processor will provide a single sixteen bit data word in response to a data request sent by the telemetry processor. The data received in response to a request will be an accumulated count for the specified spectral bin, a detected pulse height, or a dark count (spectral data from outside the defined image).

4. Functional Requirements

4.1 Overview

The GUVI Flight Software consists of two functional components, the detector processor software and the telemetry processor software. The detector processor software creates binned spectrograph data from the detector event data, while the control and monitoring functions of the telemetry processor software extend to all GUVI subsystems.

4.2 Detector Processor Software

4.2.1 Event Processing

The detector processor shall compute a two dimensional photon event position from the digitized pulse height values that are input from the spectrograph detector. The position resolution shall be 14 along track spatial pixels by 168 spectral pixels across the spectrograph focal plane. The maximum input rate shall be 200,000 counts per second.

The maximum detector event processing rate is based on the expected radiance intensities and spectrograph sensitivity defined in the GUVI Technical Requirements Specification. A maximum input count rate of 175 KHz is expected for the spectrograph detector. The detector is required to operate for input rates up to 200 KHz. The detector throughput will decrease as a function of the input count rate.

4.2.2 Pulse Height Distribution

The detector processor shall provide pulse height values for diagnostic use by the telemetry processor software. Pulse height values from at least one event per major frame shall be provided in imaging or spectrograph mode, and from at least 100 events per second in test mode.

4.2.3 Binning

The detector processor shall accumulate the photon events into 14 spatial by 5 spectral bins in imaging mode and 14 spatial by 168 spectral bins in spectrograph mode during each data frame. The bin definitions shall be provided by the telemetry processor software during initialization of the detector processor. In imaging mode, each spectral bin may consist of the sum of any combination of the 168 spectral pixels. The count in each bin shall be reset at the start of each data frame.

4.3 Telemetry Processor Software

4.3.1 Initialization

Initialization software will execute in response to a local or system wide reset. It will also execute in response to the watchdog timer should the timer expire without being reset. Initialization code will stop the instrument in a safe mode, and then it will initialize the telemetry processor so that it is ready to accept commands. Initialization code shall be stored in PROM and cannot be changed once the instrument is on-orbit.

4.3.2 Commands

The telemetry processor will accept command messages from the spacecraft MIL-STD-1553 bus. Discrete commands and block uploads will be supported. A command message may consist of a series of discrete commands. Discrete commands that are time tagged will be stored in the telemetry processor until execution time. Commands that are not time tagged will be executed immediately. Invalid command messages will be ignored. Not all commands are valid in every operating mode. Discrete commands will vary in length. The discrete command functions will be defined in the Flight Software ICD.

4.3.3 Spectrograph Data Processing

4.3.3.1 Imaging Mode Processing

Imaging mode processing software is executed in response to a command. Prior to execution, the appropriate detector selections, motor mechanism positions, and software enable functions must be set as desired. The software will check to see that the spectrograph cover is open before driving the scan mirror motor.

The imaging mode scan cycle begins with the scan mirror located at the start of scan position. The scan cycle will consist of a limb viewing section and an Earth viewing section. The number of spatial pixels and the pixel integration period for each viewing section are defined in Table 1.

During the limb viewing section, the telemetry processor commands the detector processor to begin event processing midway through each cross track pixel period to allow for mirror motion to settle. At the end of the cross track pixel period, the telemetry processor interrogates the detector processor for the accumulated detector data, and then steps the scan mirror to the next position. The data are accumulated over 14 spatial pixels by 5 spectral colors for each cross track limb pixel. Each color may consist of the sum of any combination of the 168 spectral pixels.

During the Earth viewing section, the telemetry processor commands the detector processor to begin event processing at the start of each cross track pixel period. Midway through the cross track pixel period, the telemetry processor moves the mirror one step, because each cross track pixel is accumulated over two mirror step positions. At the end of the cross track pixel period, the telemetry processor interrogates the detector processor for the accumulated detector data, and then steps the scan mirror to the next position. The data are accumulated over 14 spatial pixels by 5 spectral colors for each cross track Earth pixel.

