



National Aeronautics and Space
Administration
Jet Propulsion Laboratory
California Institute of Technology

SIM PlanetQuest

1393 Ring Bus at JPL

Description & Status

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AMAPS
June 26-28, 2007
Fayetteville, Arkansas



Objective

- SIM Planet Quest Overview & Status
- Application of the 1393 Ring Bus to SIM
- Ring Bus Verification & Validation

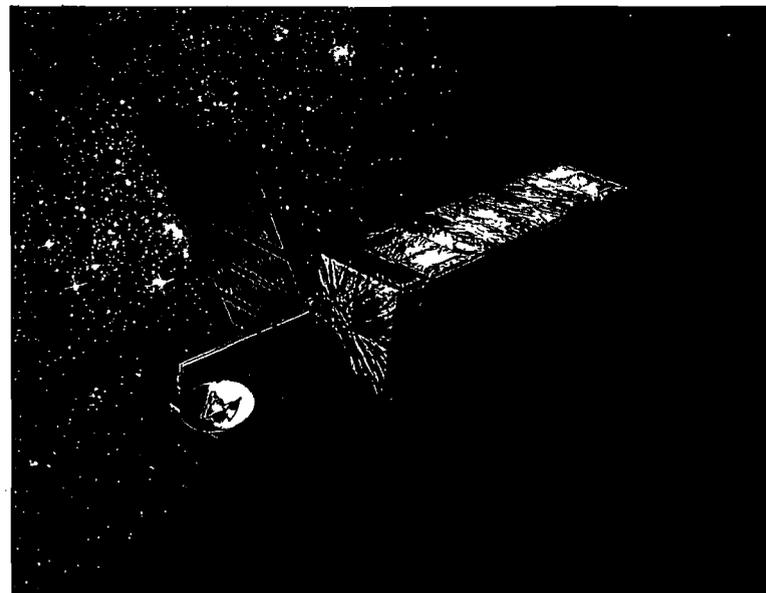
SIM PlanetQuest



SIM PlanetQuest Overview

Salient Features

- **3 parallel Michelson Stellar Interferometers**
- **9 meter baseline**
- **Visible wavelength**
- **Earth-trailing solar orbit**
- **5 year mission, with a 10 year mission goal**
- **SIM is a JPL, Caltech, NGST, KSC, and SIM Science Team partnership**



Science

- **Search for Earth-like planets orbiting nearby stars and measure the masses and orbits of the planets it finds.**
- **Survey 2000 nearby stars for planetary systems to learn whether our Solar System is unusual, or typical.**
- **Make a new catalog of star position 100 times more accurate than current measurements.**
- **Learn how our galaxy formed and will evolve by studying the dynamics of its stars.**
- **Critically test models of exactly how stars shine, including exotic objects like black holes, neutron stars and white dwarfs.**

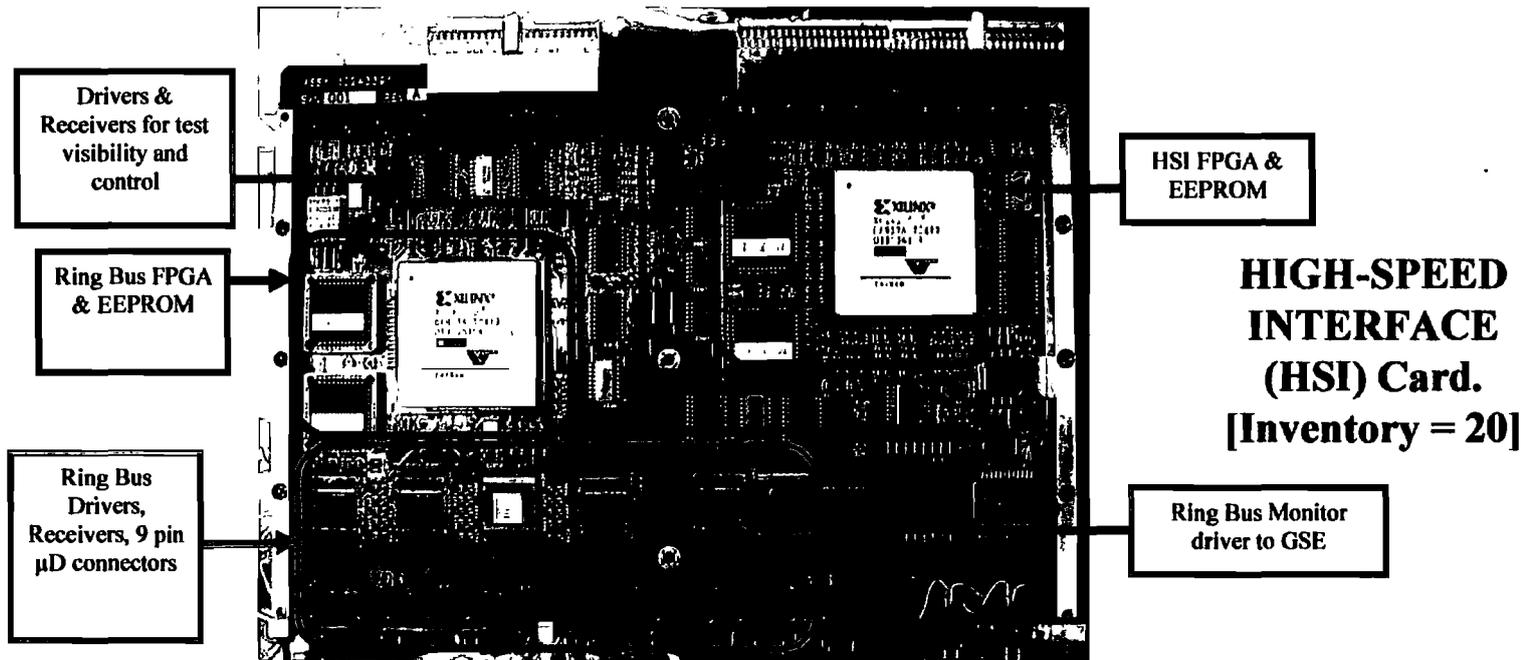
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1393 Ring Bus at JPL

