



A System to Provide Deterministic Flight Software Operation and Maximize Multicore Processing Performance: The Safe and Precise Landing – Integrated Capabilities Evolution (SPLICE) Datapath

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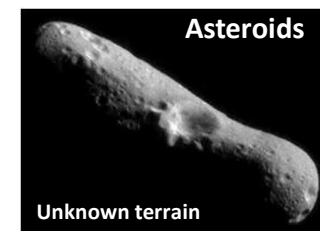
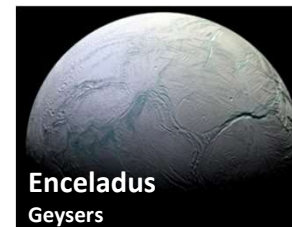
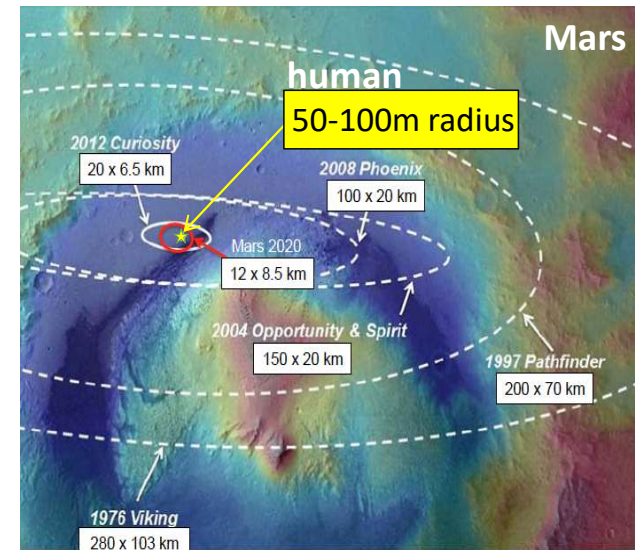
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The Motivation for PL&HA Technology

- Enable landing at locations that pose significant risk to vehicle touchdown or payload deployment (including near pre-positioned surface assets)
 - Multicore Processing
 - HPSC
 - Technology development (SPLICE)



SPLICE Components

(Commercialization/Licensing Statuses are Highlighted)

Sensors/Scanners



Passive TRN
(Imaging & Inertial)



Camera + IMU (both COTS)

**Ultra-Precise
Velocity &
Range**



Doppler Lidar

(Transitioning to COTS – Phase 3 SBIR)

**Surface Hazard
Imaging**
(Map Generation)



Scan-Array Lidar

(Early licensing/infusion in progress)

Dedicated Computing



Descent & Landing Computer
(Early component licensing discussions)

Software Functions

(Licensable or Listable in NASA SW Catalog)

TRN: Image Processing and Map Comparisons

Hazard Detection (Safe Site ID)

PL&HA Guidance

PL&HA Navigation

Architecture

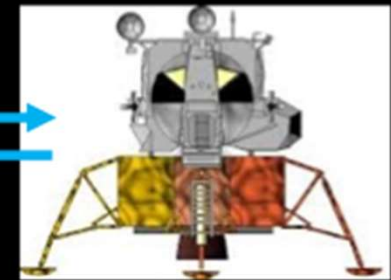
SpaceVPX Architecture (Industry Standard)

HPSC-Surrogate (COTS + rad-tolerance provisions)

