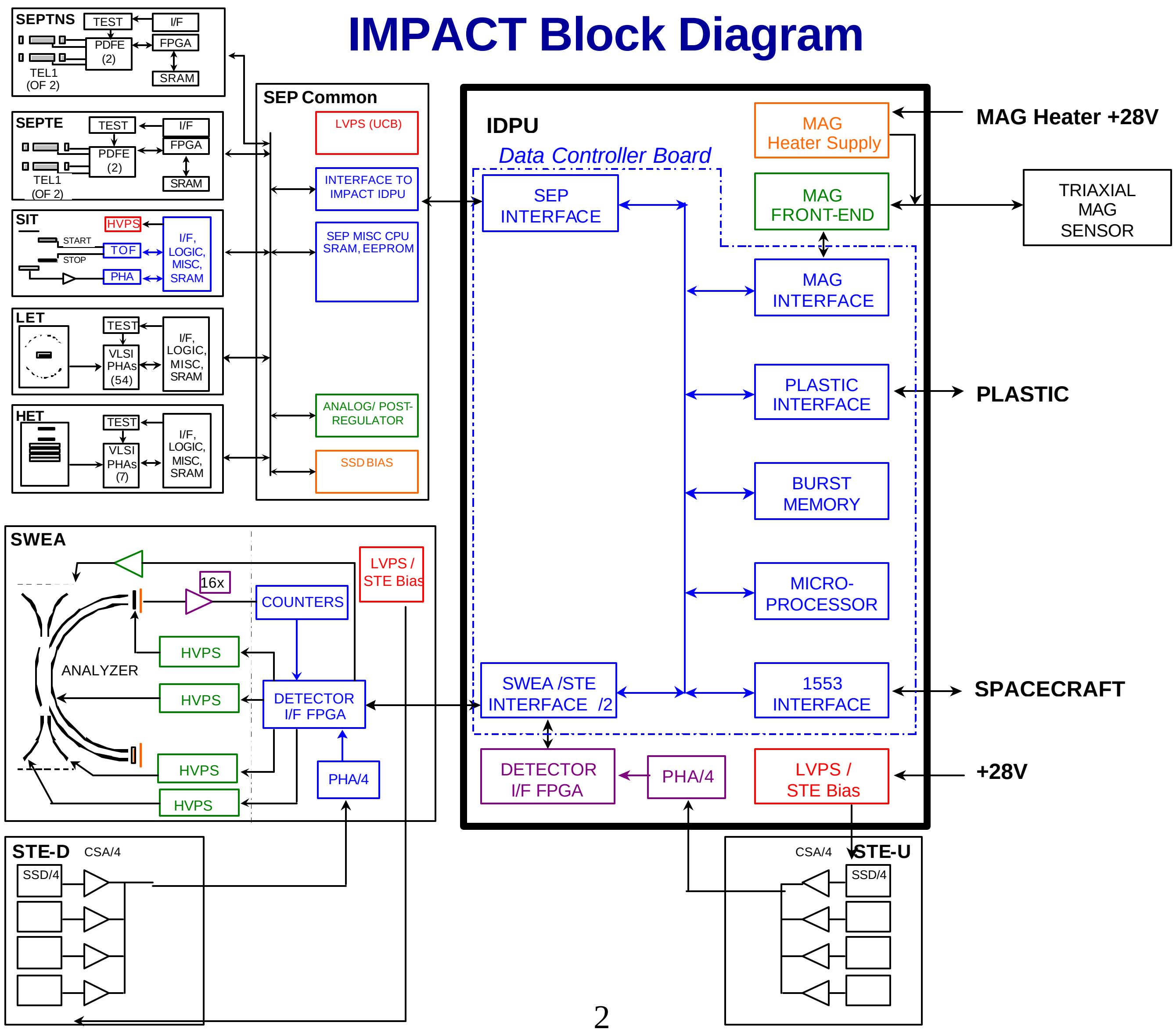
Instrument Data Processing Unit (IDPU)

David Curtis, UC Berkeley Space Sciences Lab,
dwc@ssl.berkeley.edu, (510) 642-5998

IMPACT Block Diagram



IDPU Requirements

- **A single-point interface between the IMPACT and PLASTIC instruments and the spacecraft C&DH system (1553 bus)**
- **Provide instrument control, data collection, compression, and formatting for the IMPACT and PLASTIC instruments**
  - **Note SEP has its own processor, so the IDPU acts mostly as a bent pipe for commands and telemetry to SEP**
- **Provide a home for miscellaneous instrument electronics, such as the MAG front end and the second STE front end**
- **Provide a common design, simple serial interface to the instruments tailored to meet the instrument needs**
  - **Instrument mode commands**
  - **Instrument data collection**
  - **Common sample and spacecraft timing distribution**
- **Provide a 2Mbyte Burst Memory to record short intervals of high time resolution data**

IDPU Interfaces

- **Spacecraft 1553 Interface**
  - **Command, Telemetry, Status, Timing**
  - **SWAVES Burst Trigger Exchange**
    - **RT to RT once a second in each direction**
- **Spacecraft 28V power interface**
  - **powers IDPU, MAG, Sunward STE**
  - **Separate power services provided by the spacecraft for SEP, SWEA/STE-D**
- **Serial Instrument Interfaces**
  - **SEP, PLASTIC, SWEA/STE-D**
  - **MAG and STE-U interfaces to internal cards**
- **MAG Sensor Interface**
  - **To MAG Front End Card in IDPU**
- **Sunward STE Interface**
  - **To STE-U Interface card in IDPU**

IDPU Resources

IDPU:	Mass, kg	Power, W	Telemetry, bps
Mag Card	0.30	0.38	
DIB Card (STE)	0.30	0.20	
DPU Card	0.30	2.30	
S/C Interface (on DPU card)		0.50	
IDPU LVPS	0.40	1.49	
Mag Heater Control	0.07		
BOX	0.65		
IDPU Total:	2.02	4.97	754

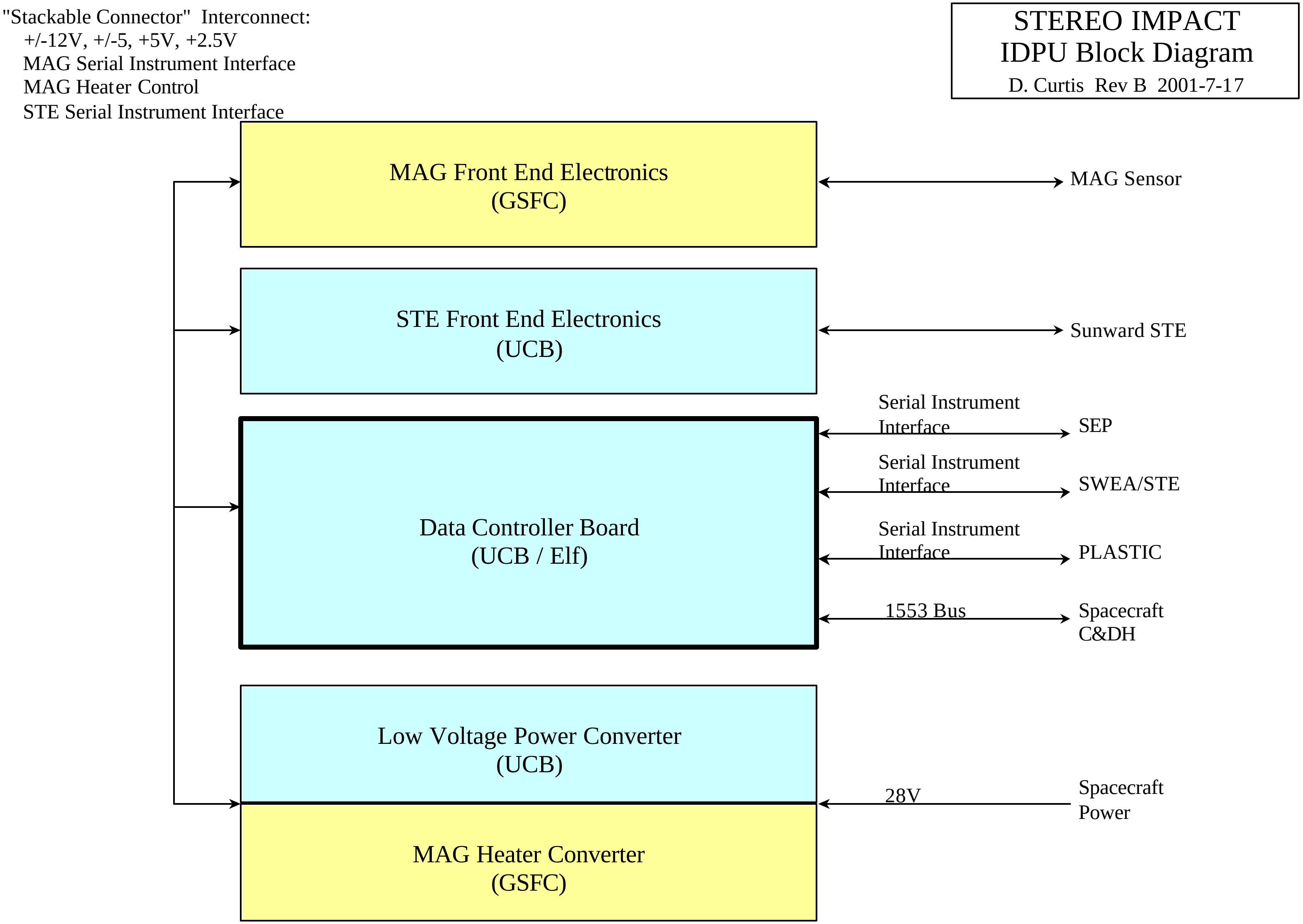
IDPU:	Packet Header		42
bps	Packet Collect Time		35
	Housekeeping		36
	Burst Playback		641
		Total	754

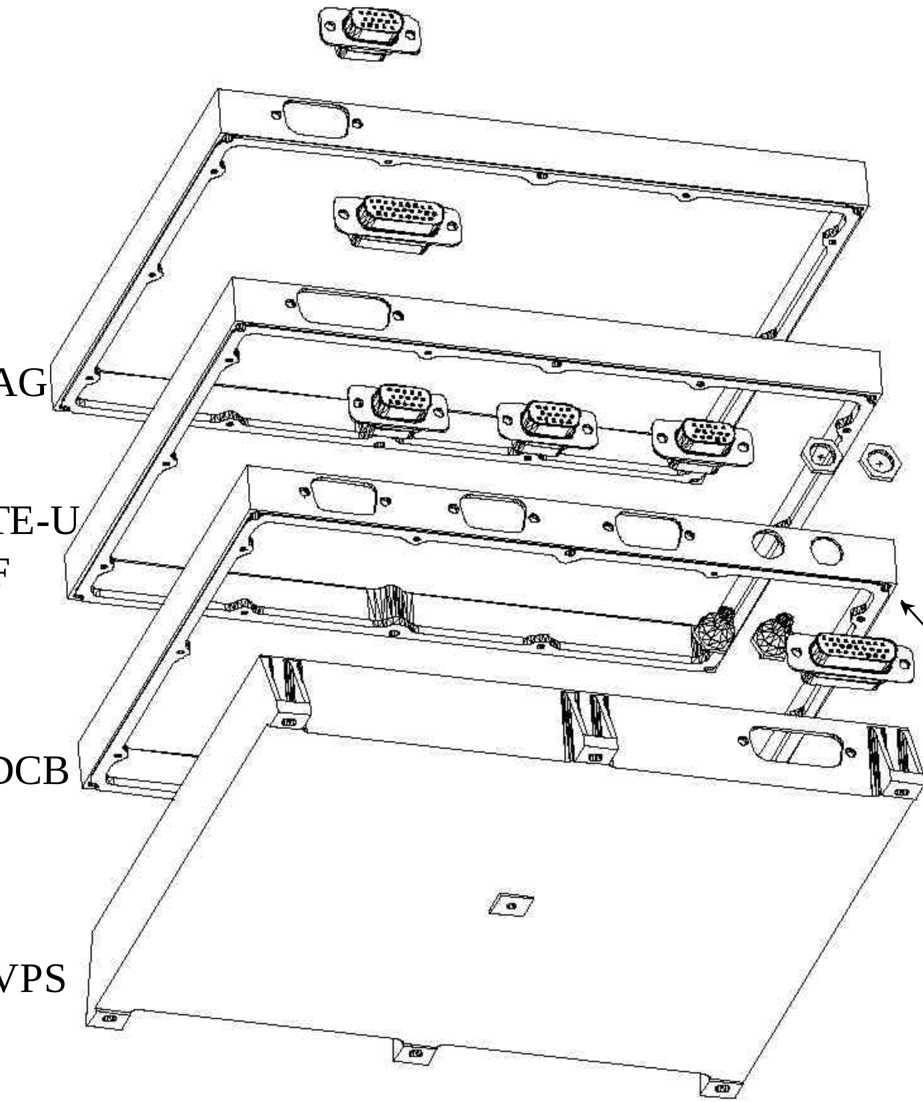
IDPU Responsibilities

- **System Design – Dave Curtis**
- **MAG Analog – GSFC / Mario Acuna**
- **MAG Heater – GSFC / Mario Acuna**
- **LVPS – Peter Berg**
- **Data Controller Board, FPGAs – Elf / Dorothy Gordon**
- **STE-U Detector Interface Board – Steve McBride**
- **Mechanical Design – Heath Bersch**
- **Flight Software – Dave Curtis / Curtis Ingraham**
- **EGSE:**
  - **IDPU Simulator Hardware – Elf / Dorothy Gordon**
  - **IDPU Simulator Top Level Software – Mike Hashii**
  - **IDPU Simulator SWEA, STE, MAG Software – Mike Hashii**
  - **IDPU Simulator PLASTIC Software – UNH**
  - **IDPU Simulator SEP Software - Caltech**
  - **Command & Telemetry GSE – Mike Hashii**
  - **SWEA, STE, MAG Science Displays – Mike Hashii**
  - **SEP Science Displays – Caltech**
  - **PLASTIC Science Displays - UNH**

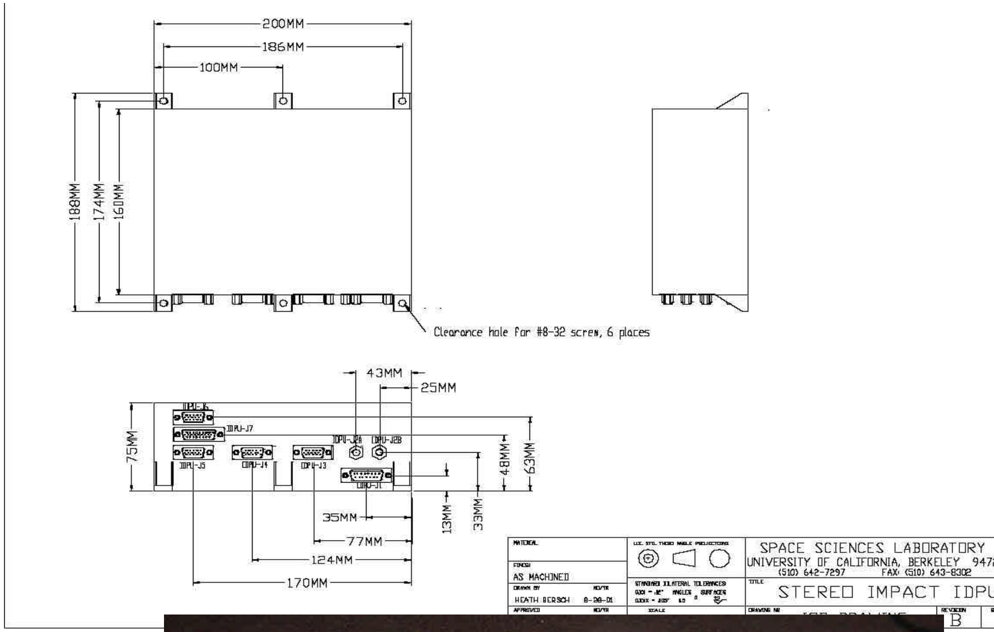
Controlling Documents

- IMPACT Performance Requirements Document covers Science Requirements on the IMPACT Suite
- IMPACT / Spacecraft ICD covers the spacecraft interface
- IMPACT Serial Interface document (ICD) covers the data interface between Instruments and the IDPU (including PLASTIC)
- IDPU Specification Document describes the IDPU (Data Controller Board) Hardware
- IDPU Software Requirements Document describes the Flight Software Requirements for IMPACT
- PLASTIC Software Requirements and Interface documents describe Flight Software Requirements for PLASTIC
- IDPU/SWAVES ICD describes data exchange
- LVPS Requirements document describes power converter requirements
- MOC/POC ICD describes the interface between GSE
- IDPU Simulator Specification covers the IDPU Simulator GSE Hardware
- IMPACT PAIP covers the performance assurance requirements
- STEREO EMC, Environmental, and Contamination Control plans
- IDPU Users Manual (first draft delivered)