- Completed V&V of Ring Bus IC (26 months from Initial Design Conception)
- Implemented a High-Speed Data Transfer Bus based upon the IEEE 1393 Standard to meet SIM Rqmts
 - Real-Time Deterministic, Distributed Systems
 - Control System Requirements
 - Fault Detection & Recovery
 - Improved Testability
 - Robust to Design Evolution
 - Time/Event Synchronization
 - Minimize Flight Software Evolution
 - Flight Operations
- JPL Implementation in general followed the standard
 - Frame Types, Input/Output FIFOs, Tx/Rx Bandwidth, CSR Registers, Fault Handling
- Exception - use of Copper Wire (LVDS) due to TDRL Readiness (original 2009 launch date)
 - Ring Bus IC firmware independent of physical media.

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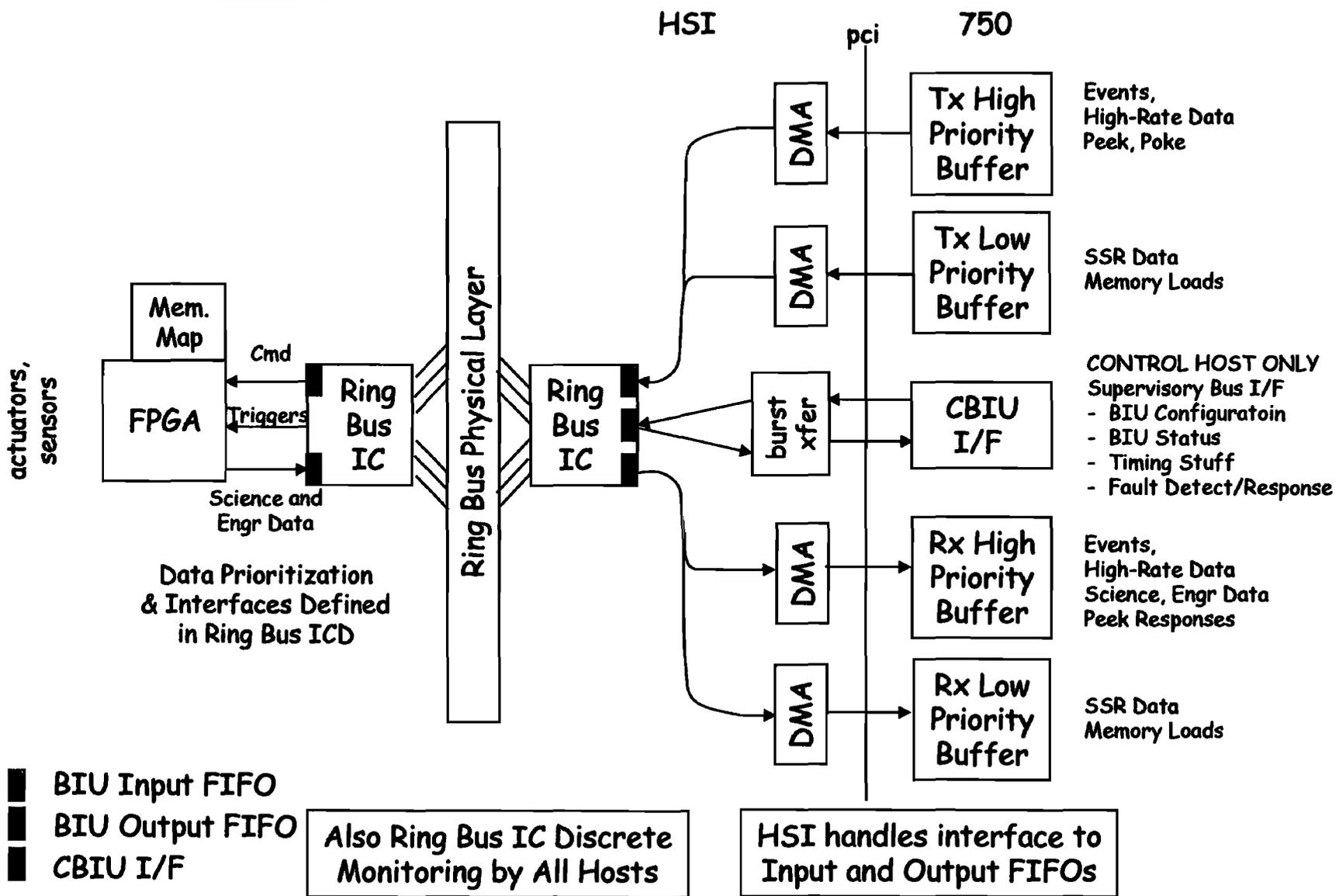