and Kintex FPGA (COTS) for I/O & co-processing

Precise EDL Navigation
PL&HA Guidance
Safe Site

Pre-EDL Navigation
Master Clock



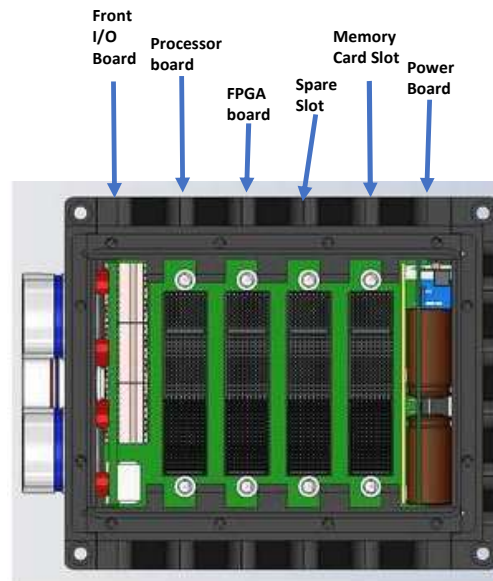
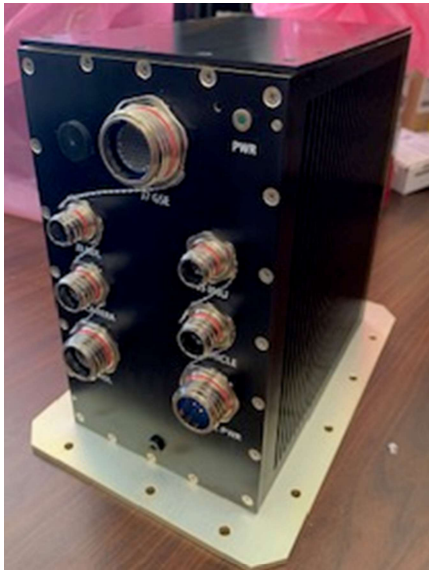
Lander & Primary Computer

EDL Functions

Vehicle Control

Non-PL&HA Guidance & Nav

SPLICE DLC EDU

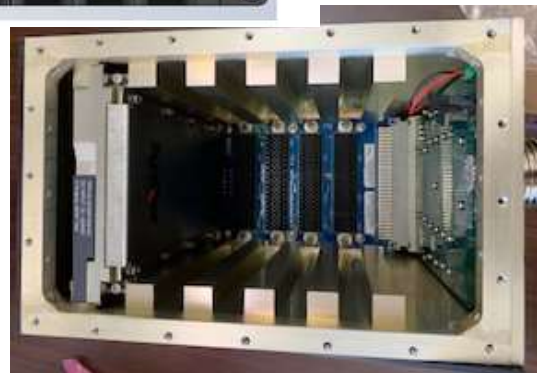


In-House Design & Development:

- Xilinx US+ MPSoC board
- Xilinx US Kintex FPGA board

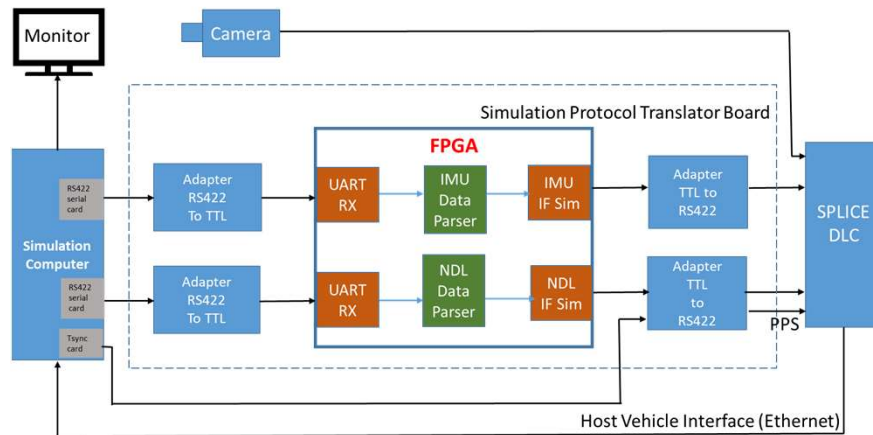
COTS 1/2 ATR Enclosure from PIXUS

- 4-slot OpenVPX backplane
- Syncor PSU
- I/O Card with Glenair 805 connectors
- COTS SSD Card from RedRock