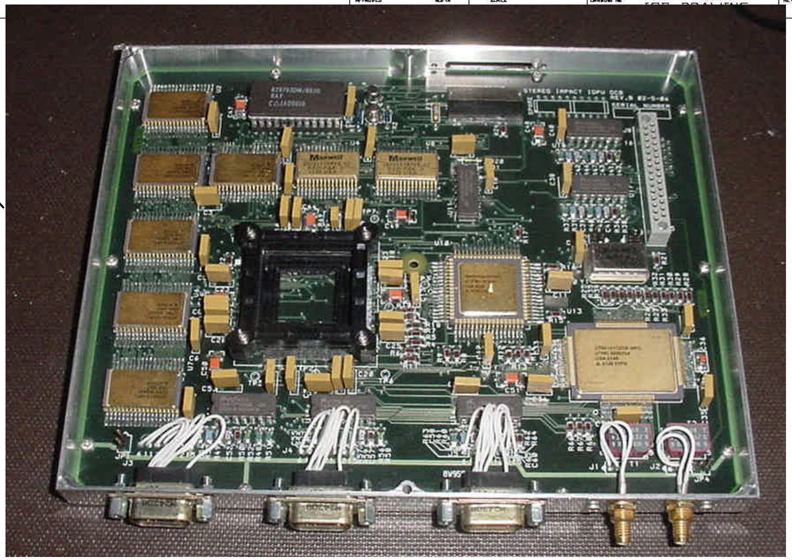

"Stackable Connector" Interconnect:
+/-12V, +/-5, +5V, +2.5V
MAG Serial Instrument Interface
MAG Heater Control
STE Serial Instrument Interface
STEREO IMPACT
IDPU Block Diagram
D. Curtis Rev B 2001-7-17
MAG Front End Electronics
(GSFC)
MAG Sensor
STE Front End Electronics
(UCB)
Sunward STE
Serial Instrument Interface
SEP
Serial Instrument Interface
SWEA/STE
Data Controller Board
(UCB / Elf)
Serial Instrument Interface
PLASTIC
1553 Bus
Spacecraft C&DH
Low Voltage Power Converter
(UCB)
28V
Spacecraft Power
MAG Heater Converter
(GSFC)

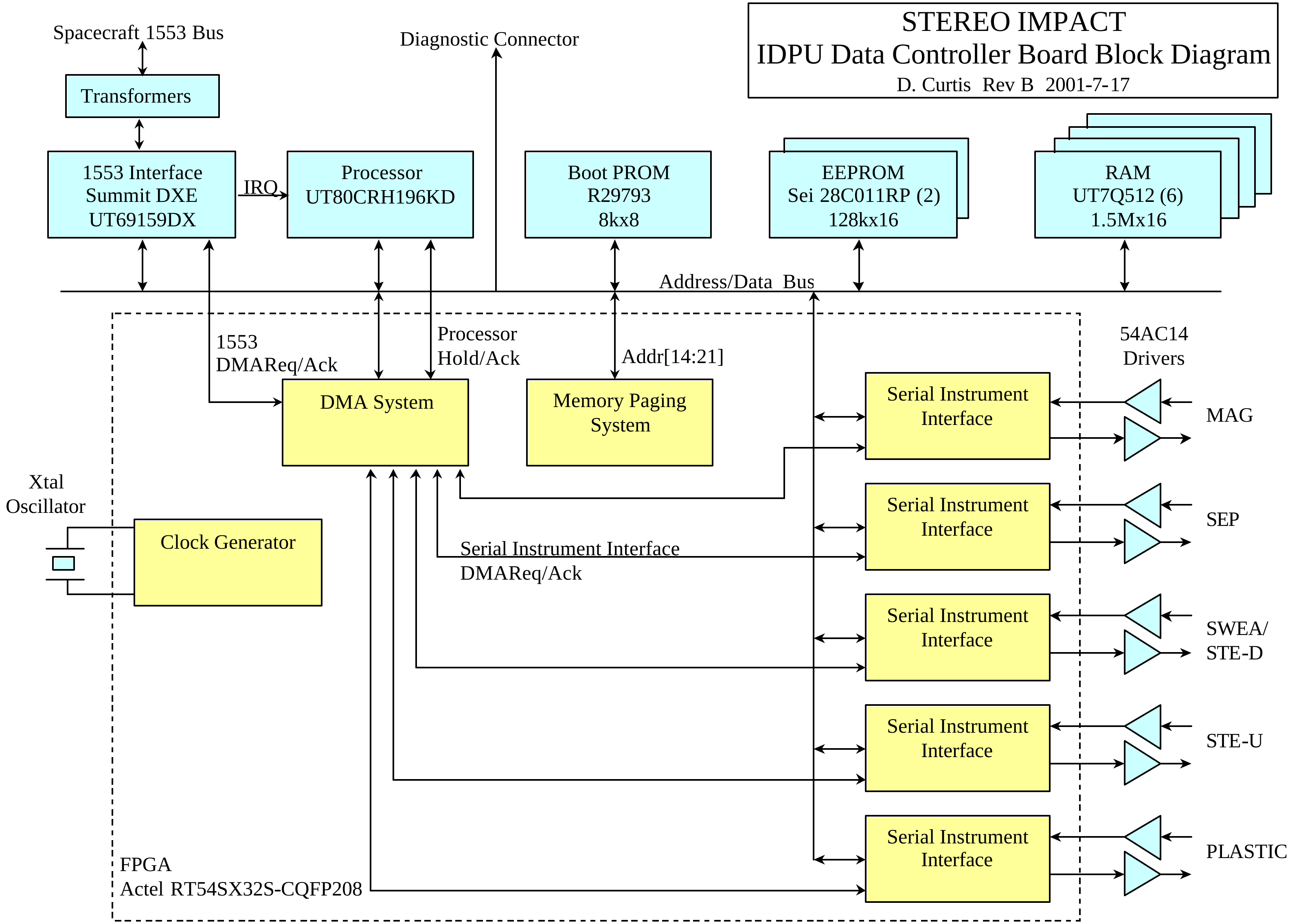


AG
TE-U
F
DCB
VPS



200MM
186MM
100MM
188MM
174MM
160MM
Clearance hole for #8-32 screw, 6 places
43MM
25MM
75MM
48MM
63MM
35MM
77MM
124MM
170MM
13MM
33MM
AS MACHINED
HEATH BERSCH
SPACE SCIENCES LABORATORY
UNIVERSITY OF CALIFORNIA, BERKELEY
STEREO IMPACT IDPU
B




STEREO IMPACT
IDPU Data Controller Board Block Diagram
D. Curtis Rev B 2001-7-17
Spacecraft 1553 Bus
Transformers
1553 Interface
Summit DXE
UT69159DX
IRQ
Processor
UT80CRH196KD
Diagnostic Connector
Boot PROM
R29793
8kx8
EEPROM
Sei 28C011RP (2)
128kx16
RAM
UT7Q512 (6)
1.5Mx16
Address/Data Bus
1553
DMAReq/Ack
Processor
Hold/Ack
Addr[14:21]
DMA System
Memory Paging
System
54AC14
Drivers
Serial Instrument
Interface
MAG
SEP
SWEA/
STE-D
STE-U
PLASTIC
Xtal
Oscillator
Clock Generator
Serial Instrument Interface
DMAReq/Ack
FPGA
Actel RT54SX32S-CQFP208

Processor

- UT80CRH196KDS available high-rel, rad-hard from UTMC
- 16-bit micro controller based on Intel design
- Can clock up to 20MHz. Adequate throughput with margins (2x) at 8MHz.
- Low power processor with high speed ALU for computational tasks (SWEA and PLASTIC moment computations)
- 64Kbyte addressing requires a paged memory system
- Built in watchdog timer
- Built in serial interface for diagnostics
- Processor Bus Arbitration scheme for Direct Memory Access scheme to get data in and out quickly with little processor overhead

Memory

- **Boot PROM contains startup code and ability to reload EEPROM and RAM from ground command**
  - **8 kbytes adequate; estimate about 5kbytes usage.**
  - **RAD Hard Bipolar PROM with power switch (off when not used)**
- **EEPROM contains normal operational code and look-up tables**
  - **128Kx16 is huge over-kill; Estimate 18kbytes of flight code.**
  - **Maxwell Technology rad-tolerant package, low SEU rate, no SEL**
  - **In-flight reprogramable via Boot PROM**
  - **Code can be copied to RAM for execution (run-time selectable)**
- **3Mbytes of static rad-hard RAM (UTMC 512K x 8), mostly for Burst memory plus some telemetry buffering**
  - **Increased from 2MBytes at PDR to allow more room for large data buffers (mostly PLASTIC)**
  - **Change to a less SEU sensitive but higher power part to accommodate running code from RAM**

1553 Interface

- **UTMC Summit part**
  - **RAD Hard, High Rel, Highly Integrated**
- **Connected to processor memory via DMA**
  - **Control tables**
  - **Data buffers**
  - **Low processor overhead**

Data Controller Board FPGA

- **Processor Interface Logic implemented in an FPGA**
- **Actel RT54SX32S**
  - **Common FPGA selected for IMPACT team**
  - **Rad tolerant (100krads)**
  - **Built-in triple-modular redundancy to eliminate SEU concerns**
  - **High Rel**
  - **2880 logic modules**
- **Actel specification to be developed by SSL (Curtis)**
- **Actel design developed/tested by Elf**
  - **Same arrangement & personnel used on HESSI**
- **Attention has been given to good Actel design practices**

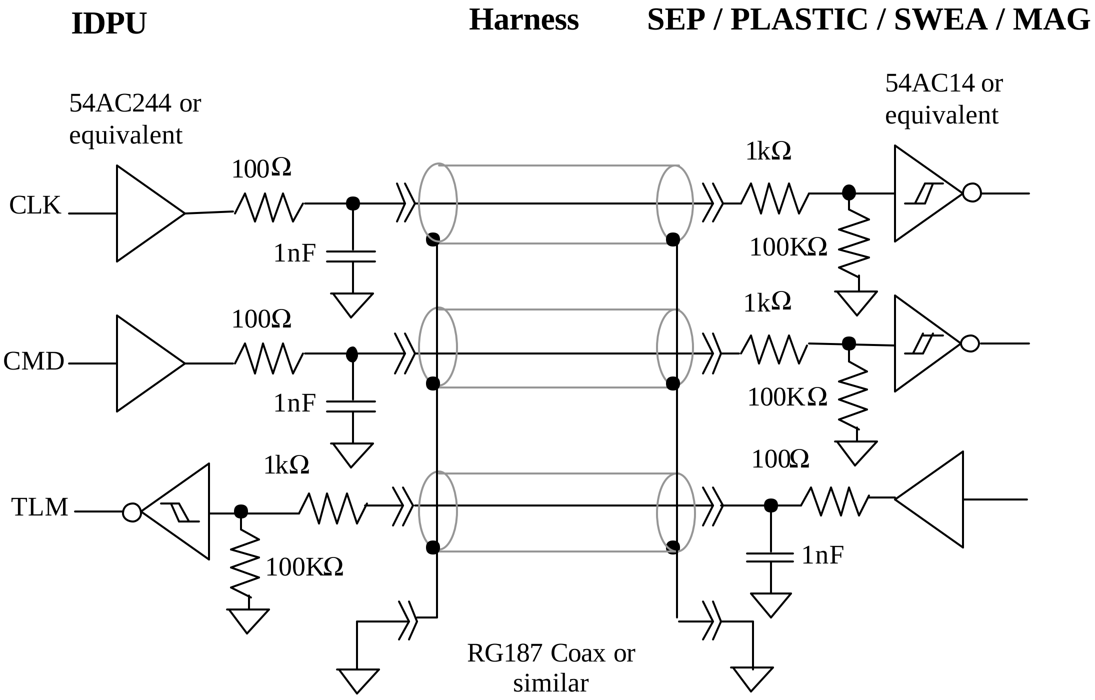
Processor Interface Logic

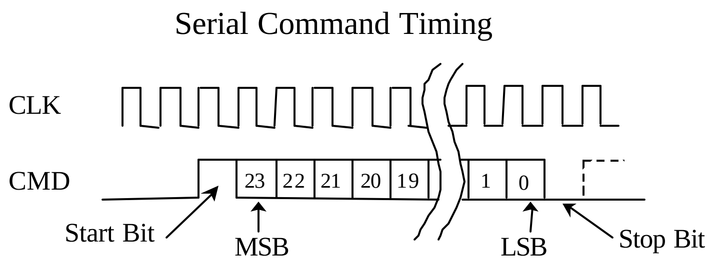
- **Instrument Serial Interface Implementation**
  - **DMA telemetry into processor memory to off-load processor**
- **Spacecraft interface glue logic (another DMA channel)**
- **Synchronous clock generation based on a 24MHz crystal**
  - **1553 interface (24MHz)**
  - **Processor clock (8MHz)**
  - **Serial interface clock (1MHz)**
  - **Sampling clock (divided down from 1MHz by instruments)**
  - **Processor Timing Interrupt (128Hz)**
- **Memory Paging**
  - **Processor 64kbyte addressing broken into three 16kbyte blocks plus a 64Kbyte code page (using processor INST signal)**
  - **Each block can be paged into one of 128 RAM pages, or 16 EEPROM pages**
  - **Boot PROM comes up in code page on reset**

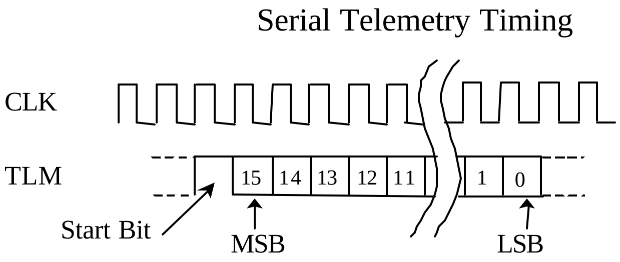
Serial Instrument Interface

- **Interface between IDPU and MAG, SWEA/STE, SEP, PLASTIC, and STE-U**
- **As defined by IMPACT Serial Interface document**
- **Three-wire serial digital single-ended interface**
  - **Continuous 1MHz Clock**
  - **Serial Data Out (Command)**
  - **Serial Data In (Telemetry)**
- **R-C rise time limiters at source end to reduce EMC**
  - **EMC Waiver granted for single-ended interface**
- **Coax or shielded wire harness**
  - **Breadboard shows good waveforms and timing with an 8m harness**
- **No handshaking; system designed to handle maximum throughput at both ends**
- **No gating; start/stop bit synchronization like RS232**
- **24 bit Commands in data out (8 bit ID, 16 bit data)**
- **Blocks of 16-bit Telemetry in**
  - **Blocks include an identifying header (5 bit ID, 10 bit block length)**
- **Synchronous 1-second time tic command**

Serial Instrument Interface







Other IDPU Boards

- MAG and STE-U Interface boards are housed in the IDPU box, but are logically part of the instruments, and are described in the STE and MAG sections.
- They are provided power by the IDPU LVPS, and are connected to the IDPU via Serial Instrument Interfaces identical to the remote instruments, but via internal connectors.
- IDPU LVPS Board discussed in the Converters section
- MAG Heater board discussed in MAG section
  - Shares the bottom tray with the LVPS

IDPU Thermal

- A simple worst case thermal analysis has been performed on the IDPU
  - Conduction-only model
  - Analysis is complicated by uncertainties in conduction between trays
- IDPU is inside the spacecraft.
  - Conducted and radiated temperature range –13 - +45 (Operating)
  - No concern with cold case
- Worst case hot predicted board temperatures are:
  - LVPS: +52C
  - DCB: +62C
  - DIB: +57C
  - MAG: +58C
- Analysis needs to proceed to the part level for parts dissipating significant power
  - Parts must not exceed their rating (some up-screened PEMs rated at 85C)
  - Any part which has a junction temperature > 100C will need a heat strap to the box
  - This is relatively easy to do in a tray design.