Two Interfaces Used in SIM

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Instrument

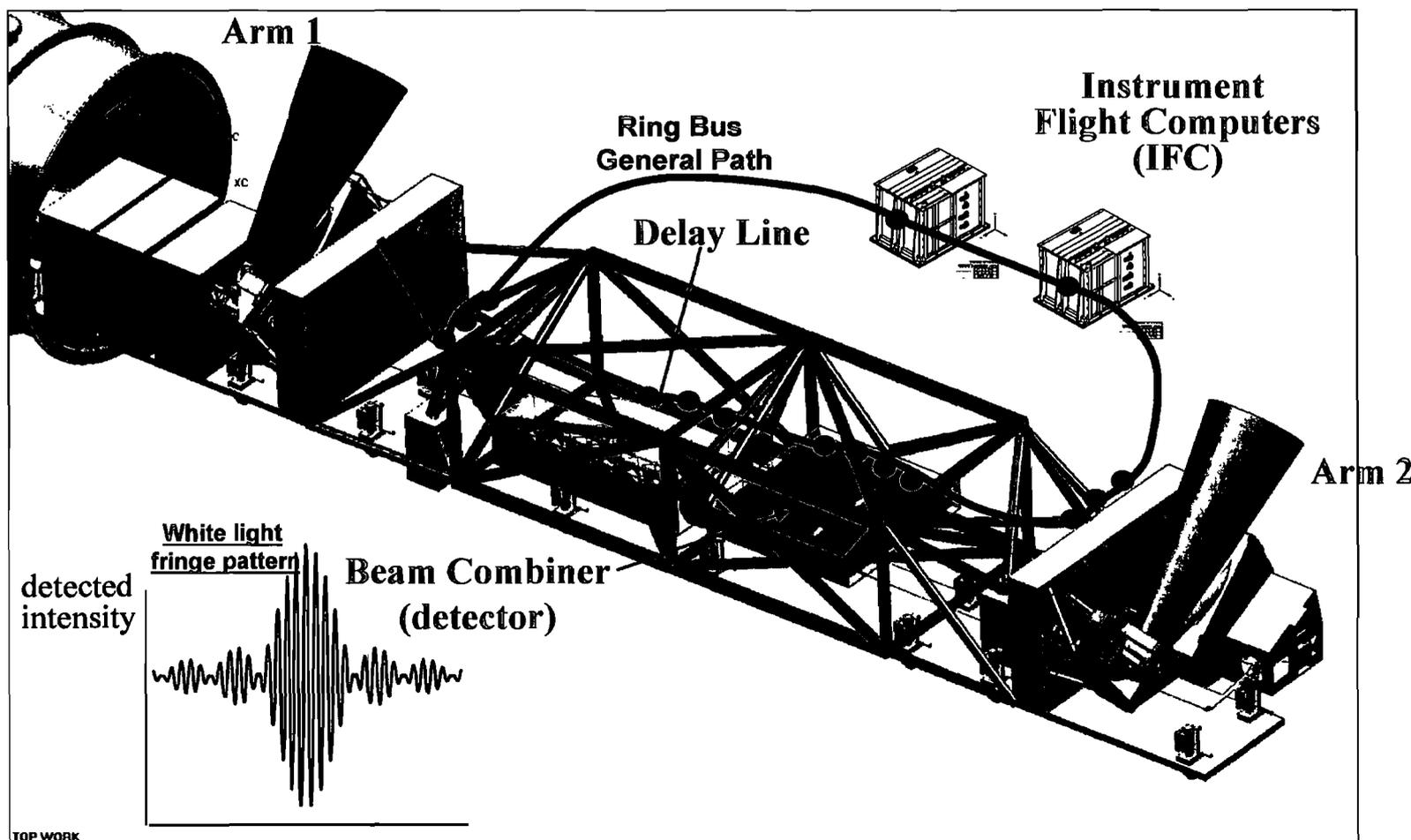
Instrument Flight Computer (IFC)





SIM PlanetQuest Status

- SIM-PQ Project is moving forward into its new Engineering Risk Reduction phase pending establishment of its new launch date.
- As part of the Engineering Risk Reduction activities, SIM-PQ Project is planning on building a brassboard interferometer.