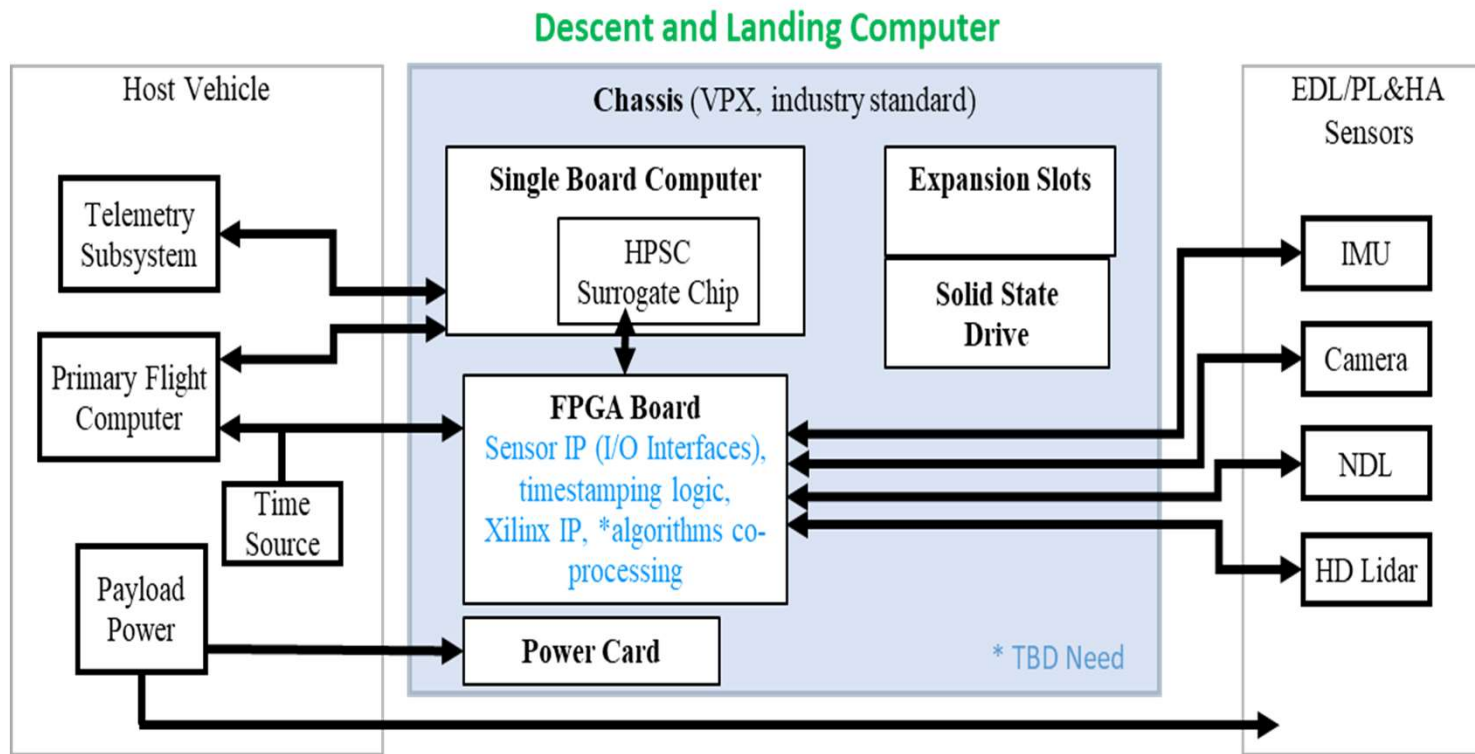


EDU Testing

- Suborbital flights on Blue Origin's New Shepherd rocket in 2020 and 2021
- HWIL simulation testing
- Workload performance measurements