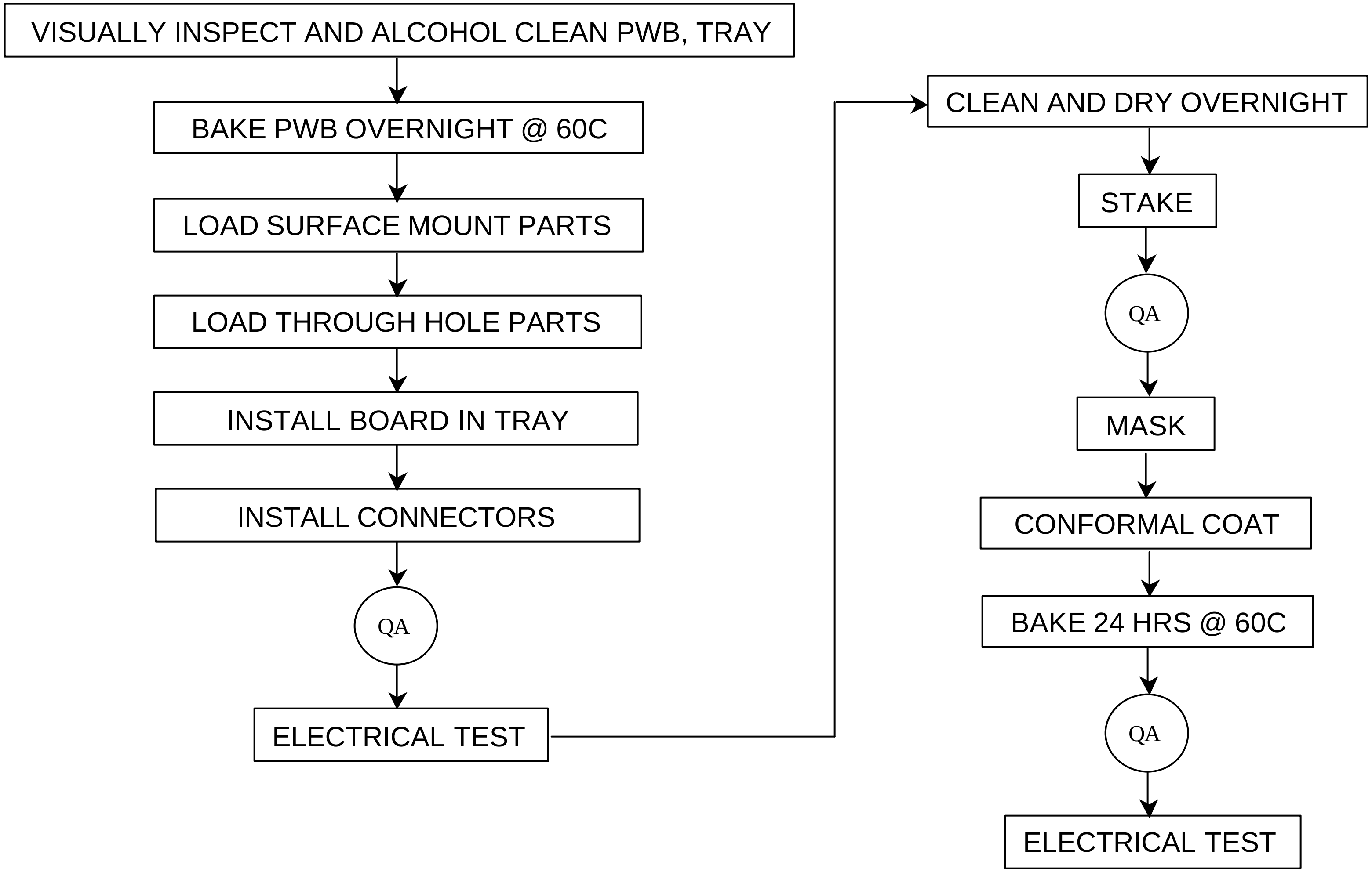
IDPU Status

- Two ETU Data Controller Boards have been manufactured and tested
  - Second ETU for use by PLASTIC team
- ETU IDPU LVPS is currently being fabricated and tested
- Breadboard MAG Front end (concentrating on new part of design, which is interface to the IDPU) has been built and is in test.
- STE-D ETU (electrically identical to STE-U Interface) has been built, and is in test.
- ETU DCB is in being used in Flight Software development and test
- IDPU ETU Box fabricated
- All IDPU DCB Flight parts in house or on order
  - Only issue is possible proton SEU sensitivity of RAM, to be tested.
  - Other IDPU board parts (LVPS, Mag, STE-U) discussed elsewhere
- IDPU Performance meets requirements (see Flight Software discussion)

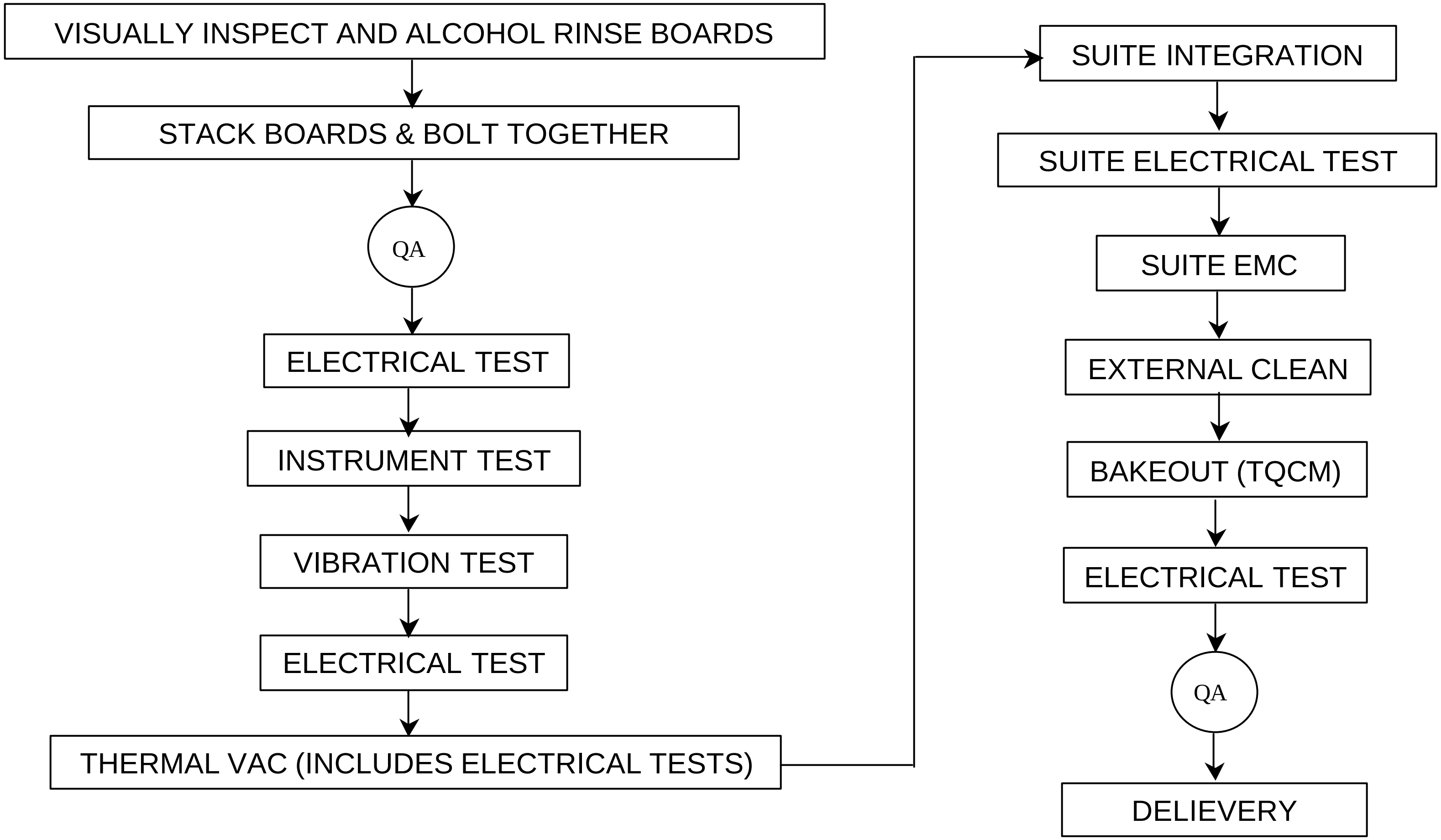
IDPU Manufacturing, Integration, and Test Plans

- The IDPU Box, DCB, STE DIB, and LVPS are built at UCB
- The MAG Front End and heater controller are built by GSFC
  - MAG card tray provided by UCB
  - An IDPU simulator GSE allows the MAG to be tested and calibrated in a stand-alone mode prior to delivery to UCB for integration
- Two flight units will be built following CDR, and integrated at UCB
  - The Boot code PROM and Flight Software Build #2 are installed at this time
- Vibration and Thermal Vacuum tests performed at the box level
- The final build of the flight software is acceptance tested and installed
- A series of interface tests with the instruments are made, followed by an EMC test of the suite.
- Prior to delivery, the IDPU exterior surfaces are cleaned and unit is baked out.

IDPU PWB Manufacturing Flow



IDPU Integration and Test Flow



IDPU Verification Matrix

Revision Date: 11/06/02
Revision Number: 2

Hardware Description		Test																	
Level of Assembly	Item	Elect. test, rm. Temp	Elect. Test, hot	Elect. Test, cold	Vibration, Sinusoidal	Vibration, Random	Shock	Acoustics	Pressure change	Voltage margins	Thermal Vacuum	Thermal balance	>100 hours Operation	EMC/EMI	Magnetics	Leak	Bakeout	Contamination	Comments
C	PWB, EM	X								X									
I	IDPU EM	X	X	X						X			X	X					EMC CE test on EM
C	PWB, F	X								X							X		
I	IDPU, F	X	X	X	X	X			A	X	X		X	H	X		X	X	EMC at Suite level

Legend:

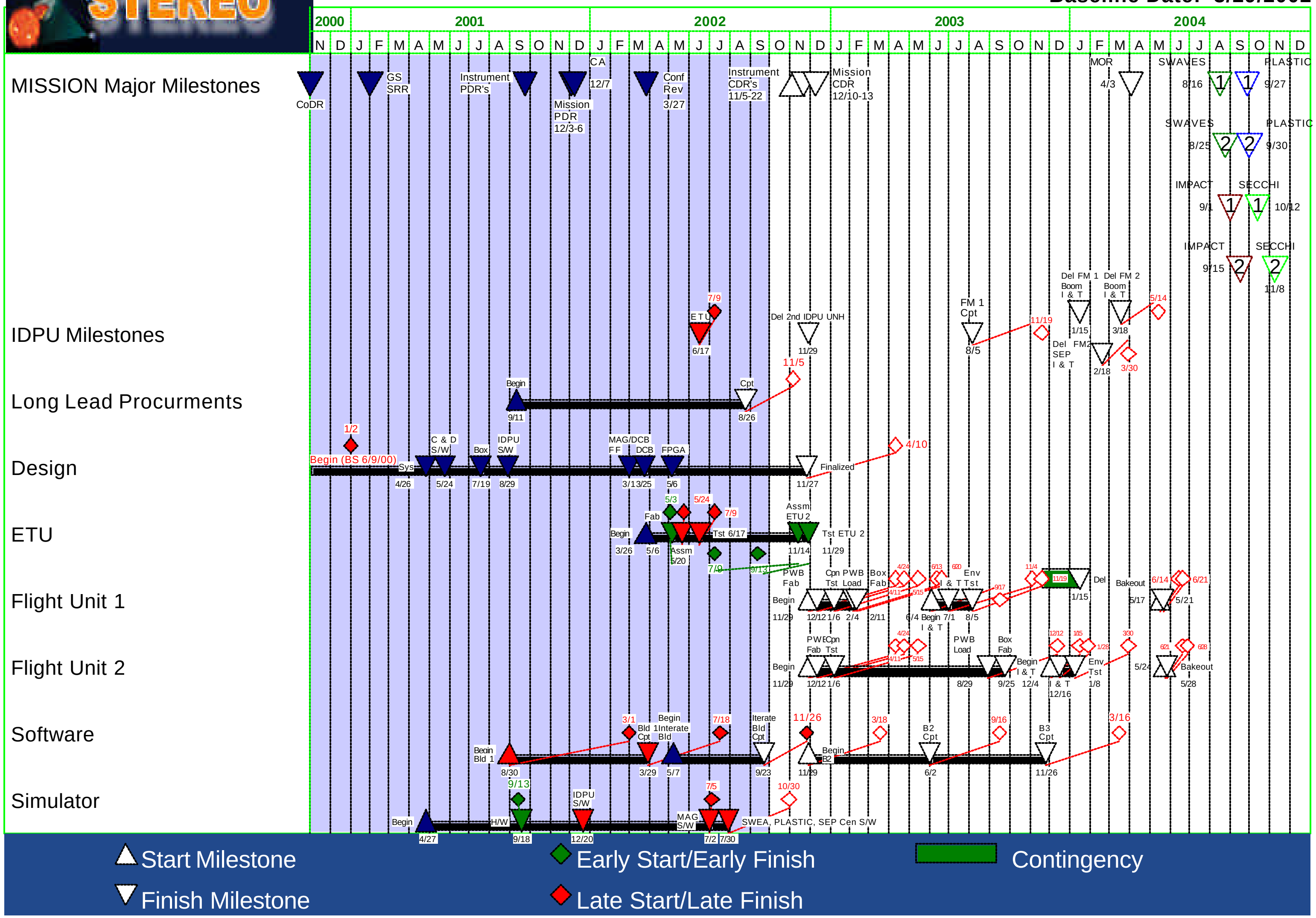
Level of Assembly	Unit Type		
			X = Test required
			A = Analysis
C = Component	BB =	Breadboard	H = at higher level of assembly
I = Instrument	EM =	Engineering Model	
	PT =	Prototype	
	PF =	Protoflight	

IDPU Test Levels

- IDPU Test Levels based on STEREO Environmental Plan 7381-9003
  - Sine Sweep per section 3.4.2.1, 16g max.
  - Random per section 3.4.2.2, 10.4g RMS
  - No acoustic or shock test
  - Measured mass properties: Mass & CG per section 3.4.4
  - Magnetics “sniff test” per 3.5
  - Thermal Vacuum per section 3.3.2:
    - One survival cycle, -38 - +65C
    - Four operational cycles, -33 - +65C
- IMPACT Suite EMC Test per 7381-9003 section 3.7 and limits in EMC Plan 7381-9030
  - CE01 per section 4.1, CE03 per section 4.2, CE07 per section 4.4 of -9030.
  - CS01 per section 4.5, CS02 per section 4.6, CS06 per section 4.7 of -9030
  - RE01 per section 4.8, RE02 per section 4.9 of -9030
  - RS03 per section 4.10 of –9030
- Contamination Control per 7381-9006
  - Bakeout test per section 5.9.3

IDPU - IMPACT Data Processing Unit

Status Date: 9/30/02
Baseline Date: 3/29/2002



Schedule Analysis

- Schedule delays are driven by assumption that Flight Unit build and Build 2 software cannot start before interface tests with SEP ETU
- Little risk in proceeding with FM without SEP ETU interface test
- Instead hold at starting FM1 environmental tests until EM SEP interface test
- Should add about 2 months to IDPU contingency

IDPU Issues and Concerns

- **Proton SEU sensitivity of DCB SRAMs still to be determined**

Instrument Data Processing Unit (IDPU) Flight Software

IDPU Flight Software Overview

- **The IDPU Flight Software runs in the processor on the Data Controller Board**
- **The software performs the following core tasks:**
  - **Controls the IMPACT and PLASTIC instruments**
  - **Collects and formats IMPACT and PLASTIC telemetry**
  - **Handles the spacecraft interface data exchanges (including SWAVES)**
- **This code is developed at UCB**

IDPU Software Requirements

- First draft of Software Requirements Document June 01
  - Rev B, October 01; Rev C, April 02
- First draft of PLASTIC software requirements from UNH 6/01
  - Rev B, November/01; Rev C, August 02
- First draft SWAVES/IMPACT ICD (data exchange) September 02
- IMPACT/Spacecraft ICD and MOC/POCC ICD detail spacecraft interface
- Top level requirements:
  - Support Spacecraft 1553 Interface per the Instrument ICD
  - Support Instrument Interfaces per the hardware and software specification
  - Collect, compress, and format telemetry data into CCSDS packets
  - Pass on mode-setting commands from the ground to instruments
  - Limited automation:
    - Set SWEA offset voltage to track spacecraft bias voltage
    - PLASTIC solar wind tracking and entrance system selection
    - MAG ranging
  - Instrument safing (response to HV anomaly, and spacecraft thruster/power down notifications)
  - Support a Burst memory system to collect high time resolution data for short intervals based on a burst trigger criteria
  - Share burst trigger data with SWAVES via RT to RT 1553 transfers

1553 Interface Requirements

- Support the interface protocol as described in the ICD
  - Receive, decode, and forward command packets
  - Send telemetry packets
    - Normal telemetry, Beacon telemetry, Housekeeping telemetry
  - Receive, decode, and synchronize local clock to UTC time code
  - Receive and act on spacecraft status
    - Power down warning; safe instruments
    - Thruster firing warning; safe instruments
    - SSR status – send only state of health when SSR partition almost full
  - Send instrument status
    - Power-down request (on fault detection)
  - Respond to Loopback, TBD mode codes
- Support 1553 Interface chip
  - Setup & maintenance
  - Interrupt on message in/out
  - Error response

MAG Software Requirements

- Average MAG data to 4 samples/second, format into CCSDS packets
- Format 32 sample/second data into CCSDS packets for Burst memory
- Average MAG data to 1 minute and pass to Beacon telemetry formatter
- Perform ranging functions to select one of two gains based on previous measurements (only expected to be used on the ground)

SEP Software Requirements

- **Pass on all SEP command packets (by ApID) and Spacecraft Time via Serial Instrument Interface**
- **Pass on all Telemetry Packets received via Serial Instrument Interface to Telemetry packet queue**
- **Pass SEP Housekeeping data received via the Serial Instrument Interface to Housekeeping packet formatter**
- **Pass SEP Beacon data received via the Serial Instrument Interface to Beacon packet formatter**

STE Software Requirements

- **Initialize and periodically reload STE Energy to Accumulator look-up table via Serial Instrument Interface from IDPU EEPROM**
- **Initialize and periodically reload STE threshold DAC values via Serial Instrument Interface from IDPU EEPROM**
- **Log-compress counters and format into CCSDS packets to pass to the Burst system (Spectra and Monitor Rates)**
- **Time Average and Log Compress counters and format into CCSDS packets for real-time telemetry (Spectra and Monitor Rates)**
- **Time and Space Average and Log Compress counters and pass to Beacon telemetry formatter (Spectra and Monitor Rates)**