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TOP WORK

AMAPS

Space Technology

JPL

LOCKHEED MARTIN

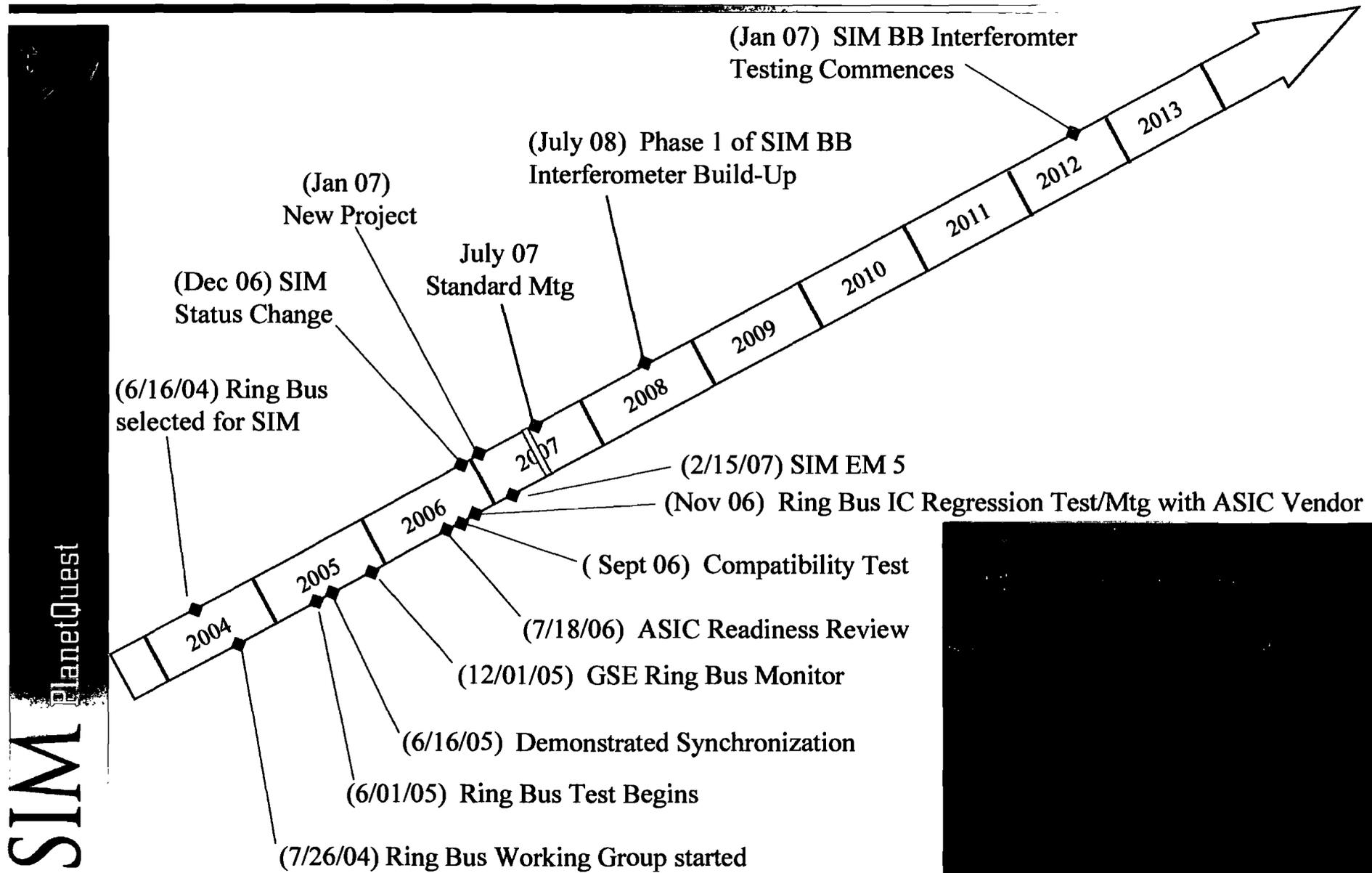


T. Wysocky

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Ring Bus Timeline (JPL)



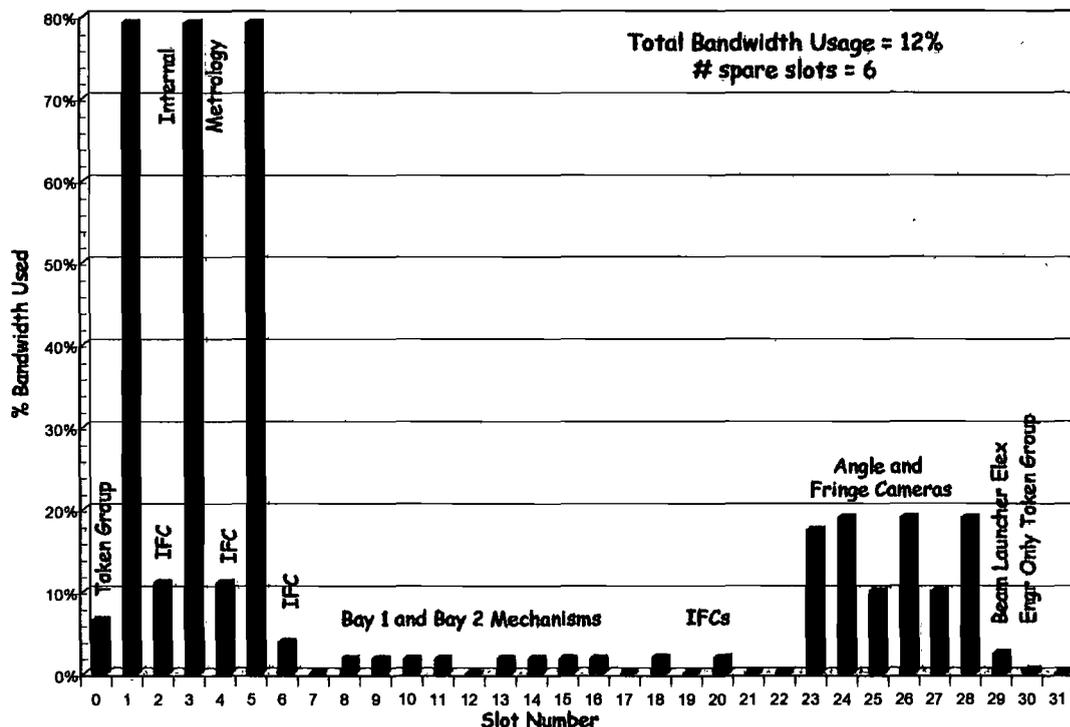
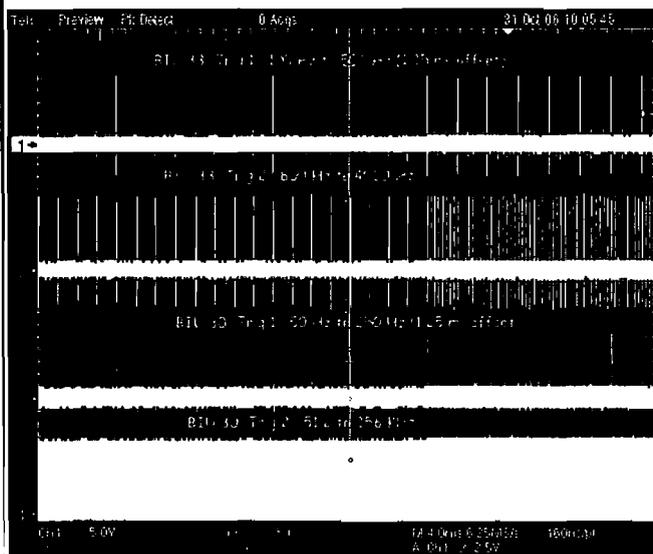