DLC (EDU) and Interfaces



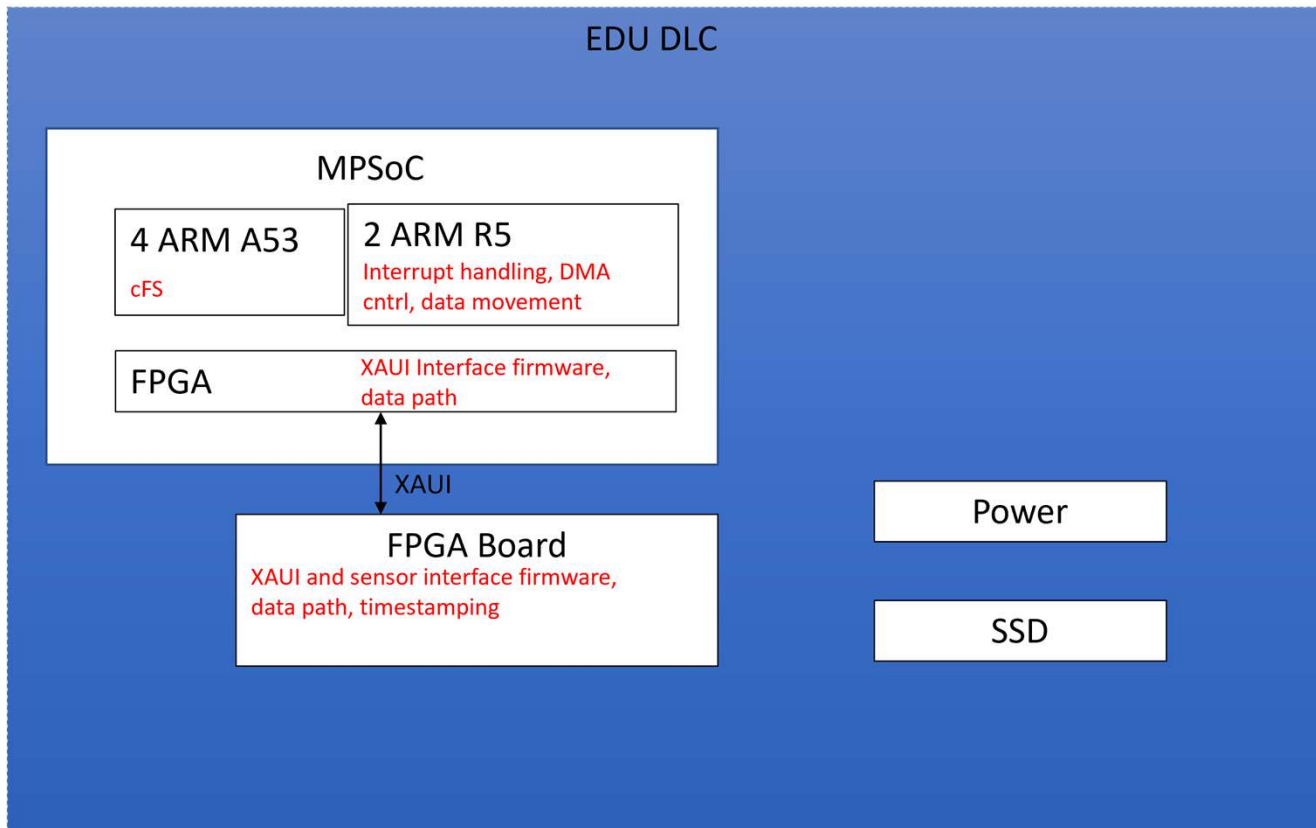


PL&HA Sensor Data Bandwidth



Sensor	Data Rate (Hz)	Packet Size (Bytes)
IMU	400	48
NDL	20	280
Camera	10	1.6M
HDL	1	30M