SWEA Software Requirements

- **Initialize and periodically reload SWEA voltage waveform look-up table via Serial Instrument Interface from IDPU EEPROM**
- **Initialize and periodically reload SWEA control registers via Serial Instrument Interface from IDPU EEPROM**
- **Accumulate raw counter measurements into a three-dimensional distribution measurement**
- **Compute Moments, Pitch Angle Distributions and Full 3D distributions with desired time and space resolution and format into CCSDS packets for the Burst, Real Time, and Beacon telemetry streams**
- **Adjust SWEA bias voltage based on measured distribution function to offset spacecraft charging effects**

PLASTIC Software Requirements

- **Instrument Control Tasks:**
  - Decoding and route instrument mode and table load commands
  - Controlling the energy at which apertures are switched based on measured count rates (previous sweep)
  - Controlling "Solar Wind Tracking Mode" when Bursts are triggered to get high time resolution data
  - HV safing in response to an Arc
- **Data Tasks: Collect, compress, and format**
  - Housekeeping data
  - Monitor Rate data
  - Matrix data (from the classification board)
    - Proton and Alpha Moments
    - Reduced Proton and Alpha Distributions
    - Heavy Ion Distributions
  - Raw Event Data
    - Event Prioritization
  - Beacon Mode data

Burst System Requirements

- **High time resolution sampling of selected data**
  - **MAG @ 32Hz**
  - **SWEA, STE at 2 seconds**
- **Continuous data collection into a circulating buffer**
  - **Buffer sized for on the order of 10 minutes of high time resolution data**
- **Continuous evaluation of burst trigger criteria based on instrument data**
  - **Trigger on changes in SWEA count rate in a selected energy band**
  - **Trigger cooperatively with SWAVES based on SWAVES activity**
- **Freeze collection buffer a fixed interval after the trigger event to provide data both before and after the trigger**
- **Continue to look for more triggers,saving the "best" event in the time interval between burst playback**
  - **Play back burst data using a fraction of the normal telemetry on a continuous basis.**

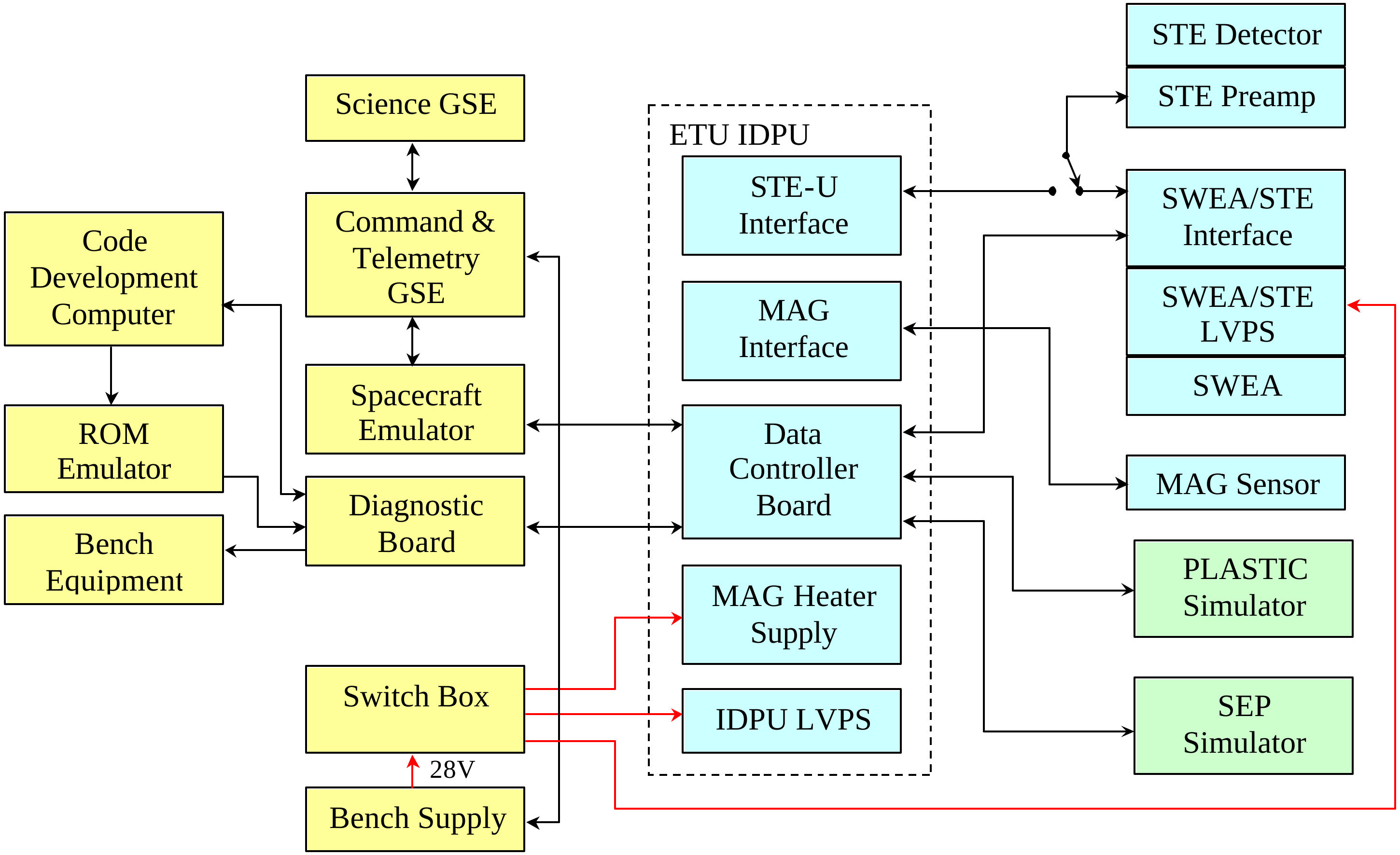
Software Development Plan

- First draft Software Development Plan 8/01 (Rev B 11/01)
- IDPU Flight Software to be developed at UCB by a two programmers
  - Most of the code is developed by a single programmer
  - PLASTIC code to be developed by a second programmer
- Code to be developed in modular, structured assembly code
- Software to be developed and tested on the ETU IDPU, with ETU Instruments and/or simulators
- Software to be tested at the module level, then at the IDPU level in an acceptance test, and finally at the system level in interface and suite tests
  - Acceptance test will verify each software requirement
- Software to be developed in builds of progressing complexity:
  - First Build to test processor hardware (Complete)
  - Second build provides at least minimal functionality required to verify suite hardware (without automation and more complex telemetry products)
  - Third build should be for Flight
- Prior to installation in the flight hardware, code is maintained using a log book which contains the development history, testing, problems, etc.
- Following installation in flight hardware, software is under the same control as the hardware (configuration control, problem reports, etc.)

Software Development Tools

- Use Commercial Phyton PC-based 80C196 development tools
  - Assembler/Linker
  - Simulator (for early module testing)
- Diagnostic board connects via DCB diagnostic connector
  - Provides assorted processor bus signals to logic analyzer, LEDs
  - External PROM option, which can contain Monitor code
  - RS232 drivers for processor diagnostic serial interface (code load, diagnostics)
- Logic analyzer (for those subtle timing problems)
- ETU Data Controller Board (second in fabrication for PLASTIC)
- EGSE:
  - APL Spacecraft Emulator
    - UCB-developed Command and Telemetry GSE
    - UCB-developed Science Display GSE (MAG,SWEA,STE)
    - SEP, PLASTIC Science Display GSE
  - UCB-developed Instrument Simulator
  - Instrument ETUs
  - UNH-provided PLASTIC simulator

IDPU Software Development Setup



Software Development Schedule

• **Software Development Plan**	**PDR (9/01)** Ö
• **Software Requirements Document(s)**	**PDR (9/01)** Ö
• **Software Requirements/Design Review**	**12/01** Ö
• **Software Design Complete, start Coding**	**1/02** Ö
• **First Build Complete, ETU Available**	**8/02** Ö
• **IDPU Software Design Peer Review**	**8/02** Ö
• **Software Design Review (part of CDR)**	**CDR (11/02)**
• **Critical Code Walkthrough / Acceptance Test Review**	**6/03**
• **Boot PROM Acceptance Test**	**8/03**
• **Boot PROM Install in DCB of FM1**	**9/03**
• **Second Build Complete**	**9/03**
• **Third Build Complete, Acceptance Test**	**3/04**

IDPU Software Architecture

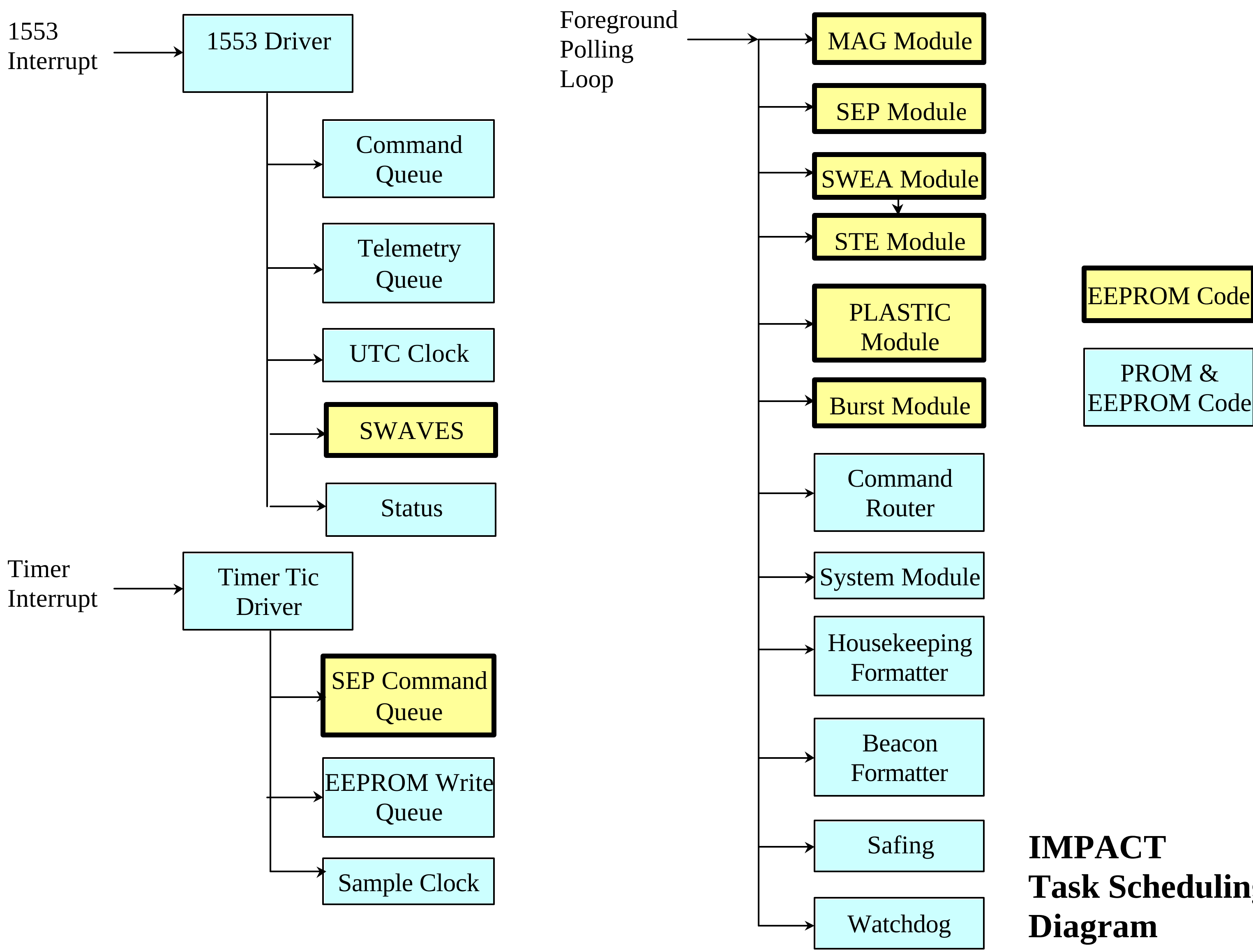
- Simple Polled-Loop operating system
  - 1553 and 128Hz interrupts take care of time-critical functions
  - Input data FIFOs hold data until the relevant task comes to collect it
  - The majority of the tasks involve short intervals of processor to deal with data, so the polling loop frequency is expected to be much greater than 1Hz, providing adequate response time to all tasks.
  - No task in polling loop requires better than 1 second latency
  - A few tasks run infrequently require more processing (such as the PLASTIC matrix data formatting) and will be broken up to level the processing load
  - A somewhat more complex priority-based time-slice operating system has been considered, but is currently more complex than is required
- Tasks are modular and as independent as possible
  - Especially PLASTIC, to allow independent operation by UNH
- Hardware designed to relieve software of most time-sensitive tasks
  - Instrument sequencers allow instruments to cycle independently
  - DMA system collects data into IDPU memory automatically
- The watchdog timer will be reset by the polling loop (timeout = 2 seconds)
  - The watchdog will monitor the interrupt tasks to verify operation
  - No 1553 activity for 10 seconds causes a 1553 interface reset.
  - No 1553 activity for 120 seconds (commandable duration) causes a processor reset
- Software will regularly re-load all instrument registers to protect against SEU

Memory Usage

- System boots on PROM
- Code is nominally copied from EEPROM into RAM and run from RAM
  - Can run from EEPROM
- Processor internal RAM is used for temporaries, stack
- External (3Mbyte) RAM is used for:
  - Burst memory
  - Data buffers
  - 1553 Interface
  - Parameter tables
  - Code page
- All code, tables, and telemetry packets are check-summed and verified periodically for SEU
  - Low SEU rate computed:
    - <1% chance of error in code page during the life of the mission
    - Bit error rate in telemetry buffers (Burst) about 1E-9

Boot Sequence

- System boots from PROM
- PROM verifies the EEPROM code image checksum
  - On bad checksum, system waits in PROM for new code uplink from the ground via spacecraft 1553 interface
- PROM waits 10 seconds for a possible abort message (or select an alternate EEPROM code image) prior to transferring control to EEPROM
  - During delay a subset of foreground polling loop is run to run 1553 interface, housekeeping, watchdog, etc.
- EEPROM code is nominally identical to PROM code, with additions for instrument operations
- EEPROM initializes each new task and then starts expanded foreground polling loop
- EEPROM can be reloaded or patched either from the Boot PROM or during operations from the RAM code page



IMPACT Task Scheduling Diagram

1553 Handler

- **Invoked by interrupt from 1553 Interface**
  - **Completed message transfer**
- **Telemetry Message:**
  - **Fetch a new packet pointer from telemetry queue (if available) and setup 1553 for next transfer**
- **Command Message:**
  - **Queue FLTCs for foreground Command Router**
- **Timing/Status Message (1/sec):**
  - **Update UTC clock**
  - **Invoke command scripts on events (instrument power-down or thruster firing)**
- **SWAVES Interface (1/sec):**
  - **Pass SWAVES data to Burst Trigger Task**
  - **Set up to send IMPACT Burst Trigger data to SWAVES**

Telemetry Queue

- Accepts CCSDS telemetry packets from various tasks
  - MAG
  - SWEA
  - STE
  - SEP
  - PLASTIC
  - Housekeeping
  - System (memory dump)
  - Beacon
  - Burst
- Provides packets in a FIFO mode to 1553 handler
  - Implemented as a linked list. Each task controls its own packet buffers. When packet is transmitted it is marked as free by the 1553 telemetry handler so the source task can identify overrun conditions.
- Tasks are expected to generate telemetry at their allocated rate
  - Some subsystems will have programmable telemetry rates. The IMPACT Team must coordinate rate allocations between tasks.