SIM PlanetQuest Status – Ring Bus

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- **Baseline= 57 active BIUs (92 total).**
- **Event Coordination**
 - **Camera, Metrology, Delay Line**
 - **Multiple Processors w/ Instrument**
 - **Actuators (Each Arm)**
 - **Metrology Elements**

- **88% Bandwidth Margin**
- **Early V&V Completion → Early Integration with Subsystems.**





Summary of 1393 Enhancements

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Standard Enhancement	Comment
Added time/event synchronization	Inherent feature of ring bus required by SIM. BIU time-stamps sensor packets.
Autonomous Start-Up to minimize Flight S/W involvement	Auto ring synchronization & configuration Auto determination of who's on ring by CBIU. Auto LAB size determination
Data Integrity	Data packets protected portal-to-portal. Option for BIU to add CRC to payload data BIU does all CRC writes and checks.
Testability	Added ring bus monitor tap
Additional Fault Handling	Used/Added discretes for fault protection of Data Hosts. More CBIU control to clear FIFOs, reset Data Hosts. Added BIU POR status and buffer EDAC testing.
CBIU/BIU in same IC	Saves S/C mass – CBIU function enabled at single BIU.
FIFO and CCIR signal interface	Added signal definition
Fault Injection	Error Counters
Miscellaneous Tweaks	Option to disable THT, remove ambiguity with FCSR parity error, etc.



Ring Bus IC V&V Summary

Comprehensive Test Matrix

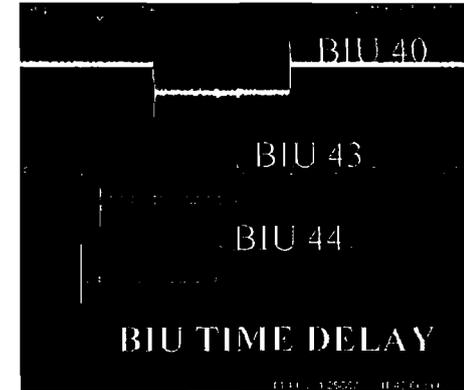
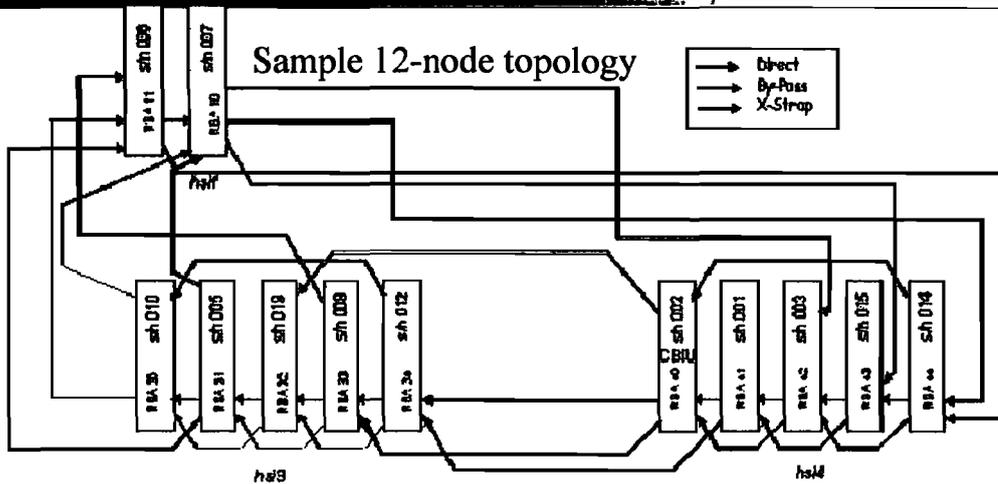
Ref	Test Category	total	tested	not yet tested
1	Ring Start-Up/ Reconfiguration	16	16	0
2	CBIU I/F/ Cmding/ Supervisory Bus	150	149	1
3	Tx/Rx Bandwidth/ATM Formats	50	50	0
4	HSI – DMA interface to Ring Bus (FIFOs); Also HSI FPGA only reqs	71	71	0
5	Fault Detect/Response	133	133	0
6	Timing Availability/ Coordination/CLK; Performance/ Manure spreader	102	102	0
7	128 MHz/PPM Accuracy	11	11	0
8	T2 & Fine-Tuning/Jitter Register/RBI to RBI synchronization/Delays	16	16	0
	Totals (Ring Bus Hardware)	549	548	1
9	Flight Cable Testing	3	2	1
10	Flight Software Use/Requirements	78	29	49
11	Peripheral Use/Requirements	38	38	0
	Totals	668	617	51

- All Items with respect to Ring Bus IC Verified Via Test except
 - Automatic Latency Adjust Buffer (LAB) Determination due to an Insufficient Number of BIUs
 - This has been Simulator Tested.
 - Can Manually Override LAB size.
- Regression Test with over 20,000 test cases
- Ring Bus Monitor Used to Verify Subframe Overhead + Payload (Tokens, etc)

