

IMAGE/FUV

**DPU Flight Software
Requirements Specification**

**Space Science Lab
University of California, Berkeley**

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IMAGE/FUV DPU Flight Software Requirements Specification

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1. INTRODUCTION

This is the **Software Requirements Specification** document for the IMAGE/FUV DPU.

This document goes beyond the controlled SRS, incorporating changes.

IMAGE/FUV instruments observe the Earth from a satellite, which spins once every 120 seconds. Data products are generated every spin. The orbit varies between 1.15 and 8 Earth radii.

1.1 Derivation of Requirements

The *UCB* **FUV Instrument Specification** describes what IMAGE/FUV is to do overall, and how it is put together.

The *UCB* **DPU Requirements** document specifies the general requirements for the DPU as a component of the MEP.

The spacecraft is controlled by the Common Instrument Data Processor (**CIDP**). The interface to the CIDP is given in the *Southwest Research* **CIDP Interface Control Document**.

Data products and their management is generally specified in the *NASA* **IMAGE MIDEX Mission - Project Data Management Plan**.

1.2 Related Documents

IMAGE FUV Commands – specifies the possible ground commands sent to the DPU.

FUV L0 Packages – an EXCEL spreadsheet file which defines the data packages sent out by the DPU.

1.3 Terms Used in this Document

byte 8-bit unsigned number

CIDP Common Instrument Data Processor — the Spacecraft Computer

DLUT Distortion Lookup Table — corrects image geometric distortion

DPU Data Processing Unit — the flight processor

MEP Main Electronics Package.

TDC Time-to-Digital Conversion — how SI events are generated

TDI Time-Delayed Integration — how WIC and SI images are accumulated

word 16-bit unsigned number

1.4 Requirements Overview

1.4.1 Instruments

IMAGE/FUV consists of four detectors:

- **WIC** is a CCD which generates a pixel image in the LBH bands.
- **SI-12** is a microchannel plate; it generates an array of photon counts, looking at 1216 Angstroms
- **SI-13** is a microchannel plate; it generates an array of photon counts, looking at 1356 Angstroms.
- **GEO** is the geocorona detector. It is an array of three photometers, pointing in different directions.

WIC and the SI's generate images only during the portion of the spin when they are pointed at the earth - about 10 seconds.

GEO takes data continuously, about 360 samples per spin.

1.4.2 Power

There are several power busses, divided into two groups:

- Standby power: always on
- Data Collection power: on only during earth-sweep data taking interval

There are numerous measurement points for power and temperatures

1.4.3 Spacecraft Interface

The DPU is connected to the CIDP using a pair of RS-485 serial lines, one for transmit and one for receive.

Ground commands are received by the CIDP and relayed to the DPU.

The DPU generates telemetry as data packages, transmits them to CIDP which encapsulates them into the rest of the satellite telemetry.

1.4.4 Time

Mission Elapsed Time (MET) is delivered from the spacecraft once per spin, just before the Nadir mark.

Time format is described in the CIDP ICD:

1.4.5 DPU Functions

The DPU is an 8085 microprocessor, plus memory and interface electronics. The major functions of the DPU Flight Software are:

- Load the DLUT in the MEP (initially)
- Turn instrument high-voltage power on during data taking; off at other times
- Calculate and set the TDI rates, offsets and durations
- Start and stop WIC and SI data taking by the MEP
- Gather GEO samples at regular intervals
- Build SI PHA Histograms
- Execute ground commands
- Monitor voltages and temperatures
- Monitor the sun-sensors
- Generate science telemetry
- Generate housekeeping telemetry

1.4.6 Telemetry

Every spin, the DPU generates a cycle of telemetry products, called data packages. The packages are defined in an EXCEL spreadsheet - filename "L0_TLM.XLS".

Telemetry is generated by a combination of direct emission of "header" data from the DPU, and hardware-controlled readouts of the TDI memories.

2. REQUIRED SOFTWARE FUNCTIONS

2.1 Initialization

2.1.1 Put interfaces into a known state

All output values shall be commanded to zero, “off”, or some appropriate benign state. High voltages shall be set to off.

2.1.2 Load Distortion Lookup Table (DLUT)

The DLUT memory in the MEP shall be loaded sequentially by rows. Each row has 512 elements. Each element is a pair of coordinates (column, row). There are 256 rows.

The DPU shall signal the MEP that a load is starting, transfer the coordinates, then signal the MEP that loading is complete.

A checksum of the WIC DLUT shall be stored in the NVRAM. If the checksum fails, the DPU shall still load the DLUT, and indicate a **DLUT Checksum Fault**.

2.2 Receive Input from CIDP.

CIDP input arrives in asynchronous message bursts. Messages begin with a 3-byte Sync Pattern, and end with a Checksum.