Housekeeping & Beacon Modules

- **Tasks provide housekeeping data to housekeeping formatter**
  - **Each task has a fixed allocation in the housekeeping packet**
- **Housekeeping packet rate is nominally once a minute**
  - **Can be increased during I&T and commissioning to improve test sequence speed**
- **Tasks provide Beacon data to Beacon formatter**
  - **Each task has a fixed allocation in the housekeeping packet**
- **Beacon Packets generated once a minute each for PLASTIC and IMPACT**

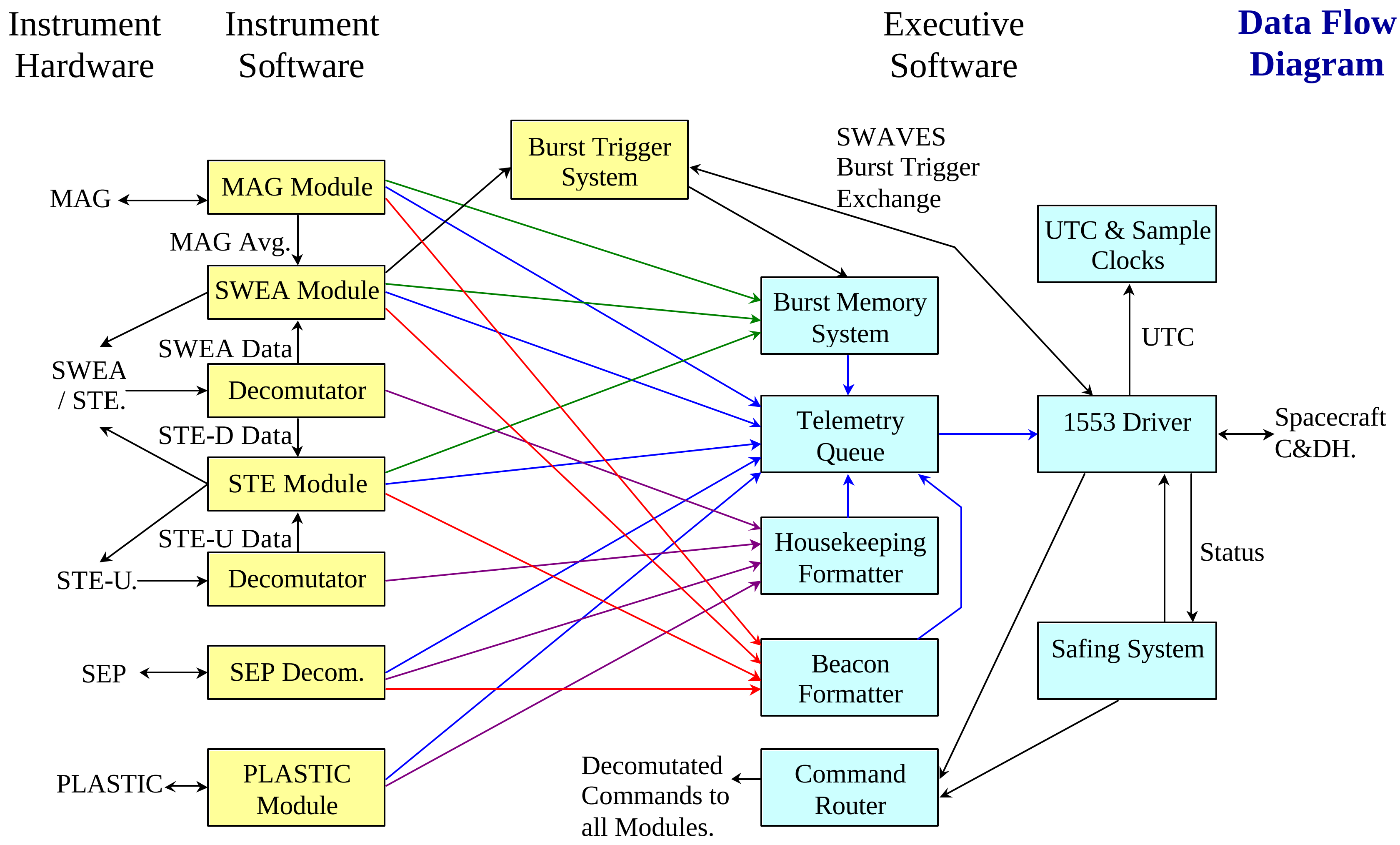
Safing System

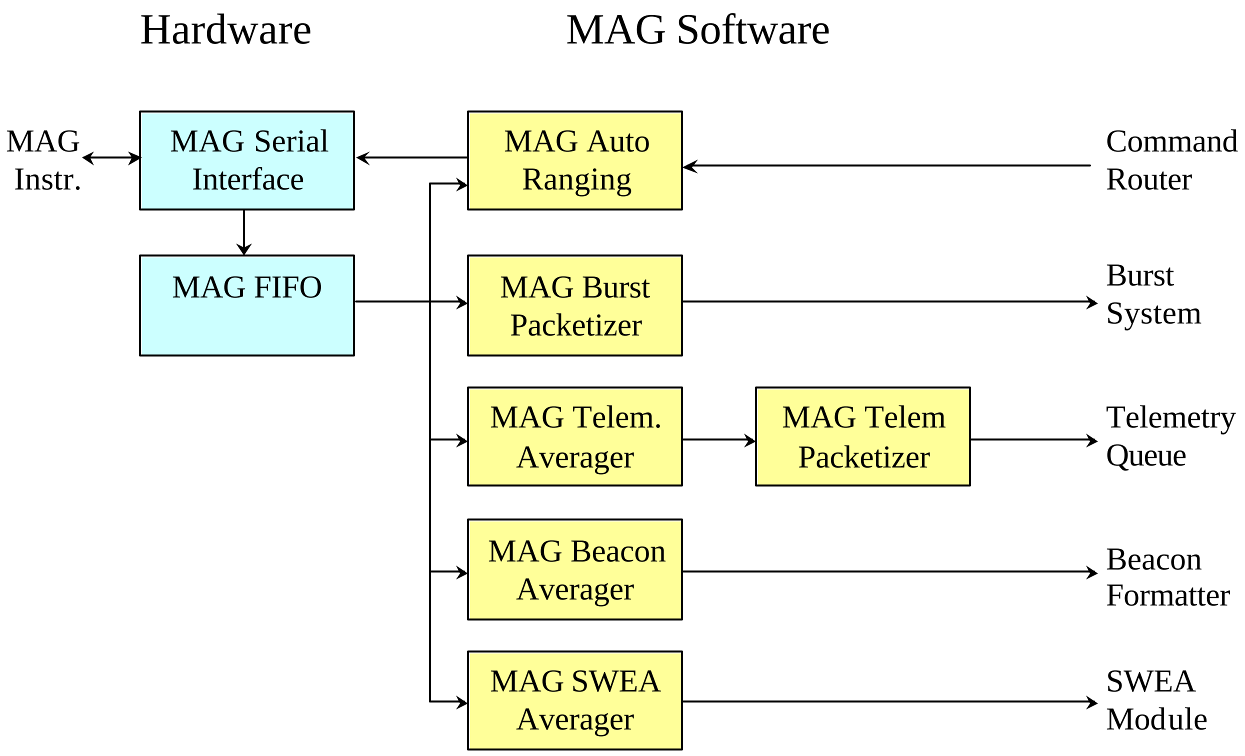
- This system is used to invoke a sequence of operations to be performed in response to an event
- The operations are executed at a fixed rate (one command a second, with an N second delay capability)
- Operations are in the form of command packets which are distributed just as if they were received over the 1553 interface
- Operation sequences are programmable from the ground to allow flexibility
- Operation Sequences can be invoked by tasks or by command
- Currently planned sequences:
  - Power Down Preparation (1553 warning)
  - Thruster Firing Preparation (1553 Warning)
  - End of Thruster Firing (1553 Warning)
  - Fine Pointing State (1553 Warning)
  - PLASTIC HV Discharge
  - Temperature / Voltage / Current limits

Burst System

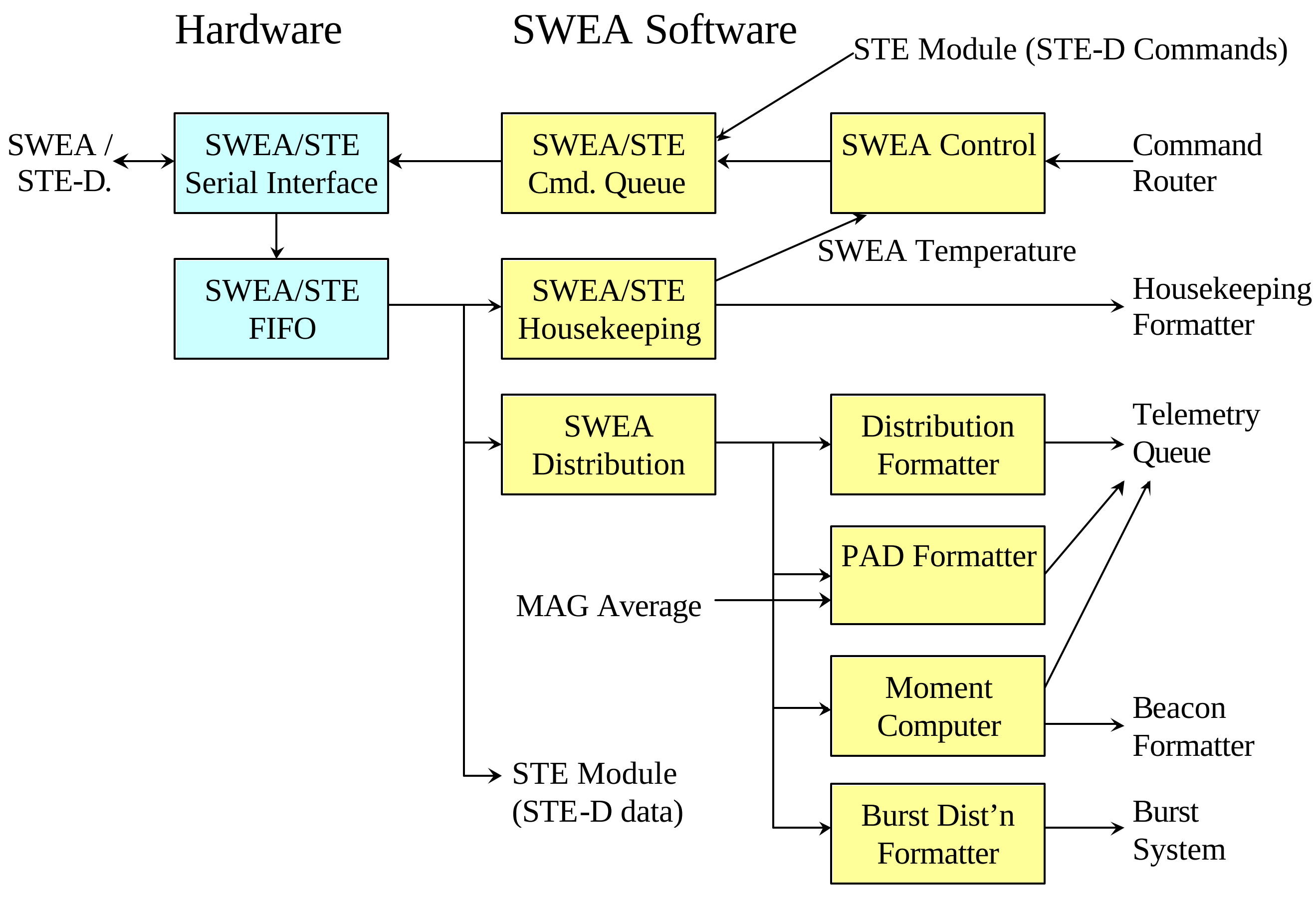
- Tasks provide a continuous stream of packets into the Burst system
  - MAG, SWEA, STE
- The Burst system records the data into a circular buffer in RAM
  - This allows pre-trigger data to be saved
  - Three buffers are allocated in RAM: Transmitting, Best, and Current
- A trigger criteria system evaluates data from SWEA and SWAVES to detect an event
- If a new event has higher criteria than the previously recorded “Best” event, the current event collection is completed, and the new buffer is saved as “Best”
  - The old “Best” buffer now becomes “Current” and is over-written with the continuous telemetry stream, looking for an even better burst
- This continues until the “Transmitting” buffer has been read out to telemetry.   The “Best” buffer now becomes “Transmitting”, and the old “Transmitting” becomes “Current”.