The detector data from each cross track pixel are compressed by the telemetry processor, and then placed into an output buffer. The detector input and output count rates from each cross track pixel are also saved in the output buffer. At the end of the scan cycle, the telemetry processor will also incorporate the background and dark counts, pulse height data, and system housekeeping data into the output buffer. The output buffer will be incorporated into the telemetry data message to be transmitted over the MIL-STD-1553 bus.

After the data collection portion of the scan is completed, the mirror is retraced to the start of scan position. The imaging mode scan cycle with retrace has a period of 15 seconds. The scan cycle will repeat until the instrument is commanded to stop processing.

4.3.3.2 Spectrograph Mode Processing

Spectrograph mode processing software is executed in response to a command. Prior to execution, the appropriate detector selections, motor mechanism positions, the scan mirror position, and software enable functions must be set as desired. The scan mirror can be set to any position within its scan range, including above the horizon to view calibration stars.

With the scan mirror set at a fixed position, the detector processor collects data for a 3 second pixel integration period. At the end of the integration period, the telemetry processor interrogates the detector processor for the accumulated detector data over 14 spatial pixels by 168 spectral bins. The telemetry processor also fetches data for the dark count, the input and output count rates, and one or more pulse heights.

After the data transfer is complete, the telemetry processor will instruct the detector processor to begin collecting data for the next integration period. The previously collected detector data are formatted into 168 spectral bins at 14 spatial pixels, compressed, and placed in an output buffer. The telemetry processor will also incorporate the input and output count rates, dark count, pulse height data, and system housekeeping data into the output buffer. The output buffer will be incorporated into the telemetry data message to be transmitted over the MIL-STD-1553 bus. The spectrograph mode processing cycle is repeated every 3 seconds, until the instrument is commanded to stop processing.

Table 1
Data Frame Characteristics

Parameter	Imaging	Spectrograph
Frame Period	15 sec	3.0 sec
Cross track pixels	32 (Limb) 159 (Earth)	1
Along track pixels	14	14
Colors per frame	5	168
Output Word Size	8 bits	8 bits
Maximum count per pixel	4096	16,384
Pixel Integration Period	0.034 sec (Limb) 0.068 sec (Earth)	3.0 sec

4.3.3.3 Data Compression

All detector data will be compressed using a constrained percent error algorithm. The encoding algorithm will compress the dynamic range of detector data from 12 bits to 8 bits in imaging mode and from 14 bits to 8 bits in spectrograph mode. Data may be encoded using a table lookup scheme or an algorithm.

4.3.3.4 Pulse Height Analysis

During both imaging mode and spectrograph mode, pulse height data will be requested from the detector processor. Once every frame in both imaging mode and spectrograph mode, the pulse height data from at least one event will be downlinked. The pulse height distribution will be computed during ground processing.

Because only a few pulse height samples are obtained in each frame period during normal operation, a test mode shall be defined that downlinks pulse height data from at least 100 events per second.

4.3.3.5 Background Count Processing

The telemetry processor will maintain a sum of all events within a single spectral bin over the frame period. The sum will be called a background count and will be downlinked every frame period. The sum shall be reset to zero at the start of the frame. The spectral bin shall be selectable by ground command. The background count is a measure of the scatter in the spectrograph. The background count will be maintained in imaging mode only.

4.3.3.6 Dark Count Processing

The telemetry processor will obtain a dark count from the detector processor which corresponds to a spectral bin outside the image produced by the spectrograph focal plane but still within the active face of the detector tube. The dark count bin shall be changed by the telemetry processor software after each frame period to prevent against a noisy detector area from corrupting the dark count. The dark count will be maintained in both imaging mode and spectrograph mode.

4.3.3.7 Detector IO Rates

The telemetry processor will obtain data from the detector interface indicating the input count rate, as measured at the detector microchannel plate, and the detector processor output processing rate. The telemetry processor shall include the input and output rates from each detector integration period in the downlinked data. The count rates are used during ground processing to correct for the dead time in the detector event processing.

