C.4 IMPACT IDPU

The IDPU shall be the single point electrical interface between the IMPACT instrument complement and the spacecraft bus. It also serves as the processing element and spacecraft interface for the PLASTIC instrument. Its tasks are to control the instruments operations, collect and compress telemetry from the instruments, and provide the command, telemetry, timing, and status interface to the spacecraft.

The IDPU shall also provide the ability to capture high time resolution data during events such as CMEs. This collection shall be coordinated with similar collection in the SWAVES instrument.

The 3DC instrument and its interface to the IDPU, included in the IMPACT proposal, were de-scoped at selection. The PLASTIC instrument interface is also new since selection. This provides better on-board science coordination between IMPACT and PLASTIC, similar to the originally proposed IMPACT suite. Sharing processing resources saves the Project mass and power.

C.4.1 System Description

The IDPU shall contain a modest 16-bit microprocessor (the UTMC UT80CRH196KD microcontroller running at 10MHz is baselined), a 1553 interface to the spacecraft, and serial digital interfaces to the instrument front-end electronics. The IDPU shall also contain a low voltage power supply and the analog front-end electronics for the Magnetometer. A block diagram of the IDPU is shown as part of the system block (figure C.1-1). The glue logic between these elements shall be implemented using Actel Field Programmable Gate Arrays (FPGA).

The IDPU flight hardware includes a PROM that shall contain the flight software. This software shall be copied into RAM on processor reset and executed there. This provides the maximum degree of flexibility to make minor or major changes to the software after launch. We are considering adding an EEPROM or Flash memory in addition to the PROM. This would allow post-PROM installation versions of the software to be semi-permanently loaded. This removes the risk of having to change PROMs due to late software modifications as a result of system level testing, and avoids having to reload post-launch software modifications on reset. The down side is finding an appropriate part, and the additional complexity (another Integrated Circuit and some minor additional software).

C.4.1.1 IMPACT and PLASTIC Instrument Interfaces

The IDPU communicates with the instruments over a set of identical high speed serial interfaces, as described in a draft specification document "STEREO IMPACT Intra-Instrument Serial Interface", dated 9-June-2000. This is a 3-wire bidirectional self-synchronizing interface including a continuous clock to allow for intra-instrument synchronization. Separate serial interfaces shall run to the MAG analog electronics, PLASTIC, SEP, and SWEA/STE. The MAG, SWEA, STE, and PLASTIC instruments communicate with the IDPU processor at a low level. The IDPU sends register-level commands to control the instrument modes and reads back counters and converted analog measurements. For these instruments the processor software is involved in an intimate way with the operations and telemetry. Interface hardware at both ends of the serial interface shall be designed to perform the routine data handling and the time-critical instrument control functions so that the processor timing requirements are relaxed. The SEP instrument sub-suite has its own processor that performs these functions. The IDPU is basically a bent-pipe for SEP commands and telemetry. The details of the functions performed for the instruments by the IDPU and the telemetry generated is described with the instrument sections.

C.4.1.2 Burst Memory

The processor system shall include a two-megabyte memory for burst telemetry collection. This burst memory shall be used to collect selected data with high time resolution when the instrument identifies an event. This memory shall then be played out as a part of the normal IMPACT telemetry over a long interval. Event identification will be made based on instrument data from SWAVES as well as IMPACT and PLASTIC, with triggers defined in the on-board software.

C.4.1.3 SWAVES Interface

SWAVES and IMPACT will coordinate burst triggering using information exchanged periodically over the 1553 bus. The Spacecraft has agreed to coordinate an RT to RT message in each direction between IMPACT and SWAVES five times a second. The design of the burst trigger scheme and its coordination with SWAVES has been delegated to a committee including one IMPACT and one SWAVES member, who will generate an ICD in Phase B.

C.4.1.4 Housekeeping

In addition to science and burst telemetry, the processor shall collect and send housekeeping information at a low rate. This data shall include instrument state of health and status information, including command verification, error flags, instrument modes, temperatures, voltages, etc.

C.4.1.5 Spacecraft 1553 Interface

The interface to the spacecraft avionics for command, telemetry, timing, and status, is via the common spacecraft 1553 bus. This is the same bus used to exchange burst trigger data with SWAVES as described above. Commands and telemetry shall be packetized into CCSDS standard packets. This interface is described in the APL Spacecraft/Investigation ICD, current draft version 1.3.