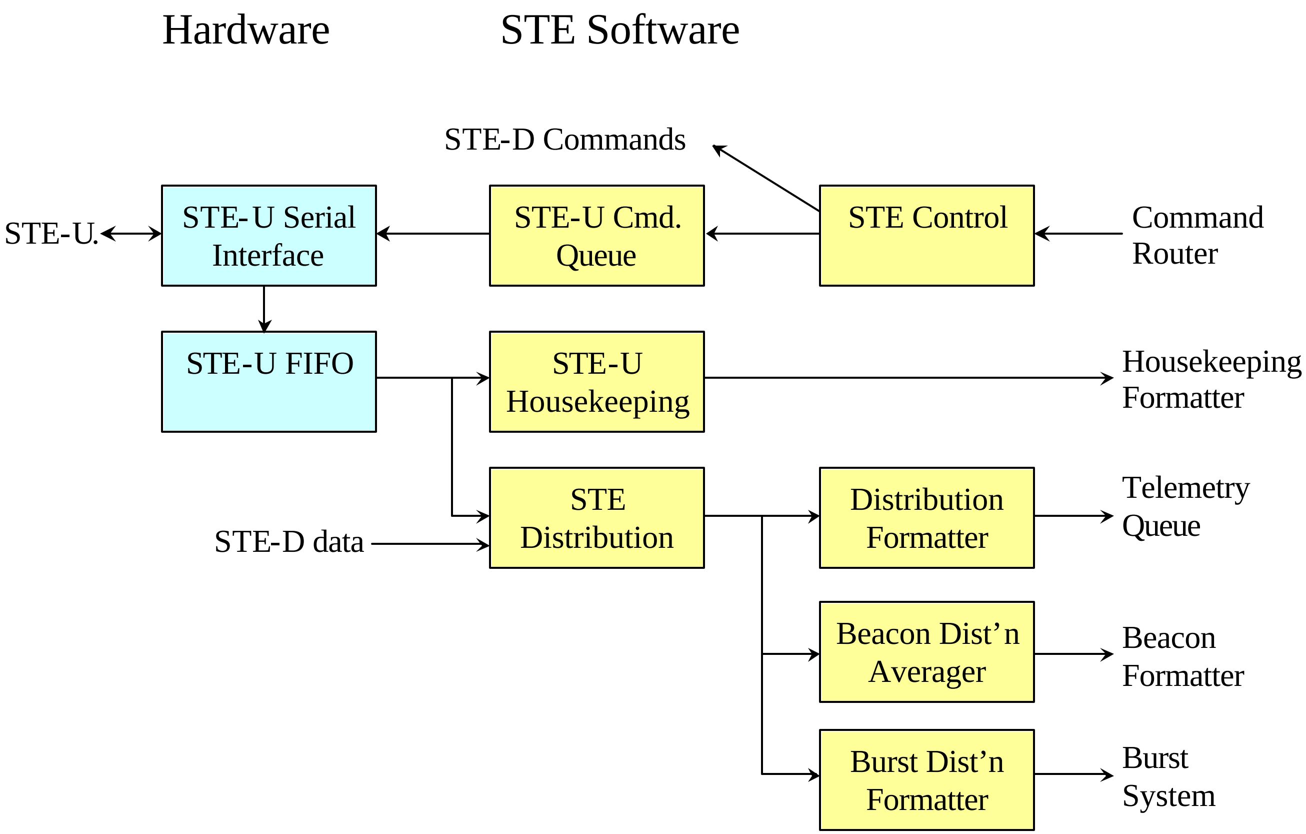
IMPACT Data Flow Diagram

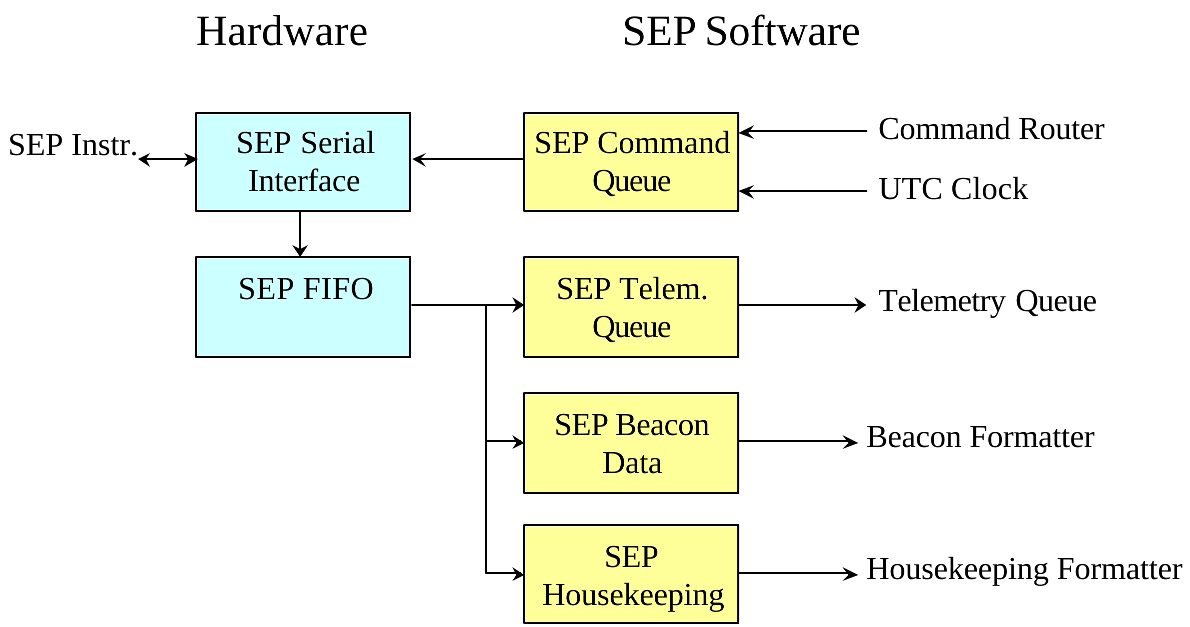


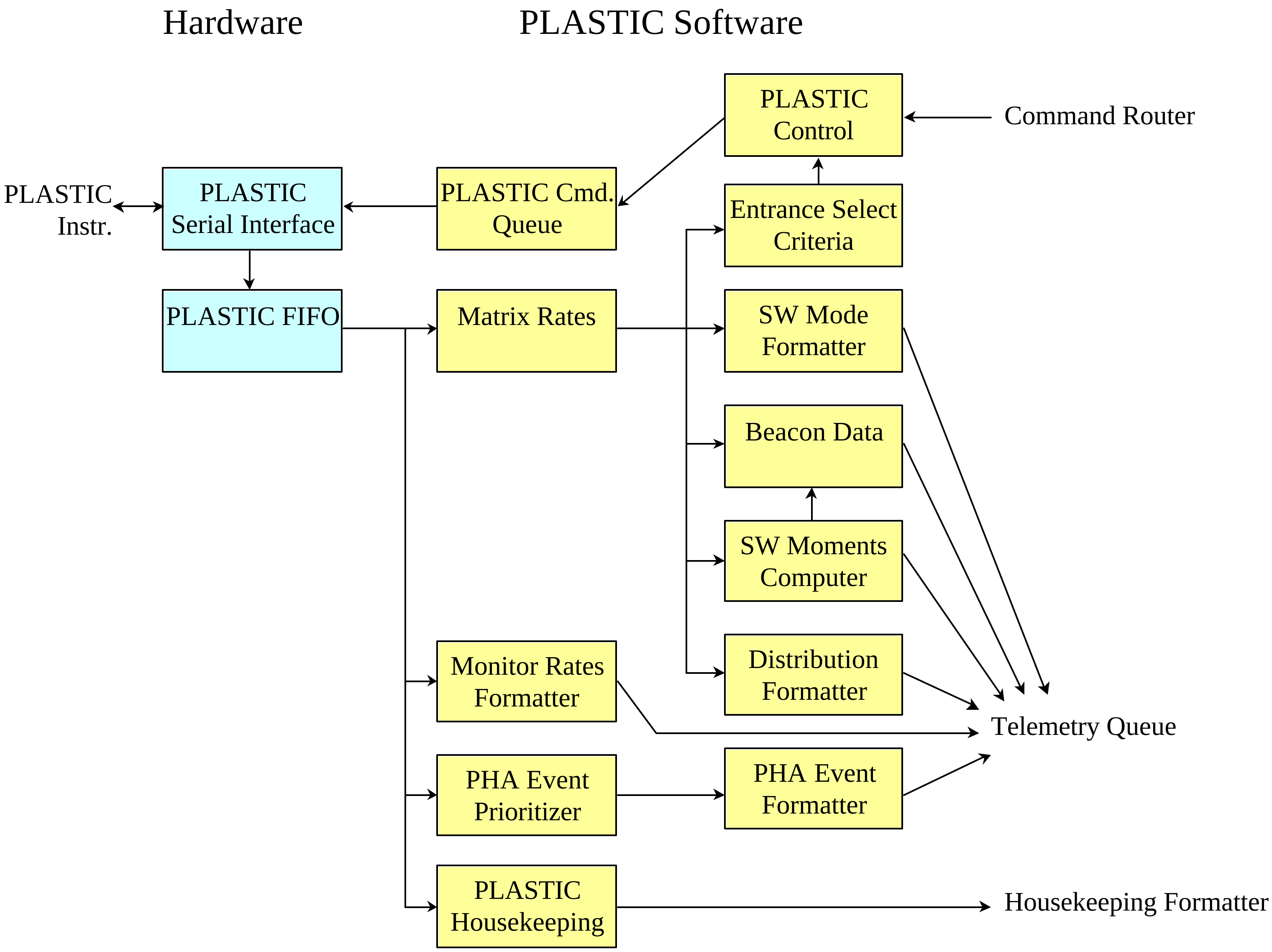


Hardware
MAG Software
MAG Instr.
MAG Serial Interface
MAG FIFO
MAG Auto Ranging
MAG Burst Packetizer
MAG Telem. Averager
MAG Telem Packetizer
MAG Beacon Averager
MAG SWEA Averager
Command Router
Burst System
Telemetry Queue
Beacon Formatter
SWEA Module

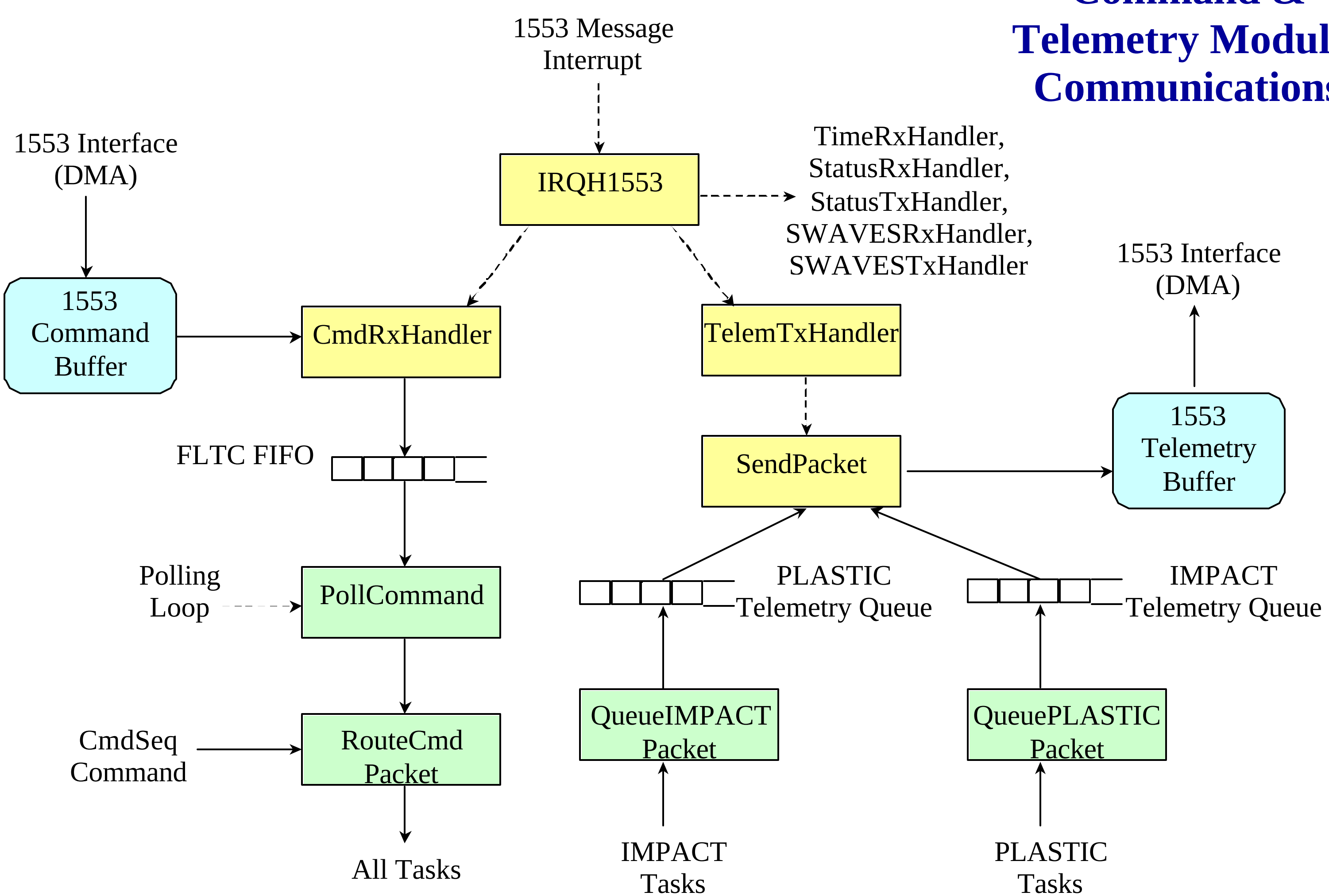

Hardware
SWEA Software
STE Module (STE-D Commands)
SWEA / STE-D.
SWEA/STE Serial Interface
SWEA/STE Cmd. Queue
SWEA Control
Command Router
SWEA/STE FIFO
SWEA/STE Housekeeping
SWEA Temperature
Housekeeping Formatter
SWEA Distribution
Distribution Formatter
Telemetry Queue
PAD Formatter
MAG Average
Moment Computer
Beacon Formatter
STE Module (STE-D data)
Burst Dist'n Formatter
Burst System


Hardware
STE Software
STE-D Commands
STE-U
STE-U Serial Interface
STE-U Cmd. Queue
STE Control
Command Router
STE-U FIFO
STE-U Housekeeping
Housekeeping Formatter
STE Distribution
STE-D data
Distribution Formatter
Telemetry Queue
Beacon Dist'n Averager
Beacon Formatter
Burst Dist'n Formatter
Burst System

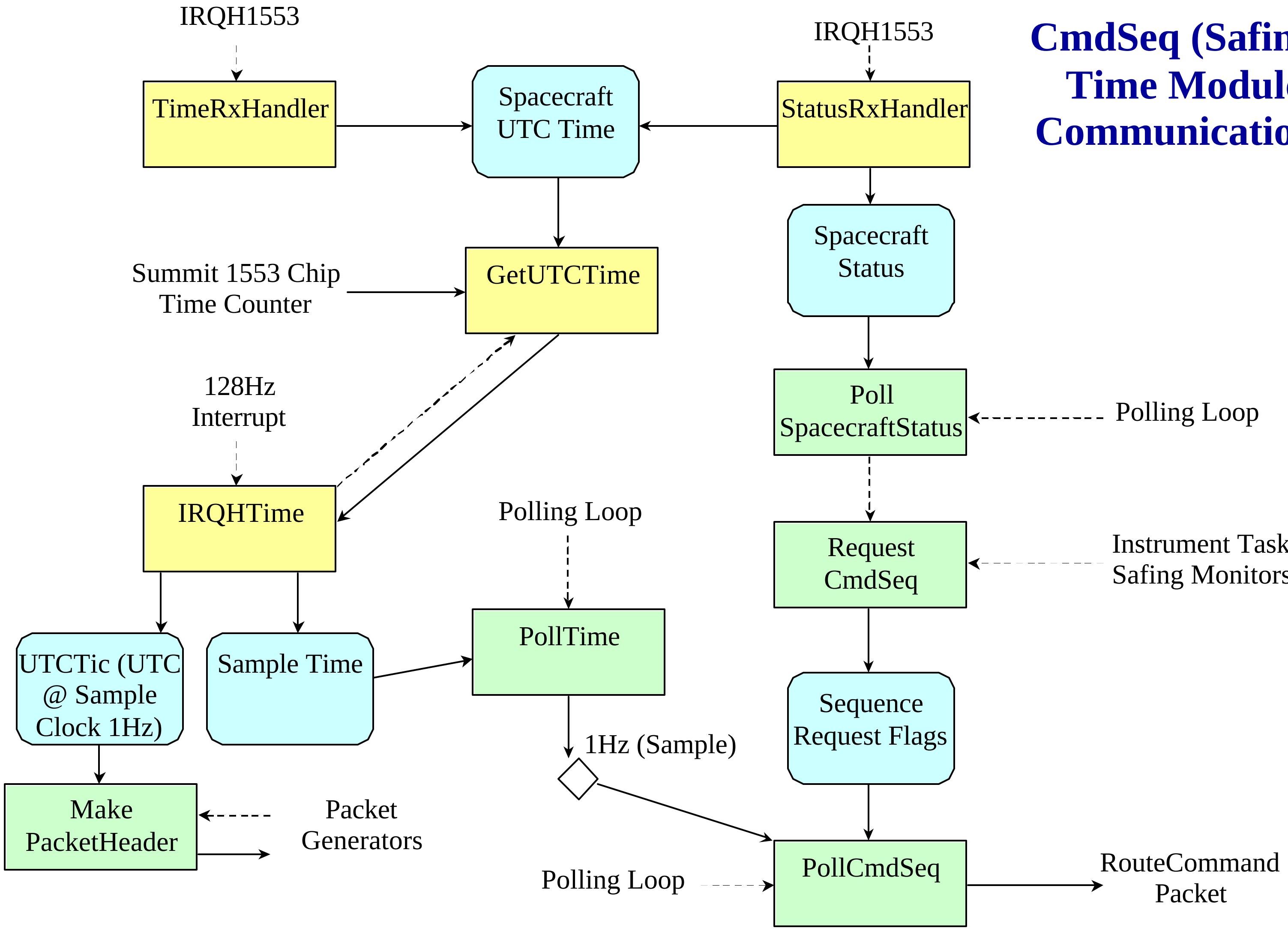

Hardware
SEP Software
SEP Instr.
SEP Serial Interface
SEP Command Queue
Command Router
UTC Clock
SEP FIFO
SEP Telem. Queue
Telemetry Queue
SEP Beacon Data
Beacon Formatter
SEP Housekeeping
Housekeeping Formatter


Hardware
PLASTIC Software
PLASTIC Control
Command Router
PLASTIC Instr.
PLASTIC Serial Interface
PLASTIC Cmd. Queue
Entrance Select Criteria
PLASTIC FIFO
Matrix Rates
SW Mode Formatter
Beacon Data
SW Moments Computer
Monitor Rates Formatter
Distribution Formatter
Telemetry Queue
PHA Event Prioritizer
PHA Event Formatter
PLASTIC Housekeeping
Housekeeping Formatter

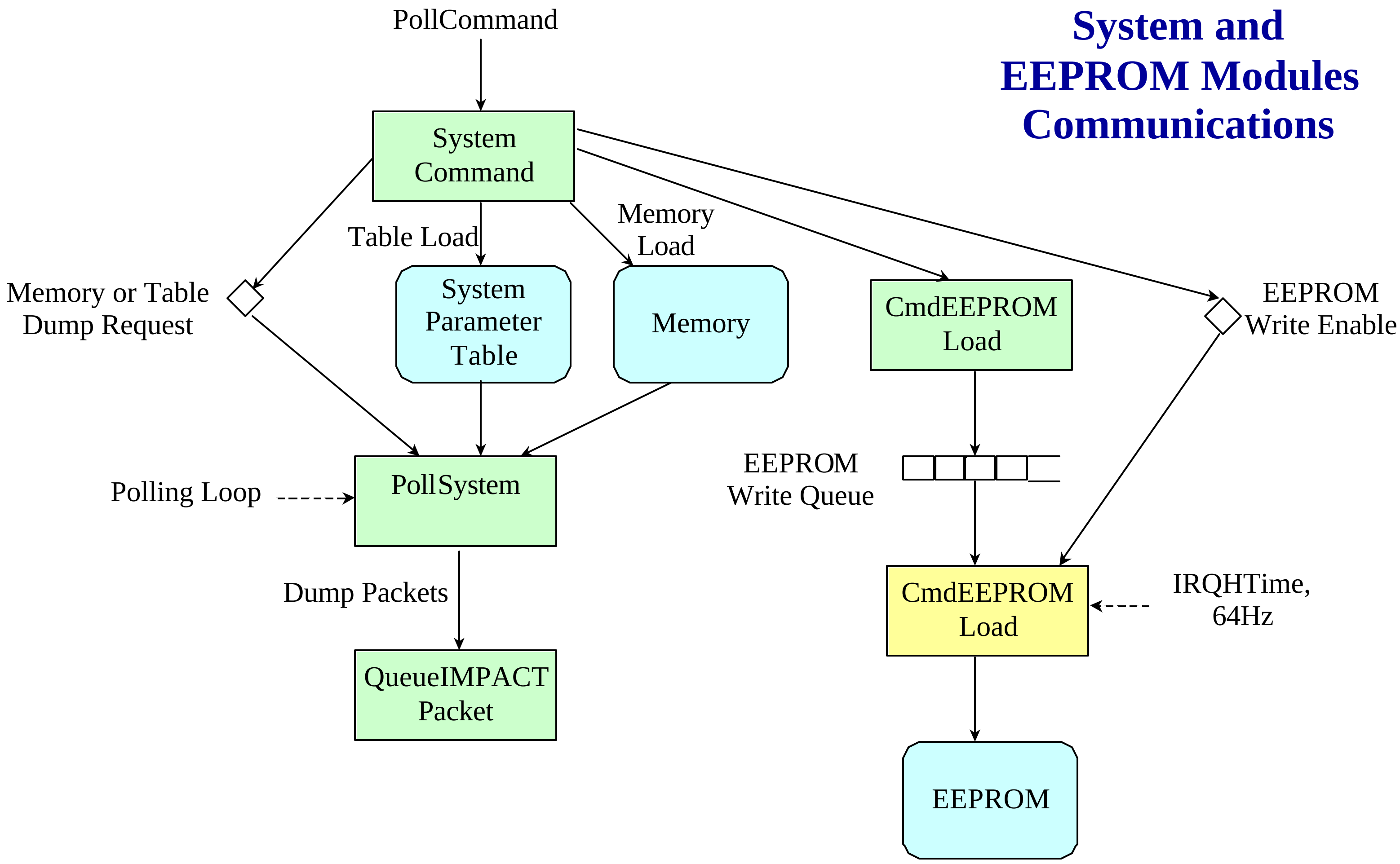
Command & Telemetry Modules Communications