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Ring Bus IC V&V Examples



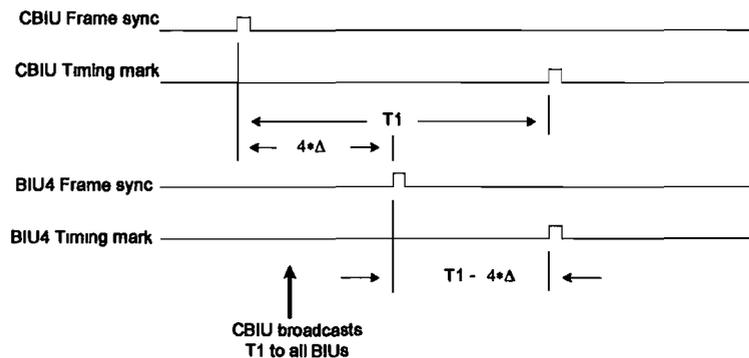
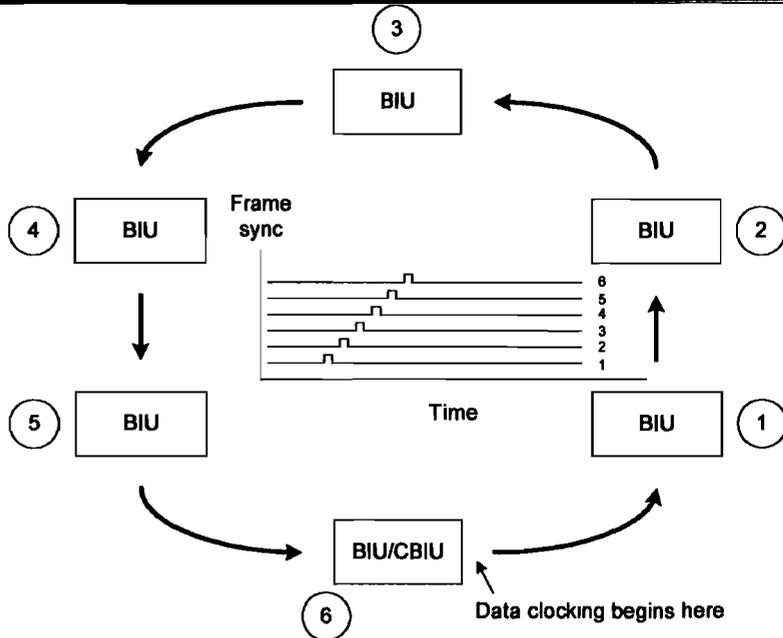
Frame Count	SFOH FC	Subframe	SFOH Claim	SFOH CRC	PRI	P4S	BIU Addr	CSR Addr	Ring Norm	Frame Type	Rx Status	L/P Cmd	Load/Poll Data	BIU ID	Comments
0	0	4	0	d7	0	0	0	0	1	2	0	0	0	1	
6700	0	5	1	d7	0	0	5	19	1	2	0	0	0	1	1st Poll Cmd
6700	0	7	1	d7	1	0	5	19	1	2	0	0	7000000	1	Poll Response
6702	0	1	1	d7	0	0	5	19	1	2	0	0	0	1	2nd Poll Cmd
6702	0	3	1	d7	1	0	5	19	1	2	0	0	7000000	1	Poll Response
6703	0	5	1	d7	0	0	5	19	1	2	0	0	0	1	3rd Poll Cmd
...															...
6835	0	5	1	d7	0	0	5	19	1	2	0	0	0	1	91st Poll Cmd
6835	0	7	1	d7	1	0	5	19	1	2	0	0	7000000	1	Poll Response
6836	0	3	1	d7	0	1	3	19	1	2	0	0	0	1	Poll 4 Status
6837	0	1	1	d7	0	0	5	19	1	2	0	0	0	1	92nd Poll Cmd
6837	0	3	1	d7	1	0	5	19	1	2	0	0	7000000	1	Poll Response
6838	0	5	1	d7	0	0	5	19	1	2	0	0	0	1	93rd Poll Cmd
6838	0	7	1	d7	1	0	5	19	1	2	0	0	7000000	1	Poll Response
6839	0	1	1	d7	0	1	3	19	1	2	0	0	0	1	P4S (Cont)
...															...
6875	0	1	1	d7	0	1	3	19	1	2	0	0	0	1	P4S (Cont)
6876	0	5	1	d7	0	0	5	19	1	2	0	0	0	1	116th Poll Cmd
6876	0	7	1	d7	1	0	5	19	1	2	0	0	7000000	1	Poll Response
6877	0	1	1	d7	0	1	3	19	1	2	0	0	0	1	P4S (Cont)
6879	0	1	1	d7	0	1	3	19	1	2	0	0	0	1	P4S (Cont)
...															...
17007	0	1	1	d7	0	1	3	19	1	2	0	0	0	1	P4S (Cont)
17009	0	4	1	d7	0	0	3	19	1	2	0	0	0	1	P4S Poll Cmd.
17009	0	2	1	d7	1	0	3	19	1	2	0	0	7800000	1	0.5s P4S Resp.

Sample Ring Bus Monitor Filtered Output

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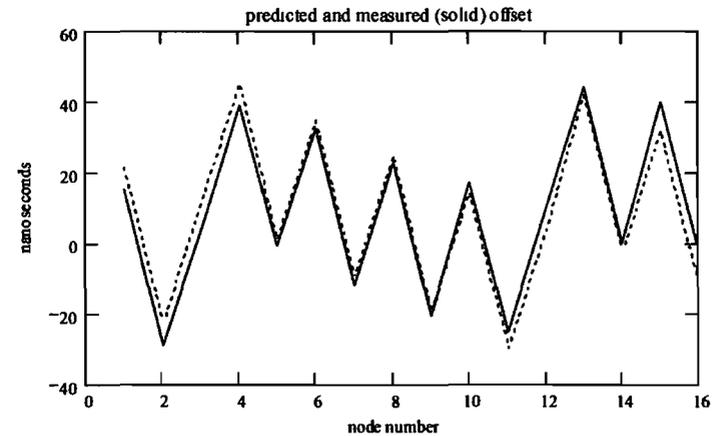