C.4.1.6 Low Voltage Power Supply

The IDPU includes a low voltage power supply that provides voltages for the processor and magnetometer analog front-end card. This supply works off a 28-volt service provided by the spacecraft, as described in the Spacecraft/Investigation ICD. The SEP and SWEA/STE units contain separate low voltage power supplies run off separate spacecraft power services. This is different from the proposed configuration, in which the IDPU contained a common LVPS for the suite. This scheme improves reliability by providing failure isolation between the major modules of the suite.

C.4.2 Development Plan

The IDPU shall be designed and manufactured by UCB, with the exception of the Magnetometer front-end electronics, which is designed and fabricated by GSFC. Software for the IDPU processor shall be written at UCB. No new technology or special development is required for the IDPU; the design shall be based on designs for many previous missions at UCB.

C.4.2.1 Requirements Refinement and ICDs

Early in Phase B ICDs shall be written for each IDPU to Instrument interface. These documents shall cover hardware and software requirements on the IDPU. The Software requirements shall evolve with the instruments, but will be sufficiently detailed to adequately size the processor resources before work processed on the IDPU design. At the same time, a more detailed IMPACT/Spacecraft ICD shall be evolving.

Following this collection of requirements, an IDPU system-level design shall be generated, sizing resource requirements, allocating tasks between hardware and software, and between different boards, and between FPGAs. At this point, long lead parts ordering for the IDPU can commence. Next detailed FPGA requirements specifications can be written, and board design can commence.

C.4.2.2 Engineering Test Unit

When designs are complete, an Engineering Test Unit (ETU) of the IDPU shall be built. This shall use the flight board form factors and parts packaging, but shall use commercial parts. This ETU shall serve as the test bed for FPGAs as well as for the development of IDPU software. Instrument ETUs shall be tested with the IDPU ETU to verify interfaces and early software drivers. Build number 1 of the flight software shall be targeted for ETU testing, having sufficient capability to verify correct operation of the hardware and interfaces.

C.4.2.3 Flight Units

Once the ETU testing is complete, and after the completing Comprehensive Design Review process, fabrication of the Flight Units shall commence. The ETU design shall be updated in response to results of ETU testing prior to fabrication of flight circuit cards. The first flight unit of the IDPU (FM1) shall complete testing prior to start of fabrication of the second unit (FM2). This shall allow lessons learned on FM1 to be fixed on FM2 before fabrication. This also provides some margin in the schedule, since FM2 could be started earlier if the schedule for FM1 slips.

The IDPU is expected to be completed in advance of the instruments due to the simpler nature of its development and fabrication. This will allow the IDPU to be available for instrument interface tests and calibrations as required. The flight software will not be finalized until after interface testing with all the instruments. This will involve a change in the flight code PROM late in the development effort. Software build number 2 will be used for flight IDPU testing and instrument interface tests, while Build number 3 is the final flight build.

The performance assurance plan for development of the IDPU is called out in the IMPACT Performance Assurance Implementation Plan (PAIP), attached as an appendix to this document.

C.4.2.4 Environmental Tests

The FM IDPU shall undergo random vibration and thermal vacuum testing as a subsystem. FM1 shall complete these tests early in the schedule to verify the design, before FM2 fabrication begins. This may involve having to re-test FM1 if changes are found to be required in system-level tests. EMC testing (Radiated and Conducted Emissions) will be performed at the system level, as soon as the full instrument suite can be assembled.

C.4.2.5 Flight Software

UCB has decades of experience in developing flight software for systems such as the IMPACT IDPU. A single programmer working closely with the hardware engineers and scientists shall develop the IDPU flight software. The software will be developed iteratively, using as a test bed the ETU IDPU, together with ETU instruments or simulators.

The first step in the software development shall be the collection of software requirements in sufficient detail that software resources can be evaluated and the software system designed. Software resource requirements must be evaluated early to the extent that they impact the hardware design (processor clock speed, memory size). Once a top level software design is in place, coding begins on build number 1, which concentrates on the software structure and low level hardware drivers. This code must be available for testing of the ETU IDPU, and be capable of testing all the hardware interfaces.

The second build must have all the basic features of the code, adequate for system-level testing of the IMPACT/PLASTIC suite. It may be missing some high-level science code such as the burst triggers, and may not have been fully tested with instruments.