The format and frequency of CIDP input messages are defined in the **CIDP Interface Control Document**.

2.2.1 Command Message

These are ground commands, passed through from the CIDP. The format of the commands are defined by FUV, in the **Commands** document.

2.2.2 All-Is-Well Message

CIDP signals that it is still running. See CIDP ICD for details.

2.2.3 SAFE Message

Signals DPU to shut down. See CIDP ICD for details.

2.2.4 Periodic Message

This message is defined in Table 12 of the CIDP ICD. Periodic messages arrive about once per 7.5 seconds. All Periodic Messages contain orientation and rate information.

Once per spin, just before the Nadir time, the Periodic Message contains the MET of the next nadir pulse.

This will set the DPU's spacecraft time. The DPU shall store the 6 bytes of time in the DPU Spacecraft Time register. Time will be set on the next Nadir pulse.

2.2.5 Commands

Command format is described in the **IMAGE FUV Commands** document.

2.2.5.1 Command Verification

If the Command Checksum fails, the DPU shall increment an error counter, store the command code as "last bad command received" and reject the command.

If the Command Data is found invalid by the DPU, the DPU shall increment a different error counter, store the command code as "last bad command received" and reject the command.

2.2.5.2 Command Echoing

Some commands shall be echoed. The DPU transmits one or more Command Echo packages. Codes shall indicate whether the command was executed, and if not, the reason for rejection.

2.2.5.3 Command Processing

The DPU shall process some commands directly. Other commands shall be sent to the hardware via the Command Data Interface (CDI).

2.2.5.4 Critical Commands

Commands designated as “critical” must be preceded with a “May I?” command. The “May I?” sets a software switch, which enables execution of critical commands. The switch shall be reset after any other command is processed.

Critical commands not preceded by “May I?” shall not be executed, but echoed with an error indication.

2.3 Set Rates and Durations

The duration of the sweep past the earth depends on the size of the earth in the image, the spin rate, and the orbital velocity (when near the earth). The DPU shall determine:

- initial offset into MEP memory
- step rate per **frame** interval, in X and Y
- duration of data taking

A separate set of values shall be computed for the WIC and the two SI (SI-12 and SI-13 are boresighted).

The DPU shall use the Geocentric Distance to access a table which gives the duration of the earth sweep. Near the earth, the Geocentric Distance (GCD) table gives a correction factor for the spin rate.

The DPU shall send the Rate and Duration values to the MEP before the earth sweep begins.

2.4 Command the Power

There are two power groups.

One group shall be commanded on by the DPU during initialization, and left on.

The other group shall be turned on at the beginning of WIC and SI data taking, and off afterward.

The DPU shall determine power groups from a fixed table.

2.5 Read the Housekeeping Channels

After each power turn-on, the DPU shall switch the various multiplexors and read the A/D converter. The results shall be stored in a Housekeeping data package.

Some power busses require a delay after turn-on, before housekeeping may be read. The DPU shall get the delays from a fixed table.

2.6 Start an Earth Sweep

Each spin, the DPU shall calculate the start-time for WIC and SI to begin data taking.

When the start-time arrives, the DPU shall command the instrument. Because of the different fields of view, WIC and SI are commanded separately.

The start time shall be such that 2 times the detector field of view sweeps past the earth, centered on the time when the center of the detector points toward the nadir.

Start = Ibore - FOV/2 + Ioffset

Ibore is the fixed angle between the nadir direction and the bore-sight of the instrument.

Ioffset is the positive or negative offset which is unique to the instrument, and the geocentric distance (see below). This comes from the GCD table.

FOV is the fixed horizontal field of view of the detector.

Angles are converted to **frame** units for actual timing.

WIC does two non-valid frames before beginning accumulation. The purpose is to clear the charge on the CCD. This means the WIC should be started 2 **frame**-times early.

2.7 Near-Earth Sweeps

When the satellite is close to earth, the field of view covers only part of the earth. During these periods, it is possible to extend the field of view along the direction of the spin plane. This is done at the expense of resolution: the MEP divides horizontal pixel coordinates by some **factor**. In addition, the duration of TDI integration is extended by the same **factor**.

Below the geocentric distance, the TDI start-time shall be adjusted to move the center of the WIC and SI field of view by a time-offset, plus or minus. The duration of data taking shall be multiplied by the **factor**.

2.8 GCD Table

The TDI rate and initial offset are different depending on the geocentric distance on the satellite. The DEP shall store table of geocentric distances, and associated parameters:

- GCD value
- rate **scale** for orbital motion
- TDI **factor** for near-earth sweeps (1, 2, 4 or 8)
- Ioffset
- duration

The table shall contain enough entries to cover the entire orbit. . The table shall be stored in monotonic increasing order of GCD. The entries near the earth will be closer together in GCD.

The DPU shall multiply the calculated X and Y rates by **scale**, and deliver the results to the MEP..