MPSoC Architecture and Functional Allocations



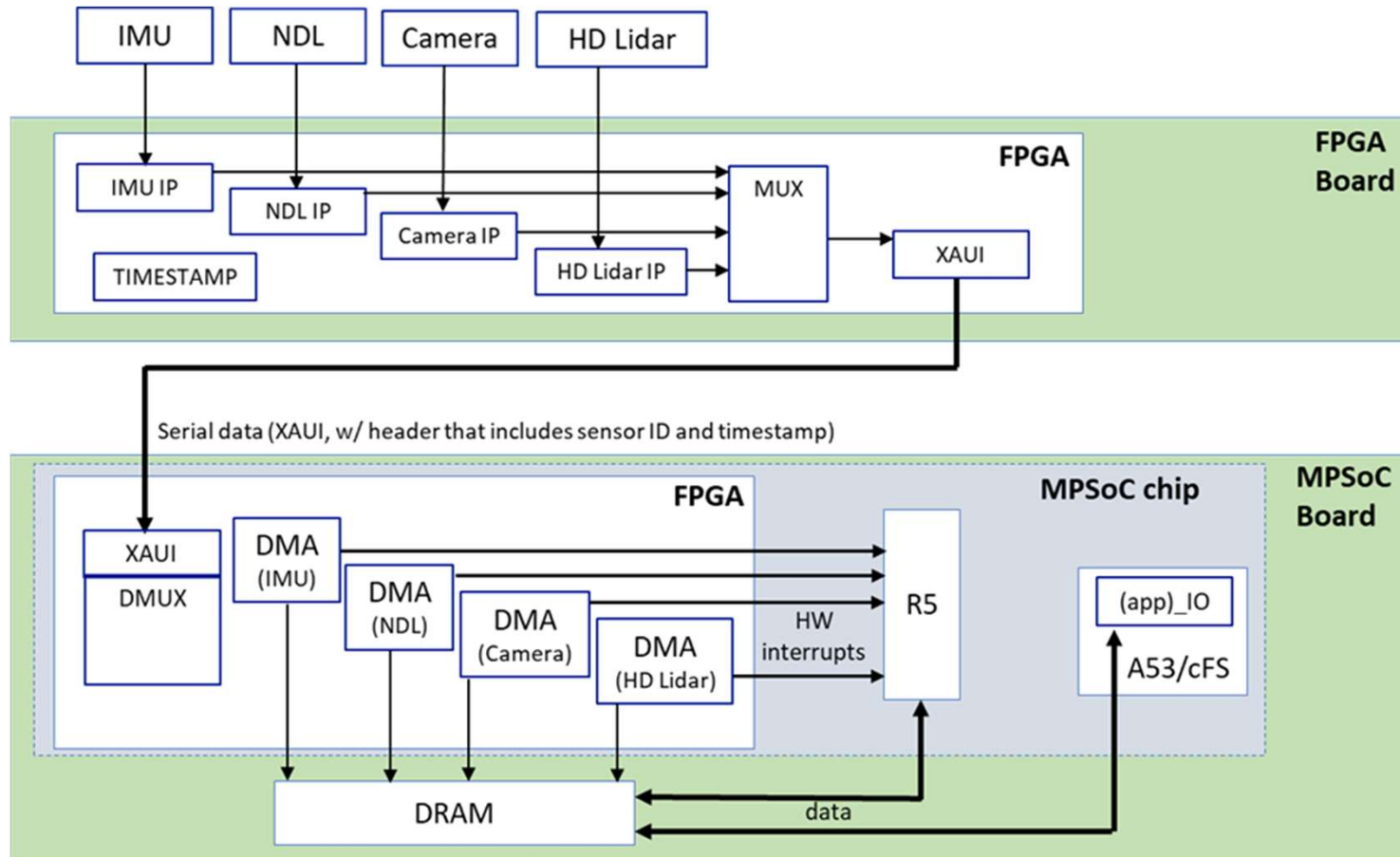


Related Work

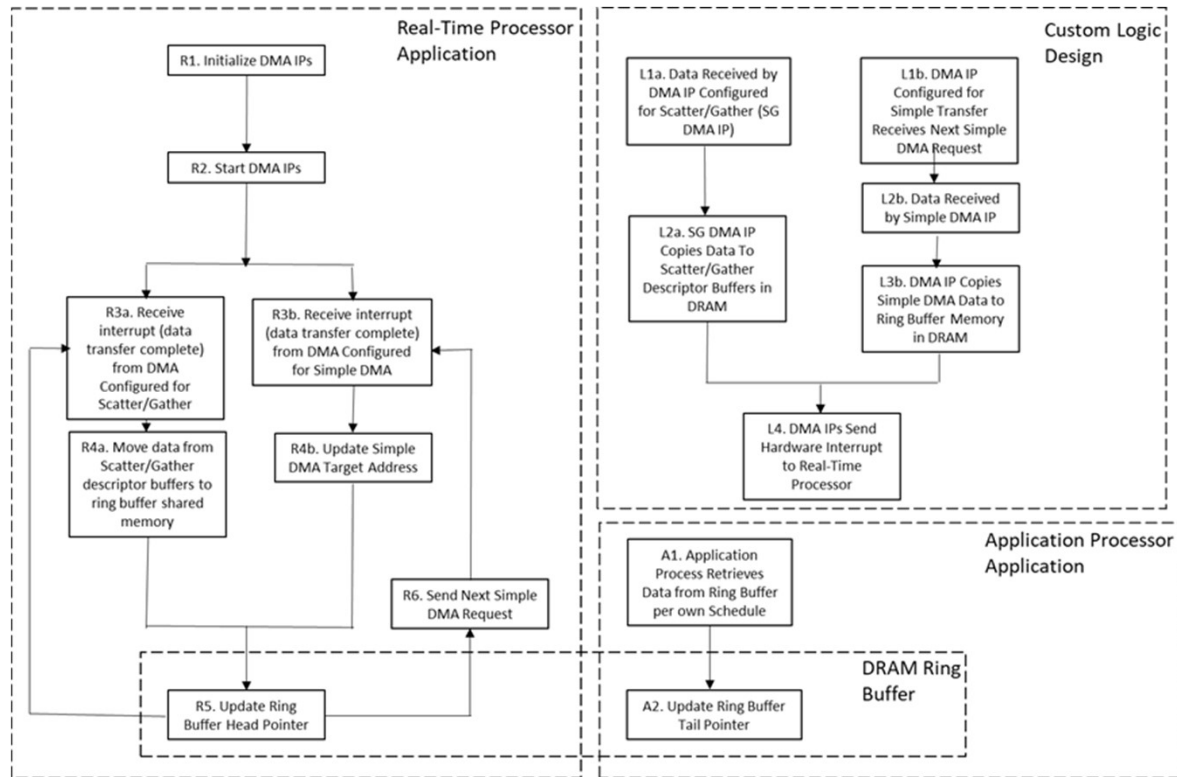


- SPLICE algorithms are complex, and must operate with low latency and deterministically to function in a real-time landing system
- Traditional systems often utilize a Real-Time Operating System (RTOS) to assure required performance
- Approach was to use embedded Linux OS and develop a datapath that isolates the application processors from interrupts associated with the sensor I/O to support deterministic operation.
 - Preserves the full set of application processors for SPLICE software
 - Departs from industry/vendor recommended template to manage communication between heterogenous processors