4.3.3.8 Detector Processor Interrogation

Since the detector processor can not process detector data while it is interrogated by the telemetry processor, the interrogation process shall not decrease the detector integration period by more than 5 milliseconds when in the imaging mode, and by more than 50 milliseconds when in the spectrograph mode. Control of the detector processor should attempt to minimize the period that the detector processor spends in the interrogation mode.

4.3.3.9 Spectrograph Sun Sensor

The telemetry processor software will monitor the detector input rate to protect the detector from bright objects. The spectrograph does not include a separate sun sensor component. The telemetry processor will disable the active detector high voltage power supply when the input rate threshold has been exceeded.

4.3.4 System Monitoring Functions

The system monitoring functions involve reading telltales, monitors, and status information and incorporating this data into the telemetry message once per frame in imaging mode or spectrograph mode. In general, all telltales and monitors are included as part of the monitoring task. In addition, several parameters relevant to the operating mode are also incorporated in the data frame. These parameters include the definitions of all five imaging mode colors, the last executed command, the dark and background counts, and the input and output rates. In imaging mode, a scan mirror indicator word is also maintained which can be used on the ground to verify proper positioning of the scan mirror. The word will indicate the cross track pixel number at which the start of scan and nadir positions were observed. The telemetry processor is also responsible for incorporating any status word(s) produced by the detector processor into the mission data stream.

4.3.5 Maintenance Mode

4.3.5.1 Software/Data Upload

The telemetry processor software will include a maintenance mode which will support upload of data and software over the MIL-STD-1553 bus to the telemetry processor memory. The software upload will allow for changes to be made to the operating code stored in the processor EEPROM as required. The telemetry processor will verify each software upload before modifying memory.

4.3.5.2 Memory Dump

The telemetry processor will support a dump of system memory, either RAM, PROM, or EEPROM, to the ground via the MIL-STD-1553 bus interface.

4.3.5.3 EEPROM maintenance

The telemetry processor software will support a mechanism for copying data or software from RAM to EEPROM and from EEPROM to RAM.

4.3.5.4 Program Execution

The telemetry processor software will support a mechanism for executing programs that have been loaded into RAM.

4.3.6 Telemetry Data

4.3.6.1 Telemetry Packet

The standard telemetry packet for the TIMED spacecraft is defined in the TIMED General Instrument Interface Specification (GIIS).

4.3.6.2 Packet Template

A general format will be used for all GUVI telemetry packets, shown in table 2. Every packet in a message will include a primary header, a secondary header, and 248 bytes of source data. The secondary header contains a time stamp, a packet identifier word, and a checksum value. The mode dependent data will be contained in the source data block.

Table 2
Items Common To All Telemetry Packets

1) Primary Header
2) Secondary Header
    - Time Stamp
    - Packet Identifier
    - Checksum
3) Source Data

4.3.6.3 Message Types

There are five different types of GUVI telemetry messages. The message types are imaging, spectrograph, test, maintenance, and housekeeping. The packet definitions for the five message types will be defined in the Flight Software ICD.

4.3.6.4 Imaging Message

The imaging message type will apply for the imaging mode. The message period is 15 seconds. The imaging message contains the pixel and rate data collected during the 15 second line scan. The imaging pixel data consist of 191 cross track pixels by 5 colors by 14 along track pixels. Each pixel word is 8 bits. The along track pixel index will vary first, the color index second, and the cross track index last. The rate data consist of a 16 bit input rate word and a 16 bit output rate word for each of the 191 cross track pixels. Imaging mode pulse height and housekeeping data are contained in the housekeeping data message.

4.3.6.5 Spectrograph Message

The spectrograph message type will apply for the star and wavelength calibration modes. The message period is 3 seconds. The spectrograph message contains the pixel data collected during the 3 second spectrograph scan. The spectrograph pixel data block consists of 168 spectral bins by 14 along track pixels. Each pixel word is 8 bits. The along track pixel index will vary first, and the spectral index second. Spectrograph mode status and housekeeping data are contained in the housekeeping data message.