The software shall select a table entry depending on the current satellite geocentric distance. The program shall search the table, starting at the lowest GCD, until the table GCD exceeds the current GCD of the satellite.

Commands shall be available to modify individual table entries.

The index of the current GCD table entry shall be stored in the FUV header of all telemetry packages.

2.9 Sample GEO detectors

The DPU shall sample the GEO detectors about 360 times per spin, using a constant integration time of 1/3 second.

The DPU gets an interrupt when a GEO sample should be taken. On the interrupt, the DPU shall read the 3 GEO detectors and store their values in an array, which will become part of telemetry.

The DPU shall record the time of the first and last sample of a set of 360. It shall also record the Periodic Message data received during the GEO sample accumulation.

2.10 Sample Pulse-Height Data

The DEP shall read the pulse-height analyzer output for SI-12 and SI-13.

Samples shall be taken as fast as possible during the data-taking period.

PHA samples shall be used to accumulate a histogram. The PHA value is 0..255, so the histogram will have 256 slots. The accumulation slot shall be a 16 bit word.

There shall be 4 histograms: X and Y for SI-12, and X and Y for SI-13.

Every 8 spins, the histograms shall be made into a histogram data package and sent to telemetry.

2.11 Monitor Sun Sensors

The DPU shall keep a table of sun-sensor state transitions, and report this data, up to 16 transitions per spin, as part of housekeeping. Each transition shall be stamped with MET.

2.12 Generate the Telemetry Stream to the CIDP

2.12.1 Data Packages

Data packages shall be generated once per spin. Packages may be sent at any time, but all packages associated with a given spin must be transmitted before the next Nadir pulse. The CIDP buffers the data packages, and builds them into CCSDS packets for transmission to the ground.

Each data package includes an ApID code, and an array of data bytes. The format is described in the CIDP ICD.

The DPU shall transmit a complete set of Science and Housekeeping data packages to the CIDP, every spin.

2.12.2 ApID Translation

To make an 11-bit CIDP ApID, the CIDP appends the FUV instrument code 0001 to the low 7 bits of the product code; the result is the CCSDS ApID.

For example, the WIC image is sent as product codes 01 and 02. These packages will appear on the ground as CCSDS ApIDs(hex) 81 and 82.

Bit 6 is used to distinguish science data (0) from housekeeping (1). They go down different channels.

2.12.3 FUV Data Header

The layout of all the FUV data packages is defined in EXCEL document “**L0_TLM.XLS**”. *The offsets in the EXCEL document start with 0, which corresponds to CIDP offset 7.*

The Spin Number shall refer to the spin during which the data was taken, or started to be taken – which need not be the spin during which the package is transmitted. *Note that the spin number on FUV data is internally generated; it will not necessarily correspond to spin number in other IMAGE experiment telemetry.*

The Header Checksum shall be computed by the DPU as the 8-bit sum of all the other FUV header bytes.

3. NVRAM PARAMETERS

The DPU shall store a set of parameters in “Non-Volatile RAM” (NVRAM), in order to retain these values between DPU resets.

3.1 Checksum

A checksum shall be maintained on the NVRAM contents. If the checksum indicates corruption of the NVRAM, the DPU shall signal this event in telemetry, and shall set all NVRAM values to nominal.

3.2 Telemetry

The contents of the NVRAM shall be send in telemetry, every spin

4. FAULTS

The DPU software shall be able to handle faults -- exceptional conditions, which may be caused by hardware malfunction, improper commanding or software error.

The general guideline is to report the fault, and quickly return the instruments and interfaces to a “safe” condition.

Fault data and flags shall be stored in NVRAM.

4.1 Missing Nadir Pulse Fault

Detected by: more than N seconds since the last nadir pulse

Software Action:

set “no nadir” status flag,

Fake the Nadir by using a stored offset from the Sun. If no Sun pulse is found, the DPU shall take data at about 120 second intervals.

Cleared by: seeing a nadir pulse.

4.2 Sun-Sensor Failure Fault

Detected by: not seeing sun-sensor transition for N spins

Software action: Set information flag in housekeeping; there are times when the sun is never in view.

Cleared by: any transition of the sun-sensors

4.3 CIDP Input Fault

Detected by: more than 2 seconds without “all is well” message from the CIDP.

Software action: Go to “safe” mode.

Cleared by: resumed “all is well” messages.

4.4 Code Checksum Fault

Detected by: failure of executable flight code to match stored checksum

Software action: execute PROM version of flight code

Cleared by: reload of the offending part of EEPROM, recompute checksum

4.5 WIC DLUT Checksum Fault

Detected by: failure to match stored checksum for the WIC DLUT stored in EEPROM.

Software action: none

Cleared by: ground command, after reload of WIC DLUT EEPROM.

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