Ring Bus Timing

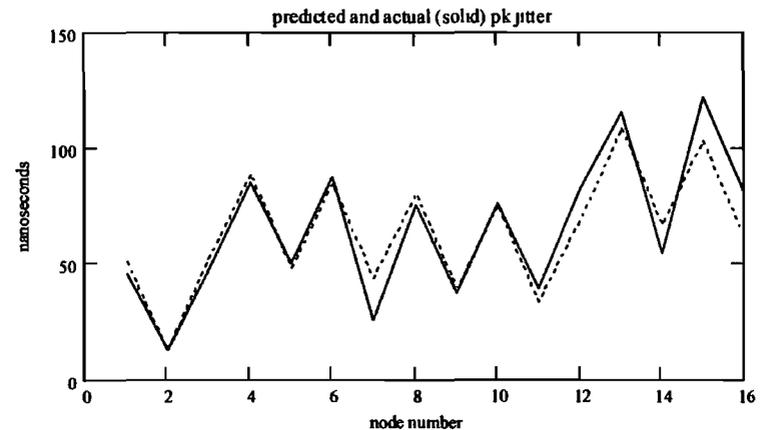


Ring Bus Interrupt (RBI) is the BIU Timing Mark whereby all BIUs synchronize with.

Predicted and Measured RBI Offset
(without fine-tuning)



Predicted and Measured Peak Jitter



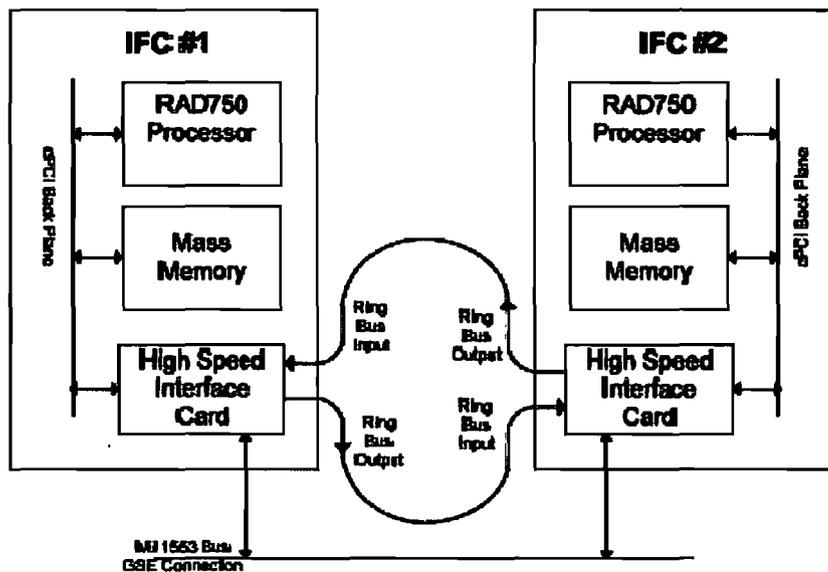
Ring Bus Time Synchronization ~ 3 orders of magnitude better than 1553B

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SIM Engineering Milestone 5

- Objective = Validate SIM's Multi-Processor Architecture using two BB IFCs, Ring Bus, and Flight Software (v2.0).
- Able to Support High-Rate, Low-Latency Distributed Control Systems.
- Measured Processing Impact on Ring Bus Driver Module in FS.W.



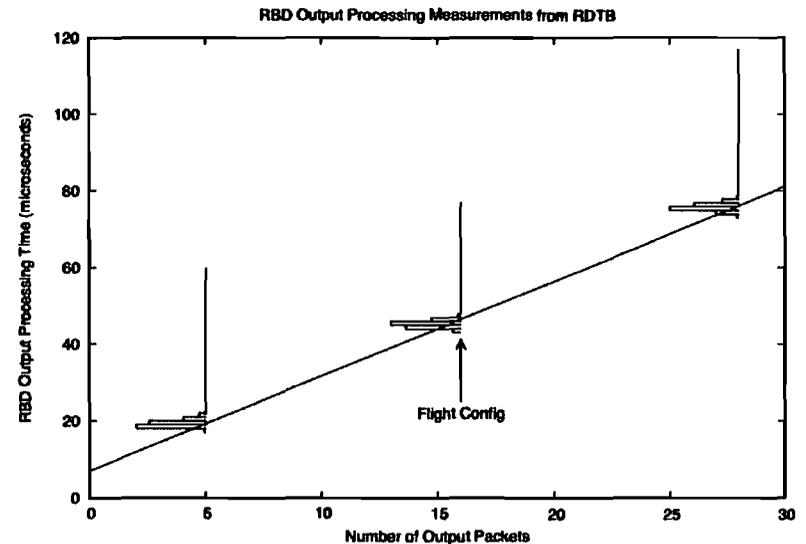
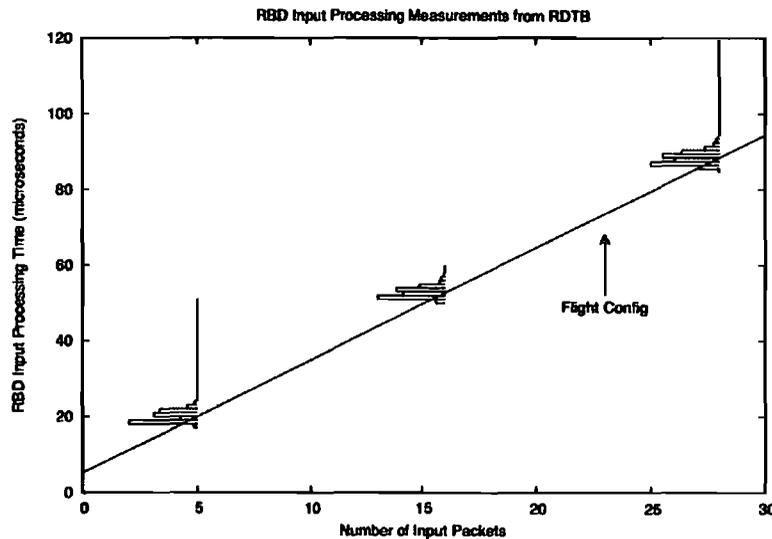
- One IFC simulated Instrument Traffic
- Other IFC Responded
- IFCs exchange Instrument Data & Commands
- Timing Stamps Added at Tx/Rx end.
- Not the Predictable Ring Bus Transit Delay.



