MICROTEL LLC

aerospace software and computer systems

SWTSv3

SpaceWire Test Set
Version 3

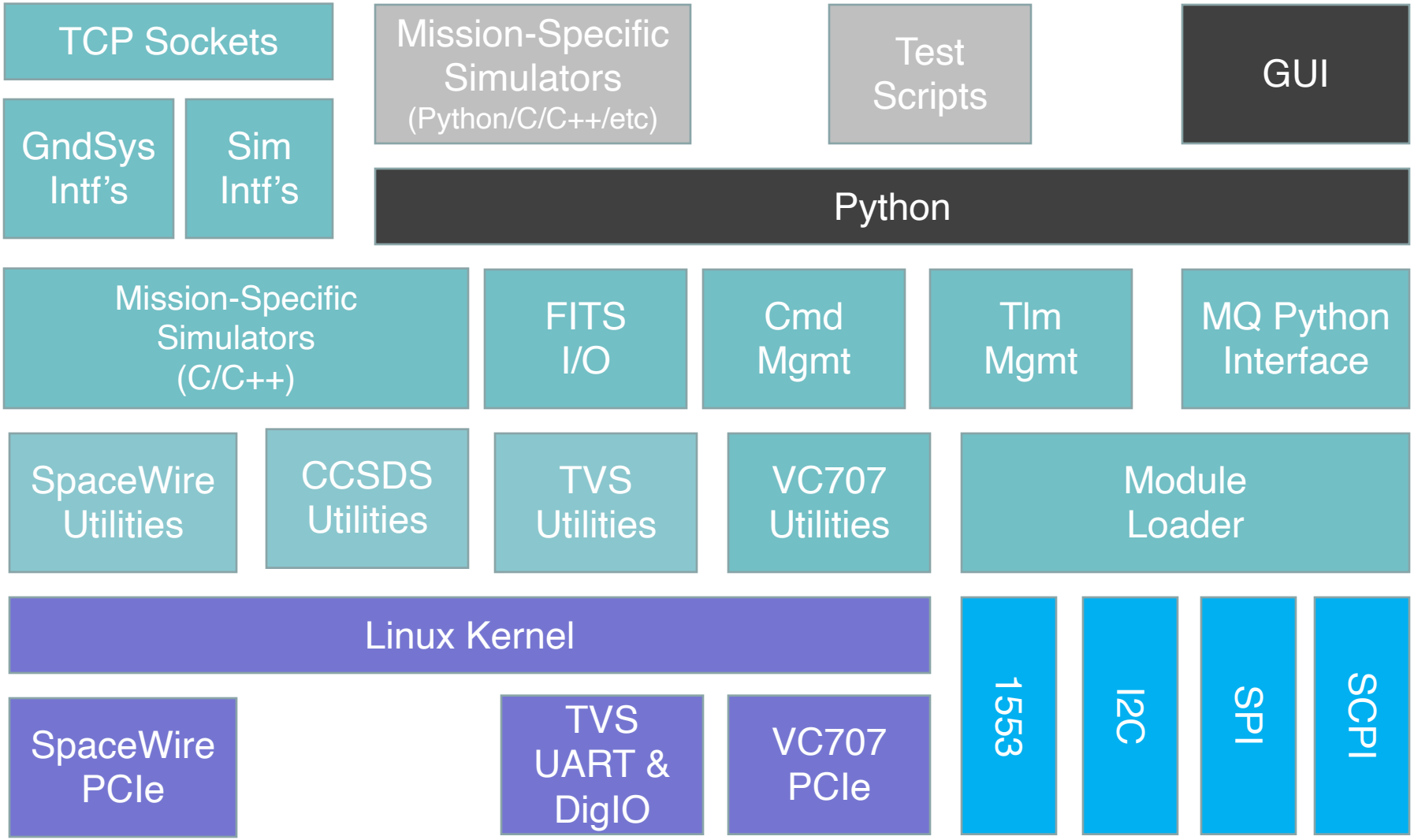
Background

- **SWTS = SpaceWire Test Set**
- **Originally developed as a SpaceWire Hardware Interface Tester**
- **Over time it has evolved into a full featured simulation and test environment**
  - Physical Interface Testing
  - Logical Interface Testing
  - High Fidelity Simulation of Flight Components
    - Instruments, C&DH Systems, Solid State Recorders, Comm Systems, etc
  - Integration with all major Ground Systems used at Goddard
    - ASIST, ITOS, ECLIPSE
- **Used extensively on nearly every mission developed at Goddard since 2003 for**
  - Flight Hardware development and testing
  - Flight Software development and testing
  - Box and System level I&T
  - Post-launch support
- **Flexible and Expandable for New/Custom Applications**
  - Multiple interfaces beyond SpaceWire supported
  - Multiple API's available for 3rd-party software/hardware expansion