The third build has all functionality and is the version that flies. The distinction between these versions is somewhat arbitrary, as the code is written iteratively with many more versions than described here. The utility of these build designators it to aid in tracking development, particularly where the software and hardware schedules are linked. They also correspond to progressively more stringent levels of configuration control.

The development plan is described in the IMPACT Performance Assurance Implementation Plan attached to this report.

C.4.2.6 GSE

While the IDPU is being designed and the ETU built, GSE will be simultaneously designed and built to support the IDPU and instruments. Two types of GSE shall be built; one shall simulate the spacecraft interface to the IDPU, and the other shall simulate the IDPU interface to the instruments. These GSE shall be PC-based systems, evolved from GSE developed from earlier missions.

C.4.2.6.1 Command and Telemetry GSE. The spacecraft simulator GSE shall be based on the APL-supplied spacecraft simulator system. On top of that, a UCB-developed Command and Telemetry GSE system shall be added. This system shall be based on the standard UCB GSE design that has evolved from program to program. It is a modular, LabView CVI-based system. It includes a text command parser, command packet formatting, and telemetry display system. The command parser can run from scripts, and these scripts have STOL-like rudimentary programming features. The display system includes numeric read-outs and graphics, and includes value conversion and limit checking. The display system is targeted primarily at housekeeping displays. The more complex science displays are added as separate modules, communicating by TCP/IP with the main Command & Telemetry GSE program. This allows the various instrument teams to develop their own displays of their data.

The Command & Telemetry GSE shall be used throughout bench, Suite I&T, spacecraft I&T, and mission operations. It is believed that the interface to the APL spacecraft simulator, the APL Spacecraft GSE, and the Science Center systems shall be a uniform TCP/IP based system. This shall facilitate transitions between stages in the development.

C.4.2.6.2 IDPU Simulator GSE. The instruments will need a GSE to simulate the IDPU during pre-integration tests. UCB shall develop such a GSE. It shall include a hardware serial interface simulator, plus software similar to the Command and Display software described above to control the instrument and display its telemetry. Particularly in the case of SEP, the GSE shall look as much alike as possible so that command scripts and Science Displays developed for one GSE can be used for the other.

C.4.3 Management Processes

C.4.3.1 Roles and Responsibilities

The IDPU hardware and flight software will be designed, fabricated, and tested by the UCB team, under the direction of IMPACT Project Manager David Curtis, with the exception of the Magnetometer front-end electronics, which shall be designed and fabricated by the GSFC MAG team under the direction of MAG CoI Dr. Acuna.

The Spacecraft Simulator GSE (2 copies) will be provided by APL, while UCB will be responsible for the IDPU Simulator hardware and the Command and Telemetry software used for both. GSE Science Displays for the SEP suite shall be developed by the SEP team, led by Caltech, while those for the PLASTIC instrument shall mostly be developed by the PLASTIC team at UNH. The rest of the GSE science displays, for SWEA, STE, and MAG, will be developed at UCB.

C.4.3.2 IMPACT Team Interfaces

The IDPU requirements are mostly derived from the instrument requirements. Before beginning design work on the IDPU, all requirements shall be documented in the form of ICDs between the instruments and the IDPU. In addition, the IDPU design team will stay in close touch with the engineers and scientists designing the instruments via weekly telecons, periodic team meetings, and technical interchange meetings, and cross-team peer reviews.

C.4.3.3 Heritage

The IDPU system is similar to units developed by UCB and flown on many previous spacecraft, such as HESSI, FAST, Wind, Polar, Cluster, AMPTE, and CRRES. The flight software structure, algorithms, and development plan is also derived from these missions. The UCB Command and Telemetry GSE has evolved together with the IDPU from mission to mission as the technology improved.

C.4.2.4 Performance Assurance Implementation Plan

The IMPACT PAIP included as Appendix B to this report describes the system to be used in the development of the IDPU.

C.4.3.5 ITAR Issues

The IDPU shall be designed, developed, and fabricated entirely inside the United States. The instrument interfaces are also with institutions entirely in the United States (the part of SWEA that interfaces to the IDPU is designed at UCB, while the part of SEP that interfaces to the IDPU is designed by Caltech). The only possible ITAR or import/export issue involved with the IDPU is that the PLASTIC team wishes to take a flight IDPU and associated GSE with them for PLASTIC calibrations in Bern, Switzerland. Any export documentation and licensing involved will be handled by the PLASTIC team.