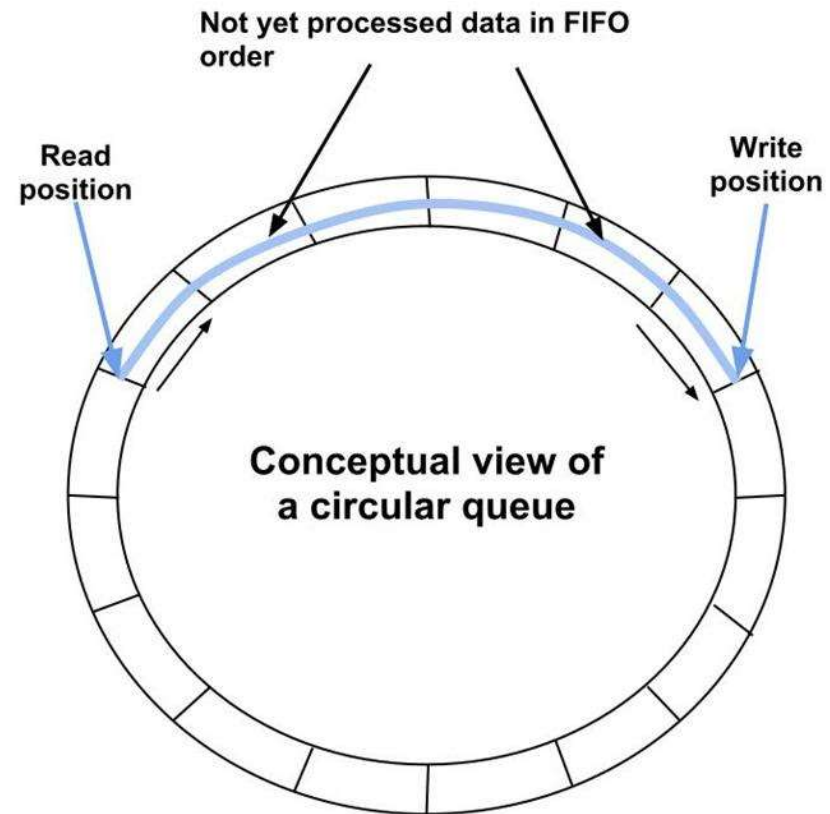
SPLICE Datapath



Datapath Event Sequence



Ring Buffer Queue





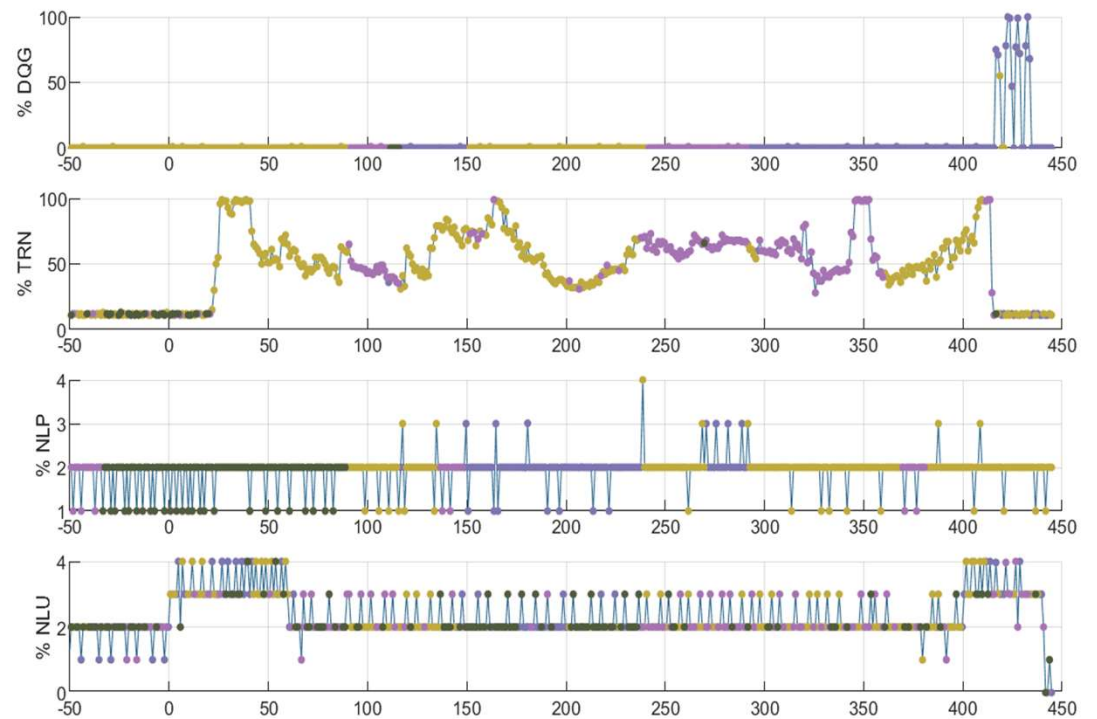
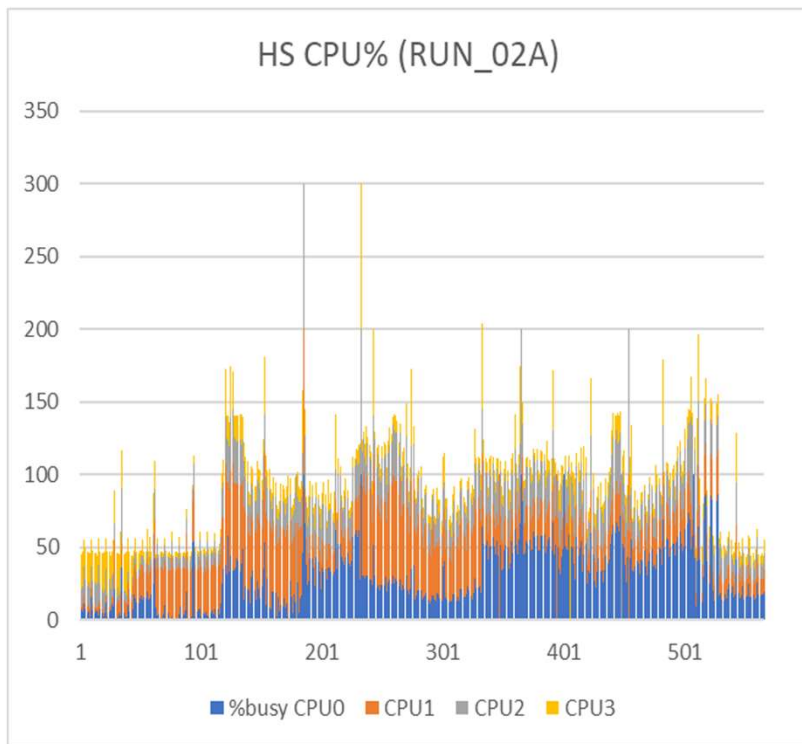
Discussion



- Experimentation revealed that DMA scatter/gather was not efficient for larger packet size data (e.g. camera). Change to simple DMA increased image data rate from 2 to 10 Hz.
- Data path tested in HWIL simulation for adverse effects on the deterministic operation of the flight software
 - Run for many days straight without data packet drops or corrupted data
 - Over a dozen simulated flights using trajectories from flight tests showed no behavior that could be attributed to the datapath operation that was non-deterministic



EDU DLC Processor Utilization During Simulated SPLICE Flight





Conclusions/Future Work



- Testing of the SPLICE EDU data path indicate that the design supports deterministic flight software operation while preserving application computing capacity on the DLC platform.
 - Accomplished without the use of a real-time operating system
- The data path design is being used in the next version of the DLC that is being developed to support a robotic lunar test flight.
 - Additional channels are being added for the Hazard Detection LIDAR sensor and a vehicle interface
 - Enhancements will be made to the command path of the interface (not discussed here.)