4.3.6.6 Test Message

The test message type will apply for the test mode. The message period is 1 second. The test message contains the pulse height data collected during the detector test mode. Test mode housekeeping data are contained in the housekeeping data message.

4.3.6.7 Maintenance Message

The maintenance message type will apply for the maintenance mode. The message period is 1 second. The maintenance message contains memory dump data from the GUVI flight processor. A scrolling or fixed location memory dump can be performed. Maintenance mode housekeeping data are contained in the housekeeping data message.

4.3.6.8 Housekeeping Message

The housekeeping message type will apply for all operating modes. The housekeeping message will contain instrument status and housekeeping data. The housekeeping message will use a separate application process identifier in the primary header. The housekeeping message will consist of a single packet. The message period will be equal to the period of the current operating mode message.

4.3.7 Instrument Status Word

The GUVI instrument status word is a 64 bit word that indicates the current operating mode and status of the instrument. The status word is used by the ground station to obtain real time status of the instrument. The instrument status word will be defined in the Flight Software ICD.

5. Special Requirements

5.1 Hardware Requirements

The GUVI Flight Software will execute on microprocessors resident in the GUVI ECU. The detector processor is a Harris RTX2000 microprocessor. The RTX2000 was selected because it will meet the detector processor requirement for photon event processing rate (200 KHz maximum). The telemetry processor is an 80C186 microprocessor.

The telemetry processor will have three types of memory - RAM, EEPROM, and PROM. The PROM will provide unchangeable storage, the EEPROM will provide storage which can be changed by command, and the RAM temporary storage which is lost when powered off. The detector processor will consist of PROM and RAM memory. All flight software will reside in either PROM or EEPROM, but may execute out of RAM.

5.2 Programming Language

The detector processor flight software will be written using the Forth language. The telemetry processor flight software will be written using the C++ language. If necessary, assembly language may be used as either inline code or as a linked module for both the detector and telemetry processor software.

5.3 Processing Resources

Processing resources shall be adequate to meet all requirements with a 30% margin for growth to the maximum extent practical. The resources include processing units, input/output devices, peripheral devices, software, and firmware.

5.4 Maintainability

The GUVI instrument shall provide the operator with enough diagnostic information to efficiently and effectively detect and correct program errors. The software shall be designed to provide maximum flexibility for modification and expansion.

Any on-orbit modifications to the GUVI Flight Software will require the approval of the GUVI software review board. The GUVI program will retain software development capability to provide support for on-orbit modifications of the GUVI Flight Software during the operational life of the instrument.

5.5 Software Delivery

The operational GUVI Flight Software will reside in both PROMs and EEPROMs, which will be installed in the GUVI instrument upon delivery. In addition, source code will be available on magnetic medium. The software version number shall be a part of the object code, and downlinked via a memory dump.

5.6 Data Base Requirements

The GUVI instrument is not required to provide non-volatile storage of GUVI data. The on-orbit storage capability is provided by the TIMED spacecraft. The GUVI Flight Software shall provide buffer storage for at least 15 seconds of GUVI data to allow for uninterrupted data transfer to the spacecraft.

The telemetry processor shall provide non-volatile storage for GUVI operating mode states and data tables used for color definition and data compression.

5.7 Identification And Marking Requirements

The deliverable software elements shall be identified by the processor name and board number in which the software element is located. The software shall also be identified as either PROM or EEPROM resident elements.

6. ACRONYMS AND ABBREVIATIONS

C&DH	Command and Data Handling
Co-I	Co-Investigator
ECU	Electronics Control Unit
EEPROM	Electrically Erasable Programmable Read Only Memory
GIIS	General Instrument Interface Specification
GSE	Ground Support Equipment
GUVI	Global Ultraviolet Imager
ICD	Interface Control Document
IO	Input/Output
JHU/APL	The Johns Hopkins University/Applied Physics Laboratory
KHz	Kilo-Hertz
nm	nanometer
PI	Principal Investigator
POC	Payload Operations Center
PROM	Programmable Read Only Memory
RAM	Random Access Memory
SIS	Scanning Imaging Spectrograph
TIMED	Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics
UV	Ultraviolet