SWTS Evolution

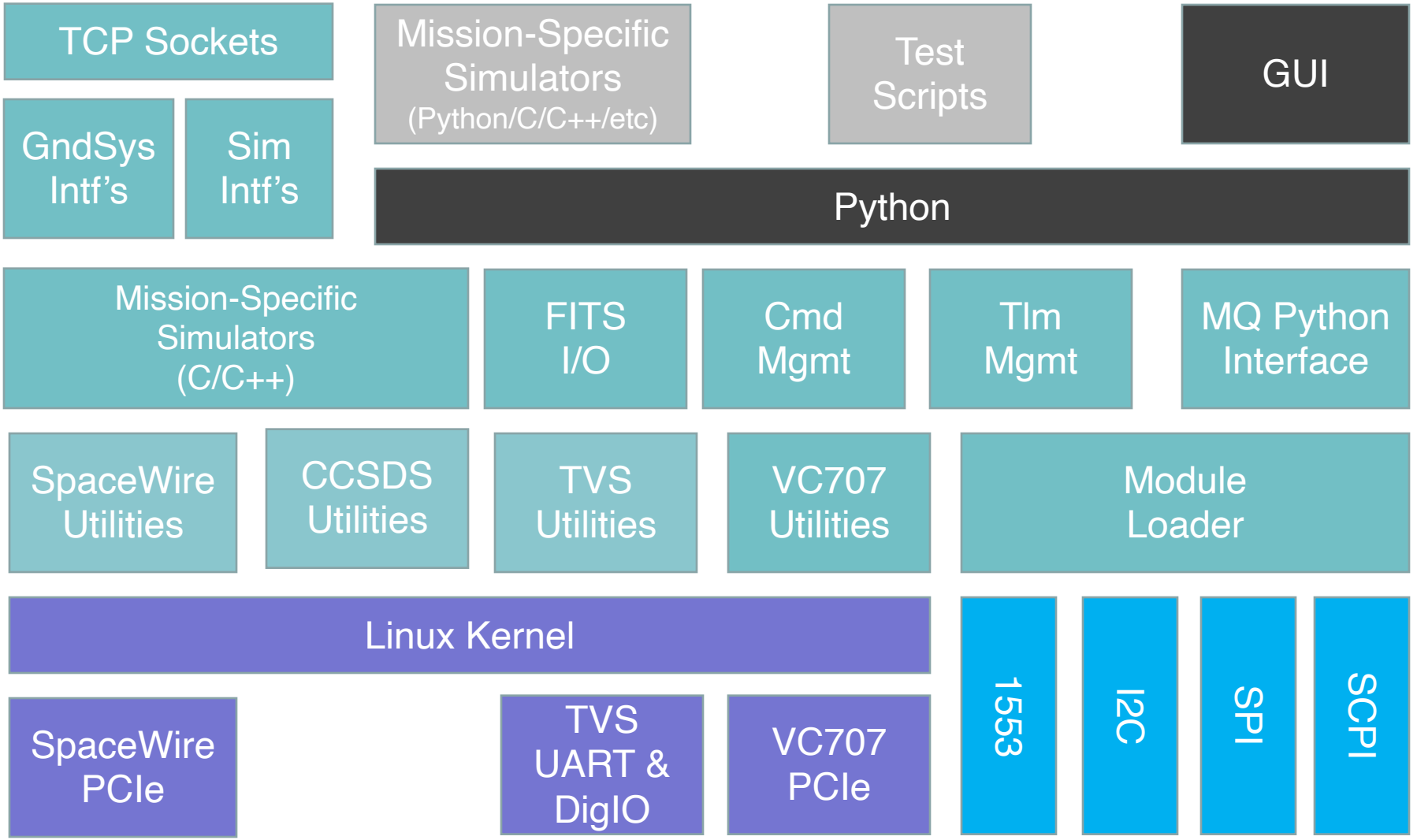
- **SWTSv1**
  - Developed: 2003
  - Status: Obsolete.
  - OS: Windows XP
  - SpW HW: COTS USB
  - Ground Systems: ECLIPSE
  - Missions: JWST
- **SWTSv2**
  - Developed: 2004
  - Status: End of Life
  - OS: Windows XP/7
  - Spw HW: Custom PCI Card
  - Ground Systems: ECLIPSE, ASIST
  - Missions:
    ASTRO-H, ATLAS, GPM, JPSS, JWST, LCRD, LRO, MMS, MOMA, and others
- **SWTSv3**
  - Developed: 2017
  - Status: Active Development
  - OS: Linux
  - Spw HW: Custom PCIe Card
  - Ground Systems: ECLIPSE, ASIST, ITOS
  - Missions:
    JWST, OCI, PACE, RESTORE-L, WFIRST, XRISM, and others
  - New Hardware Support:
    - 1553
    - Xilinx VC707
    - Analog I/O
    - SCPI
    - TVS
      - Discrete Digital I/O
      - UARTS
      - Pulse In/Out
      - I2C
      - SPI
      - And others
  - New Software APIs for customizing
    - Loadable Modules (C/C++)
    - POSIX MQ Interfaces (C/C++, Python, etc)