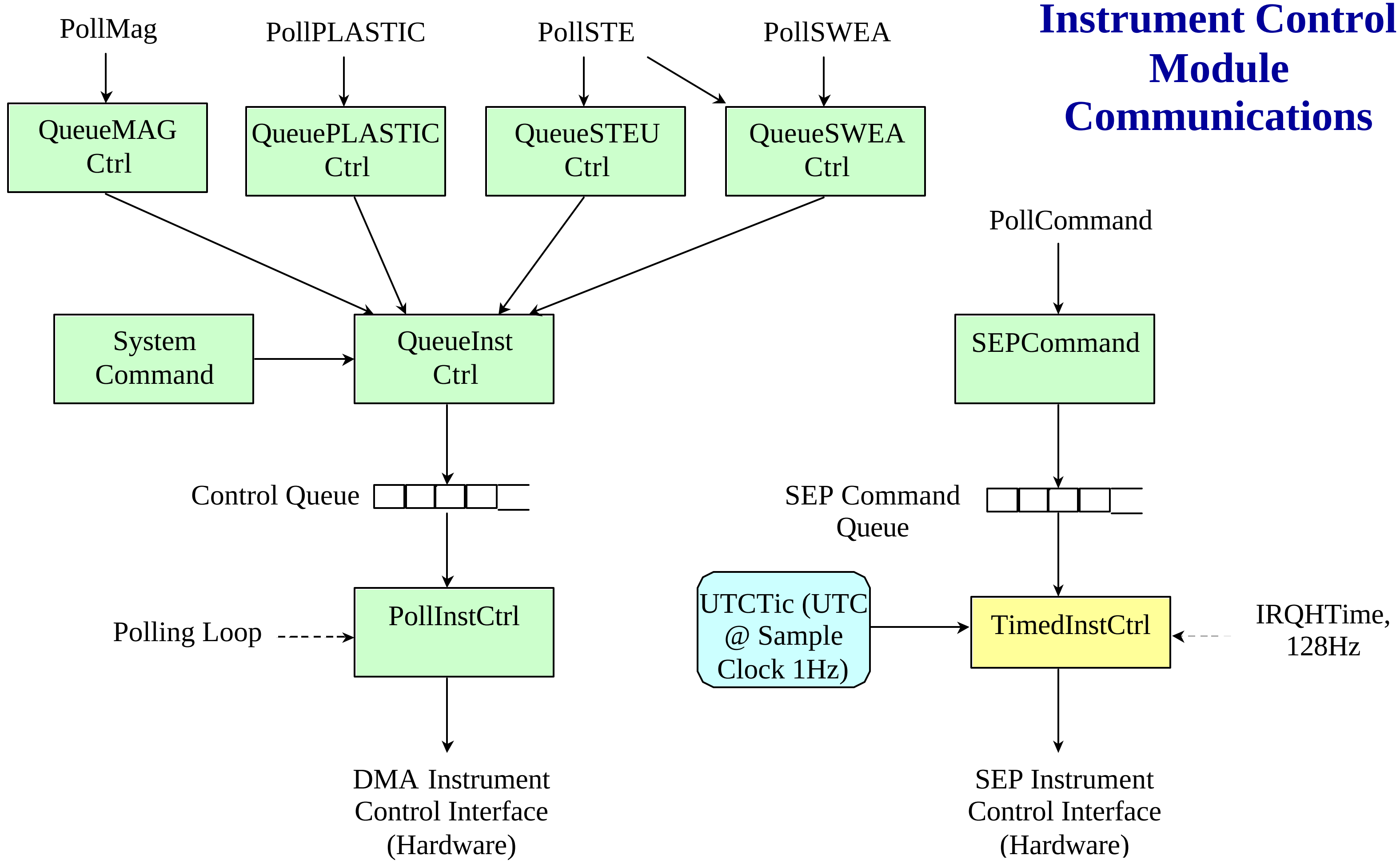
CmdSeq (Safing), Time Module Communications



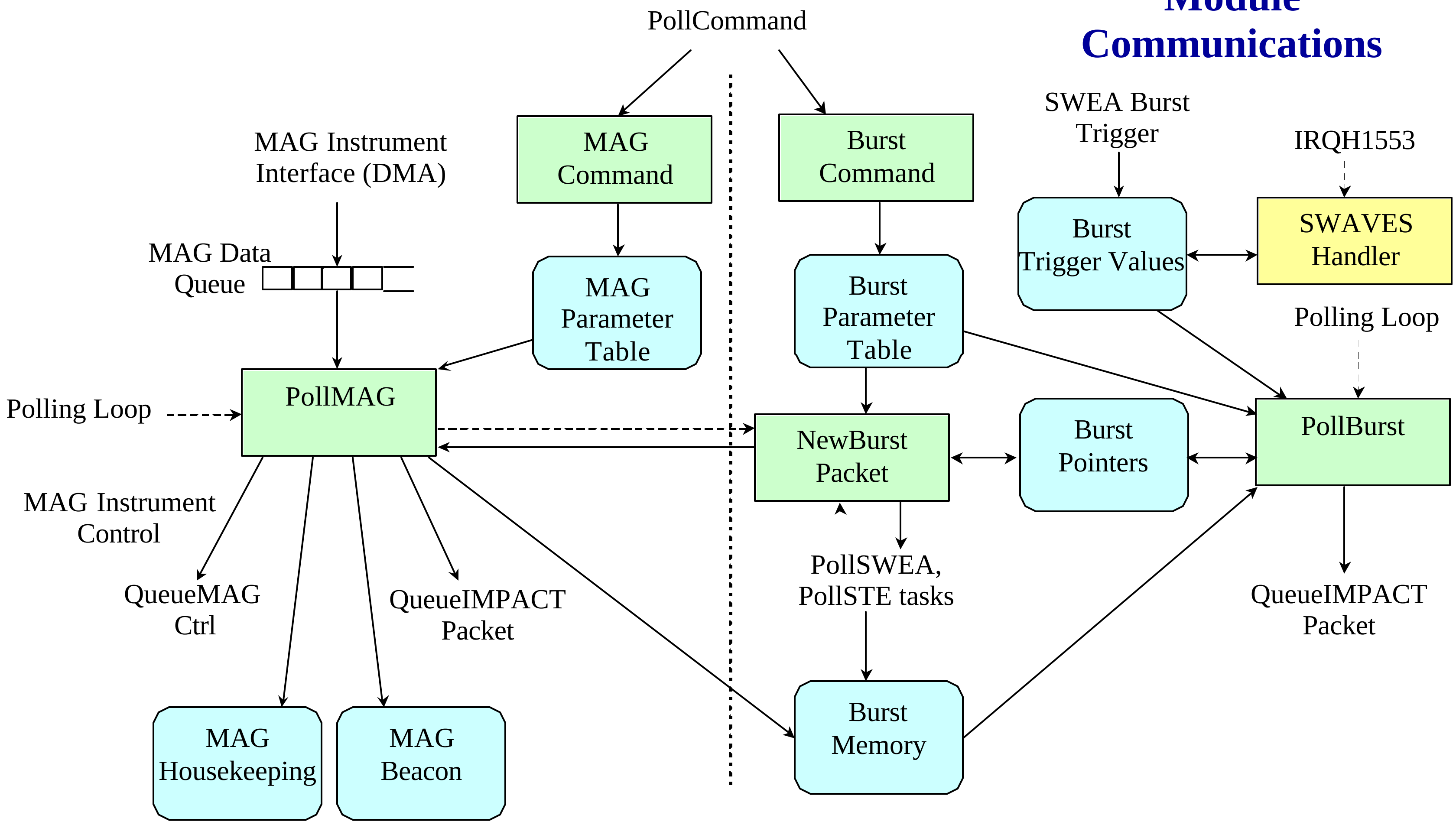
System and EEPROM Modules Communications



Instrument Control Module Communications



Mag and Burst Module Communications



IDPU Flight Software Resource Estimates

Task	Processor Cycles, %	Code Size, kbytes	Buffer Memory, kbytes
Service Software:			
System	1%	1.3 (b)	66.3
1553 Interface	1%	1.7 (b)	2.0
Command Router	<1%	0.5 (b)	2.0
Telemetry Packet Queue	<1%	0.2 (b)	0.1
Burst System	1%	1.0	1500.0 (*)
Time	<1%	0.3 (b)	0.1
Housekeeping	<1%	0.2 (b)	0.8
Beacon Telemetry	<1%	0.2	0.6
EEPROM Manager	<1%	1.1 (b)	2.0
Misc	<1%	0.4 (b)	0.3
MAG Software	1%	1.3	1.2
SEP Software	1%	0.8	3.1
SWEA Software:			
SWEA Moments	21%	1.0	17.0
SWEA Distributions	4%	2.5	10.8
SWEA Misc.	1%	1.0	2.5
STE Software	1%	1.0	3.7
PLASTIC Software:			
PLASTIC Distribution	6%	2.0	185.6
PLASTIC PHA	5%	0.5	46.6
PLASTIC Moments	5%	1.0	45.6
PLASTIC Misc.	1%	1.0	2.5
Total	**55%**	**19.0**	**1892.8**
Available	100%	64	3072
% Usage	55%	29%	62%

(*) Nominal value. Burst memory will expand to use all unallocated memory space.

(b) To be included (at least in part) in Boot PROM. PROM = 8kbytes, usage = 72%

Green code has been written, testing in progress

IMPACT Command & Telemetry Database

- **Describes all commands and telemetry down to the bit level, including addresses, conversion, limits, mnemonics, etc.**
- **C&T GSE extracts information from this database**

IMPACT

IDPU COMMAND AND TELEMETRY

File: IMPACT_CTM_B.xls

Revision: 2002-Aug-8

Sheet	Name	Sheet	Name		
1	APIDS	6	TABLES	11	ApID 201 (Dump)
2	TMSOH	7	Definitions	12	ApID 208,209 (MAG)
3	CMDS	8	ADC	13	ApID 220, 221 (STE Monitor Rate
4	CmdSeq	9	YSICONV	14	ApID 222,223 (STE Spectra)
5	ERRORS	10	Compress (19-8)	15	

Software Status

- **Build #1 is complete**
  - **Written by the IDPU hardware designer to verify the hardware**
- **Build # 2 is in progress**
  - **A lot of code was written while waiting for the DCB ETU to be available**
  - **DCB ETU was delivered in August and code debugging has started.**
  - **Boot PROM code runs, generates housekeeping**
- **The following modules have been written:**
  - **Boot**
  - **System**
  - **1553**
  - **Time**
  - **Command Router**
  - **Command Sequencer**
  - **Telemetry**
  - **Status**
  - **Housekeeping**
  - **Watchdog**
  - **EEPROM**
  - **RS232 (diagnostic)**
  - **Instrument Controller**
  - **MAG**
  - **SEP**
  - **STE (in progress)**

Software Status (continued)

- **Modules remaining to write for Build 2:**
  - **SWEA (no moments)**
    - **Note: Moments code code has been coded to verify resource requirements**
  - **PLASTIC (simple)**
- **Code for Build 3**
  - **Burst Trigger (including SWAVES exchange)**
  - **Beacon**
  - **SWEA Moments**
  - **PLASTIC Moments**
  - **PLASTIC Solar Wind Tracking**
  - **Some of the other more complex PLASTIC code, such as event prioritization.**

IDPU Flight Software Reviews

- **Requirements Review held 12/01**
  - **Science Team input**
- **Flight / POC Software Peer Review held 8/02**
  - **19 RFAs, of which 4 were directed at Project**
  - **Responses to all IMPACT RFAs submitted**

IMPACT IDPU Software Design Review CLOSURE STATUS (8/27/02)

Action No.	Action Item TITLE	ORIGINATOR	STATUS	DATE CLOSED
1	RAM Memory SEU rate	Jerry Hengemihle	Response 2002-9-19	
2	SSR status	Jerry Hengemihle	Response 2002-9-18	
3	Triana and Swift Lessons learned	Jerry Hengemihle	Done	
4	80196 Lessons Learned	Jerry Hengemihle	Done	
5	Hold STEREO 1553 Telcon	Jerry Hengemihle	Pending Project	
6	Autonomous reset	Jerry Hengemihle	Response 2002-9-18	
7	IDPU reboot and SEP operation	Jerry Hengemihle	Response 2002-9-19	
8	Health and safety monitoring	Jerry Hengemihle	Response 2002-9-19	
9	PLASTIC HW/SW ICD	Jerry Hengemihle	Response 2002-9-21	
10	Verification of CPU loading	Jerry Hengemihle	Response 2002-9-21	
11	Valid Mode Codes	Harry Culver	Pending APL input	
12	Commercial configuration management tool	Kequan Luu	Response 2002-9-18	
13	Timing Requirement verification	Kequan Luu	Response 2002-9-18	
14	Software Testing	Kequan Luu	Response 2002-9-21	
15	Software ICD's	Kequan Luu	Response 2002-9-18	
16	CPU Processing time	Kequan Luu	Response 2002-9-21	
17	Critical Commands	Kequan Luu	Response 2002-9-18	
18	Increase number of ground systems	Kequan Luu	Response 2002-9-18	
19	Implement NOOP command	Kequan Luu	Response 2002-9-18	

Changes since PDR

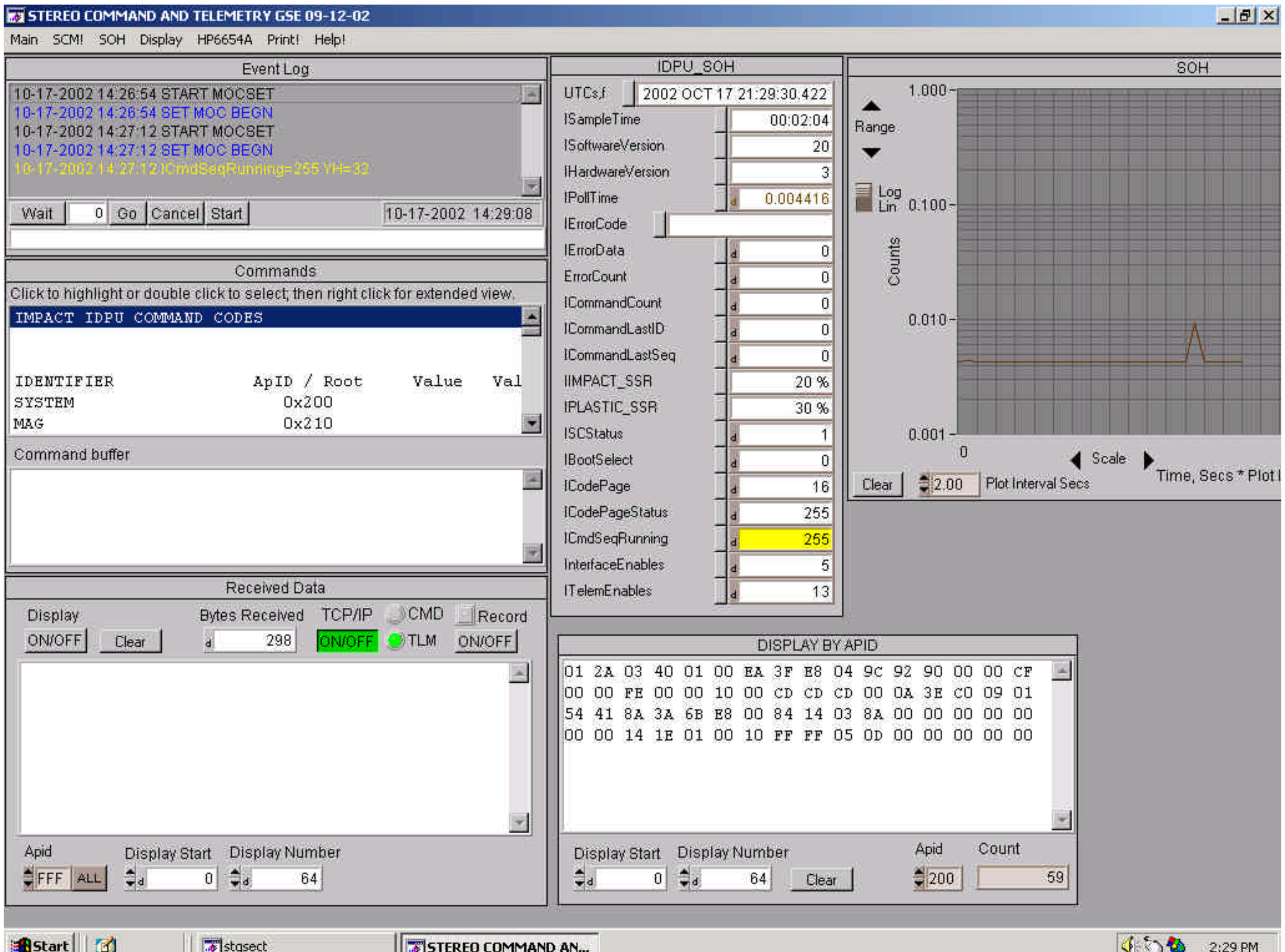
- Added a second programmer for PLASTIC code
  - Avoids a bottle-neck during development and test
- Increased the Burst Memory size 2MBytes -> 3MBytes
  - PLASTIC Buffer requirements larger than anticipated
- Changed memory type for lower SEU sensitivity
  - Allows code to be run from RAM, more flexibility, less chance of upset

IDPU GSE & POCC

Command & Telemetry GSE

- Works with Spacecraft Emulator at IDPU and Suite I&T level
- Works with MOC at Spacecraft I&T level
- Becomes the code of the Payload Operations Center (POC)
- Runs commands and command scripts
  - STOL-like language
- Remote commanding & display via secure internet connection
- Displays housekeeping and instrument status information with limit-checking / alarms
  - Will have the ability to send messages to operator pagers
- Can display science packets in Hex format for diagnostics
- Provides a TCP/IP socket for forwarding commands and telemetry from remote institutions
  - Will be used during Suite I&T, perhaps also at Observatory I&T
  - Uses the same interface as the MOC/POCC system
- PLASTIC command scripts may be run on the IMPACT C&T GSE during IDPU testing
  - Will be run on a PLASTIC-developed GSE during PLASTIC development (with IDPU ETU), Observatory-level tests & Operations.