SIM Engineering Milestone 5 Results

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- Measured Timing Fits Well into Overall Timing Budget for a 500 Hz Control Loop
- Linear Relationship to # Packets Processed Each 2 msec.
- Billions of Packets Passed Through the Physical Layer Without RB Error.



- Original Allocation (Input) = 100 μ sec
- IRQ H/W Response + ISR Processing averages 23.5 μ sec
- No End-Cell Used on Transmit

- IFC not in final-flight configuration (VxWorks: debug task, network task w/ higher priority than 500 Hz task).



xMET & RTC BIU Compatibility Test

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HSI brassboard



xMET BIU prototype



Compatibility Test:

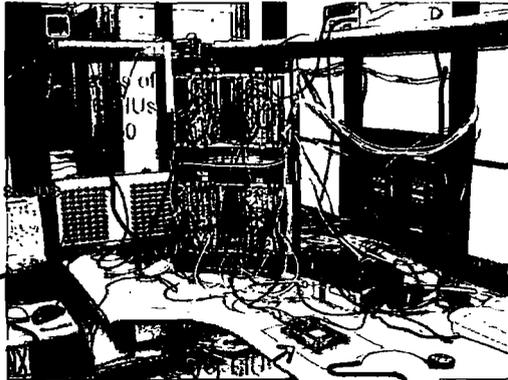
An evaluation between independent subsystems with intent to show they are capable of orderly, efficient integration and operation as a system with no modification or conversion required.

What was tested?

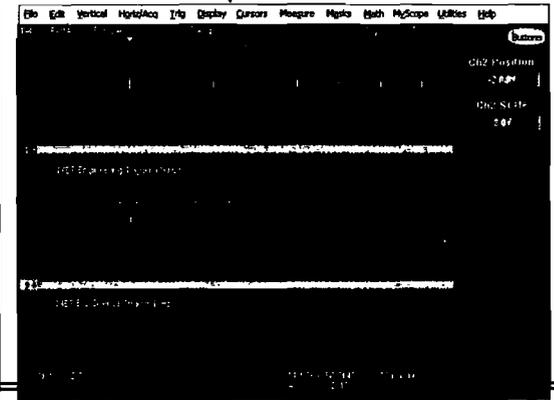
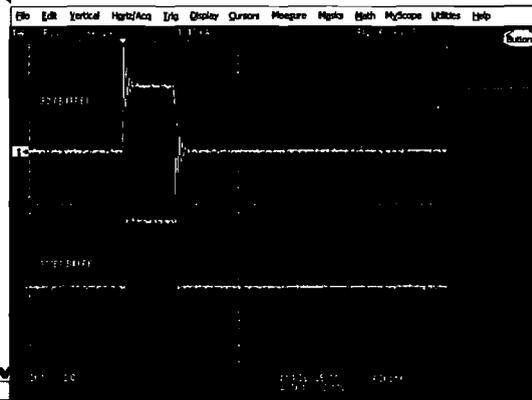
1. RTC/XMET BIU's configured in two node ring
2. Able to write to XMET BIU registers
3. 128 MHz measured good at XMET BIU
4. XMET to HSI RBI jitter measured
5. XMET soft reset: initial values seen
6. XMET RB Hard reset: RB Bus reconfigures
7. XMET Triggers verified
8. XMET Trig1 and Trig4 produce "science" and "engineering" packets; Data recovered at HSI BIU; Basic protocol layer verified.
9. xMET Peek command verified
10. Discrete outputs verified
11. Mechanism to track xMET crystal oscillator drift verified (i.e., via "Terry Trick")
12. SVC (BIU "request for service") tested
13. Corrupted command (CRC error) command emulated; xMET command rejection verified!

Problems?

1. RTC Ring Bus FPGA pin definitions swapped for Discrete outs 2 and 3
2. xMET Poke command wasn't functioning; Tuan has fixed
3. RTC IFC BIU packet alignment issue being investigated.
4. Chassis grounding being worked



PC running test software
used for control and
analysis





Summary

SIM PlanetQuest

- **Completed Ring Bus IC V&V Phase**
 - **Ring Bus Test Plan Completed for SIM Project**
 - **Applicable to Other Projects**
- **Implemented a Avionics Bus Based upon the IEEE 1393 Standard**
 - **Excellent Starting Point for a General Purpose High-Speed Spacecraft Bus**
 - **Designed to Meet SIM Requirements for**
 - **Real-time deterministic, distributed systems.**
 - **Control system requirements**
 - **Fault detection and recovery**
- **Other JPL Projects Considering Implementation**
- **Flight Software Ring Bus Driver Module Began in 2006, Continues**
- **Participating in Standard Revision**



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