Command & Telemetry GSE User Interface



Science Display GSE

- Decodes and Displays science data from instruments
- Provides adequate information to determine the health and functionality of the instrument in the I&T, Commissioning, and mission environment
- Runs on a second workstation (PC) in order to provide more display space, separate science and engineering functions, and improve the reliability of the C&T system
- Science Display GSEs will get data from the MOC or Spacecraft Emulator
- Science displays shall be developed by the instrument teams:
  - MAG, SWEA, STE – UCB / Hashii
  - SEP – Caltech
  - PLASTIC – UNH

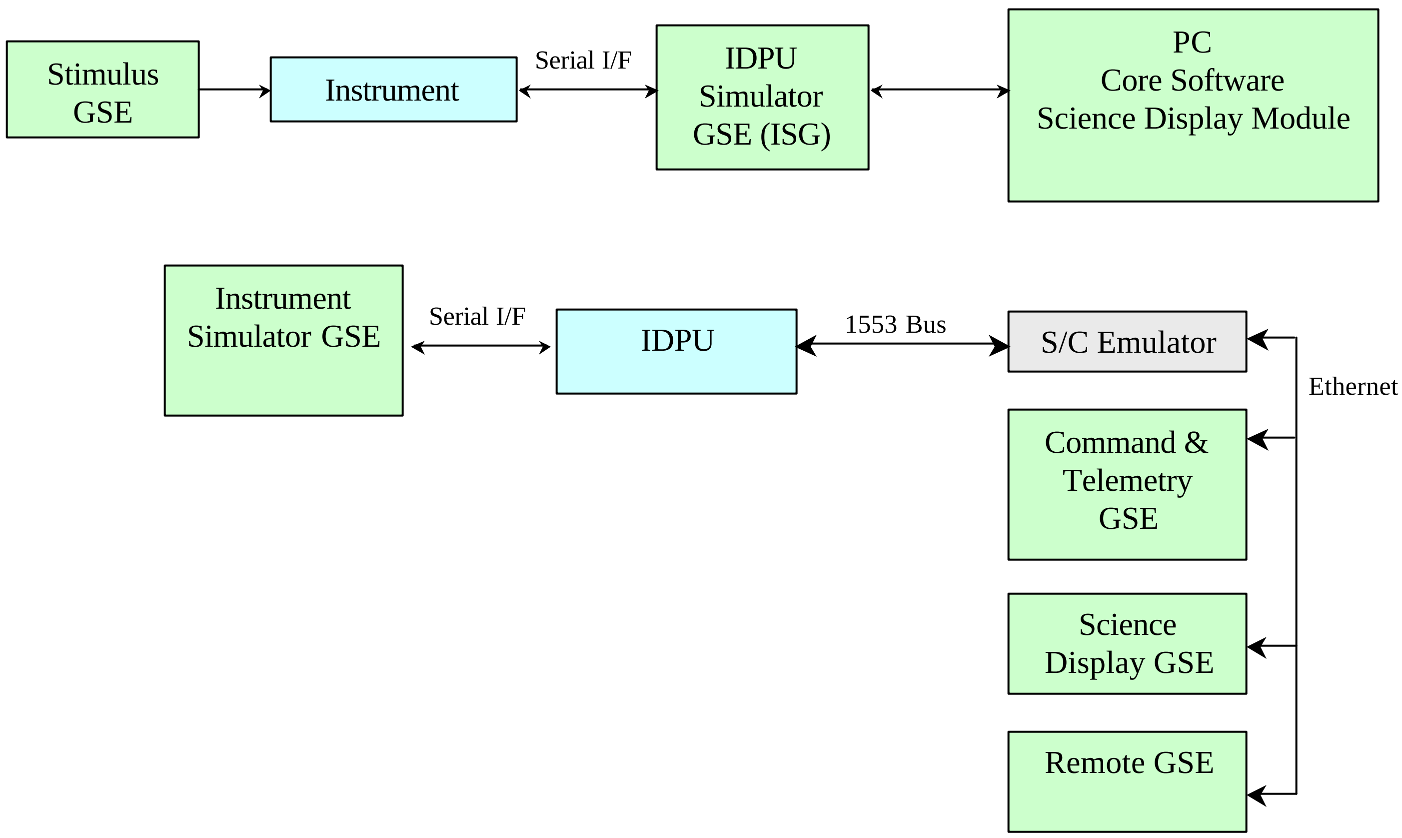
IDPU Simulator GSE

- Developed at UCB (with Elf)
- Provides ability to test instruments in the absence of the IDPU and verify the instrument/IDPU interface
- Consists of a black box (IDPU Simulator GSE, ISG) plus a PC
- ISG includes most of the functionality of the Data Controller Board, minus the 1553 interface
  - Designed to IDPU Simulator Specification Document by Elf (who also designs the DCB)
  - Has an added Instrument Simulator feature which works the serial instrument interface in the reverse direction for IDPU testing
- PC software shall be developed at UCB
  - Based on LabWindows CVI development system
  - HESSI GSE heritage; STOL-like scripted command system
  - Science display modules written at the instrument home institution
    - UCB develops MAG, SWEA, STE displays
    - Caltech develops SEP displays, UNH develops PLASTIC Displays

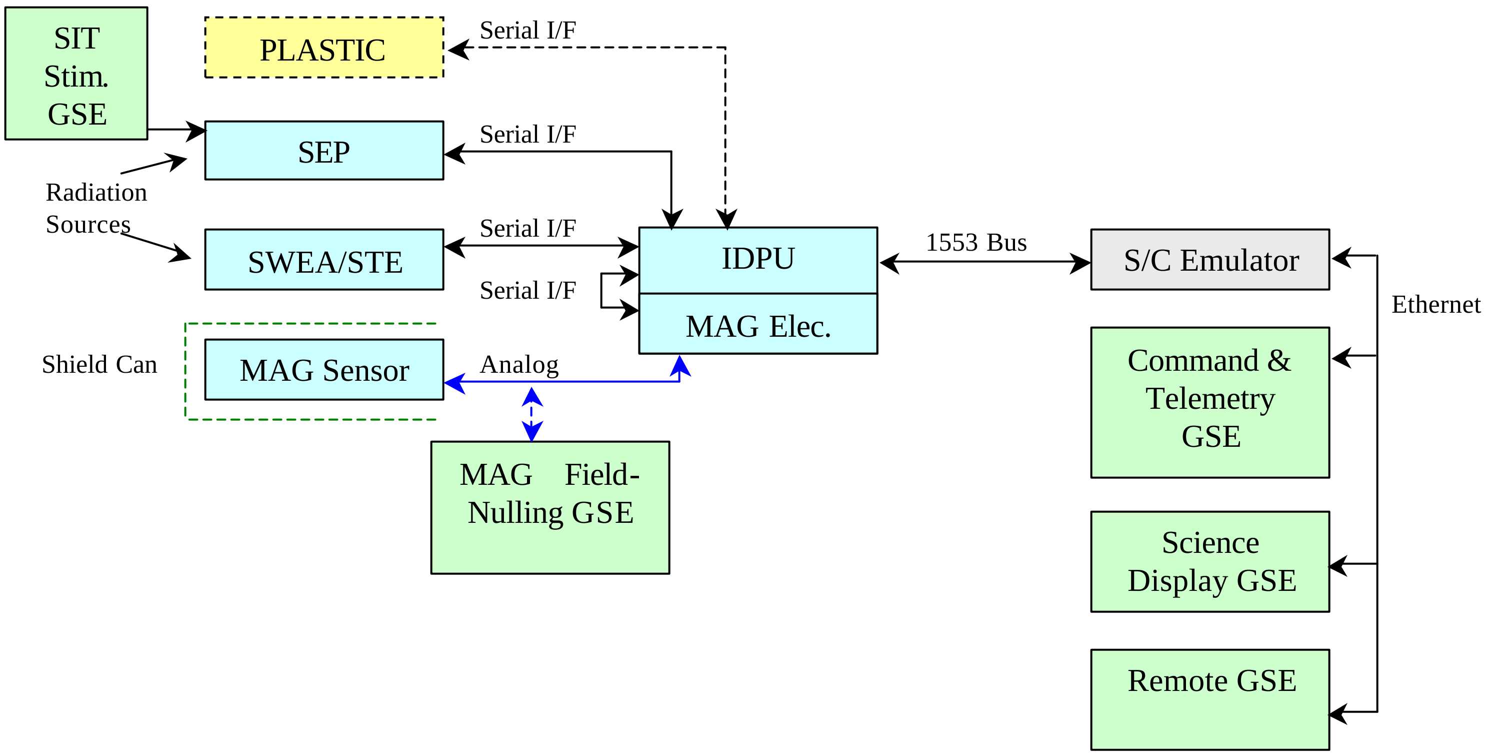
Controlling Documents

- GSE Software Development Plan
- MOC/POC ICD
- CCSDS standards
- STEREO IMPACT GSE Requirements
- IDPU Simulator Specification covers the IDPU Simulator GSE Hardware
- Command Format Document describes command encoding
- Command Verification Spec defines command verification scheme
- IMPACT Command & Telemetry Database defines telemetry and command packets, mnemonics, conversion, and limits.

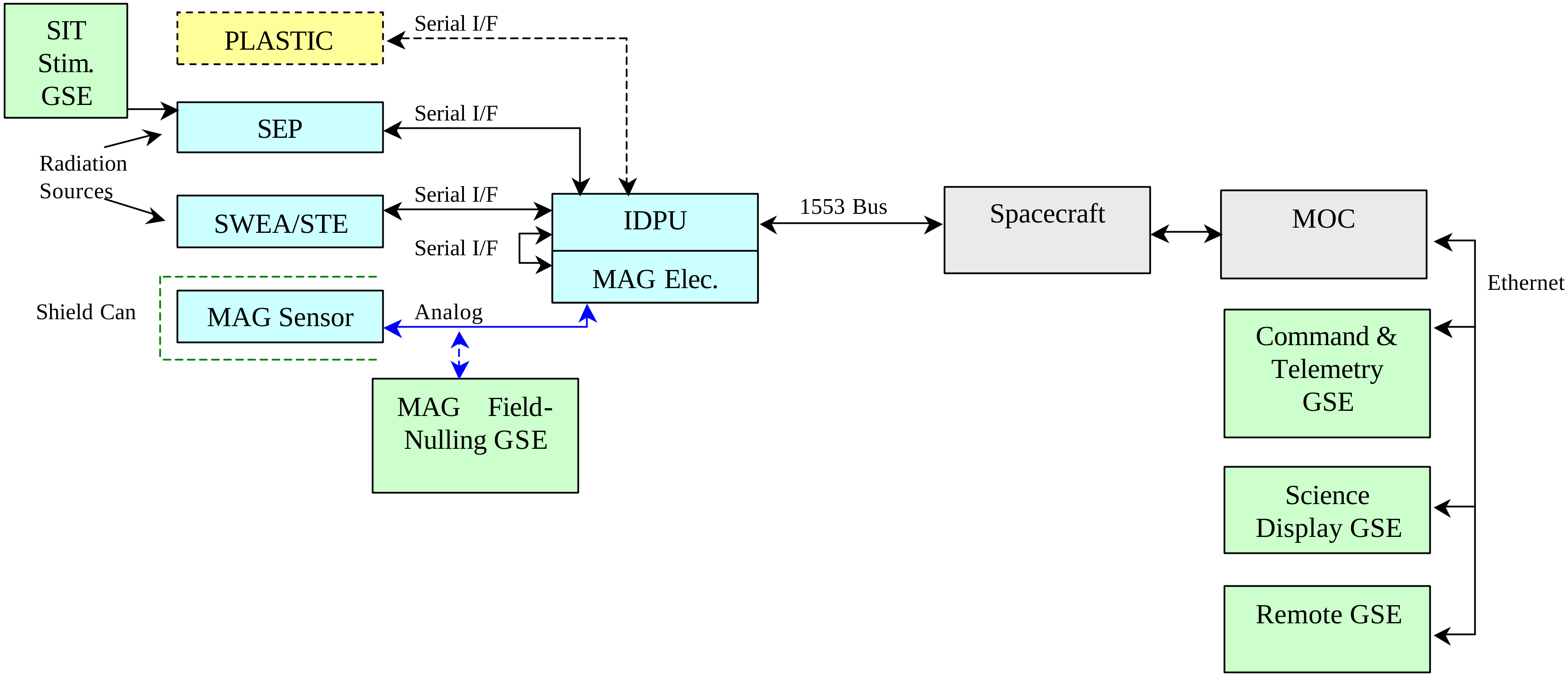
Instrument Bench Checkout Configuration



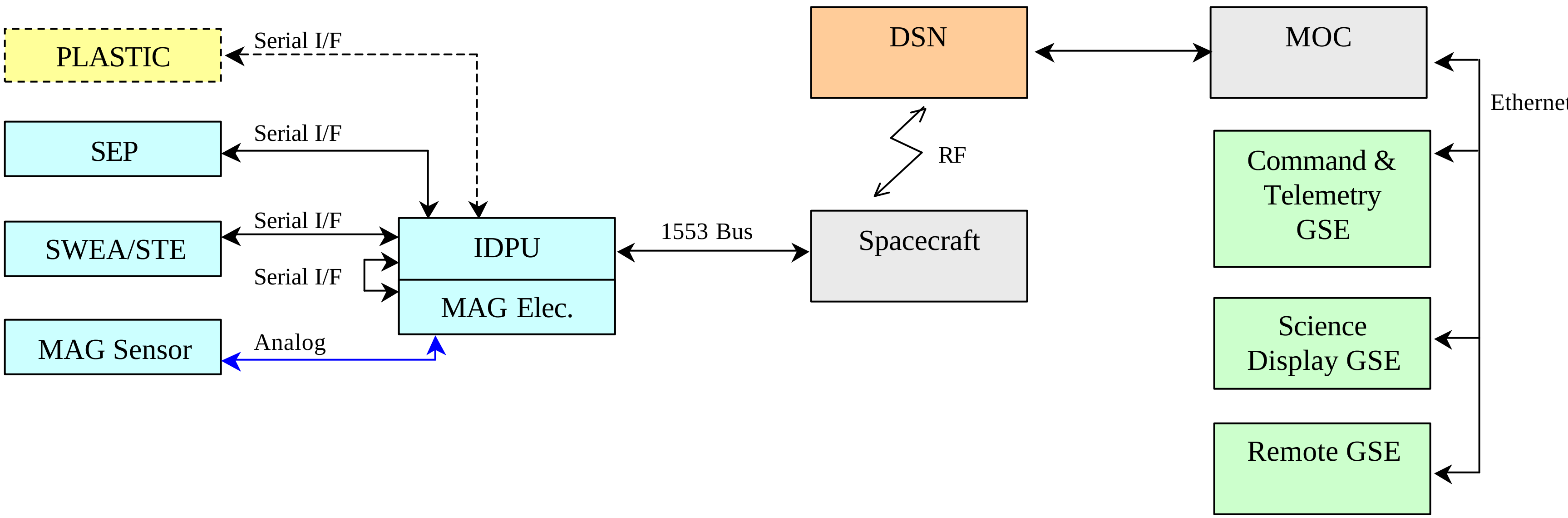
IMPACT Suite Integration GSE Configuration



IMPACT Spacecraft Integration GSE Configuration



IMPACT Mission Operations GSE Configuration



GSE Software Development

- The IMPACT IDPU Simulator, Command & Telemetry, and Science GSE are PC-based systems running LabWindows-CVI based software
- The software is based on a long series of GSE developed at Berkeley, most recently for Lunar Prospector and HESSI.
- The software is modularized allowing a lot of code re-use

GSE Development Status

- **C&T GSE (POCC) software is working with the Emulator and ETU IDPU.**
  - **A few features still to be added, such as Operator Pager access**
  - **POCC Design Peer Review held 9/2002**
- **Science Displays**
  - **Work has started on the MAG science displays.**
  - **Remaining Science displays**
- **IDPU/Instrument Simulator**
  - **ISG hardware complete (6 copies)**
  - **ISG IDPU Simulator / Instrument Simulator Core software complete**
  - **ISG MAG Displays for IDPU Simulator complete; ISG & Software shipped to MAG team and in use at GSFC**
  - **ISG SWEA/STE software in progress**
  - **ISG Hardware and core IDPU Simulator software provided to PLASTIC team at UNH**
  - **ISG Hardware and core IDPU Simulator software ready to be provided to SEP team at CIT**
  - **ISG Hardware and Instrument Simulator software in use in IDPU Software development**

GSE Remaining Work

- **Add remaining features to POCC**
  - **Operator Paging**
  - **Hazardous Command Warnings**
  - **Command & Telemetry forwarding**
- **Instrument Science Displays**
- **Support added feature requests for the POCC and IDPU Simulators as needed**