SWTSv3 Software Architecture



SWTSv3 Software Architecture

Deep Dive into one component of SWTS software as example…



SWTSv3 Software Architecture

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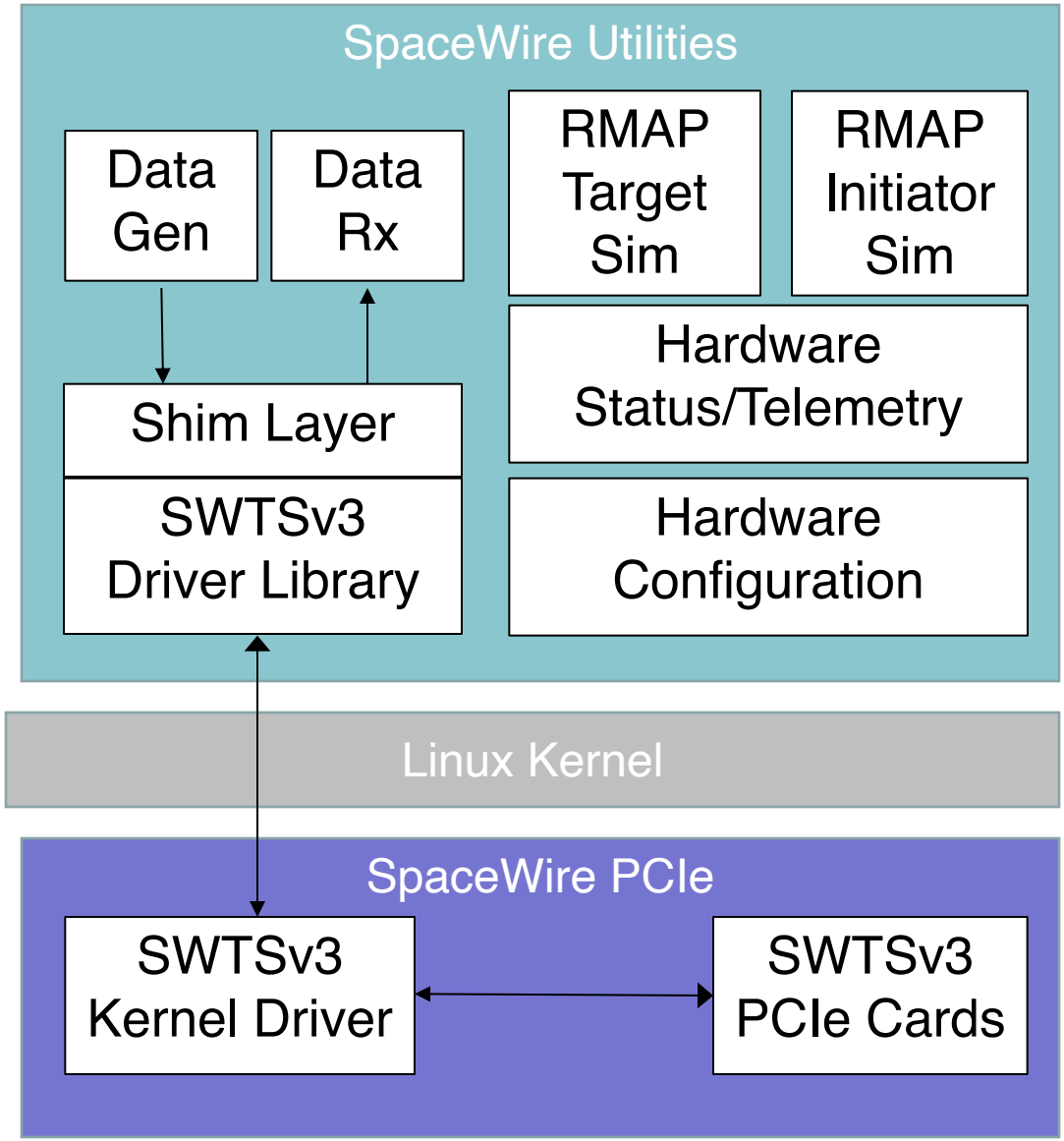
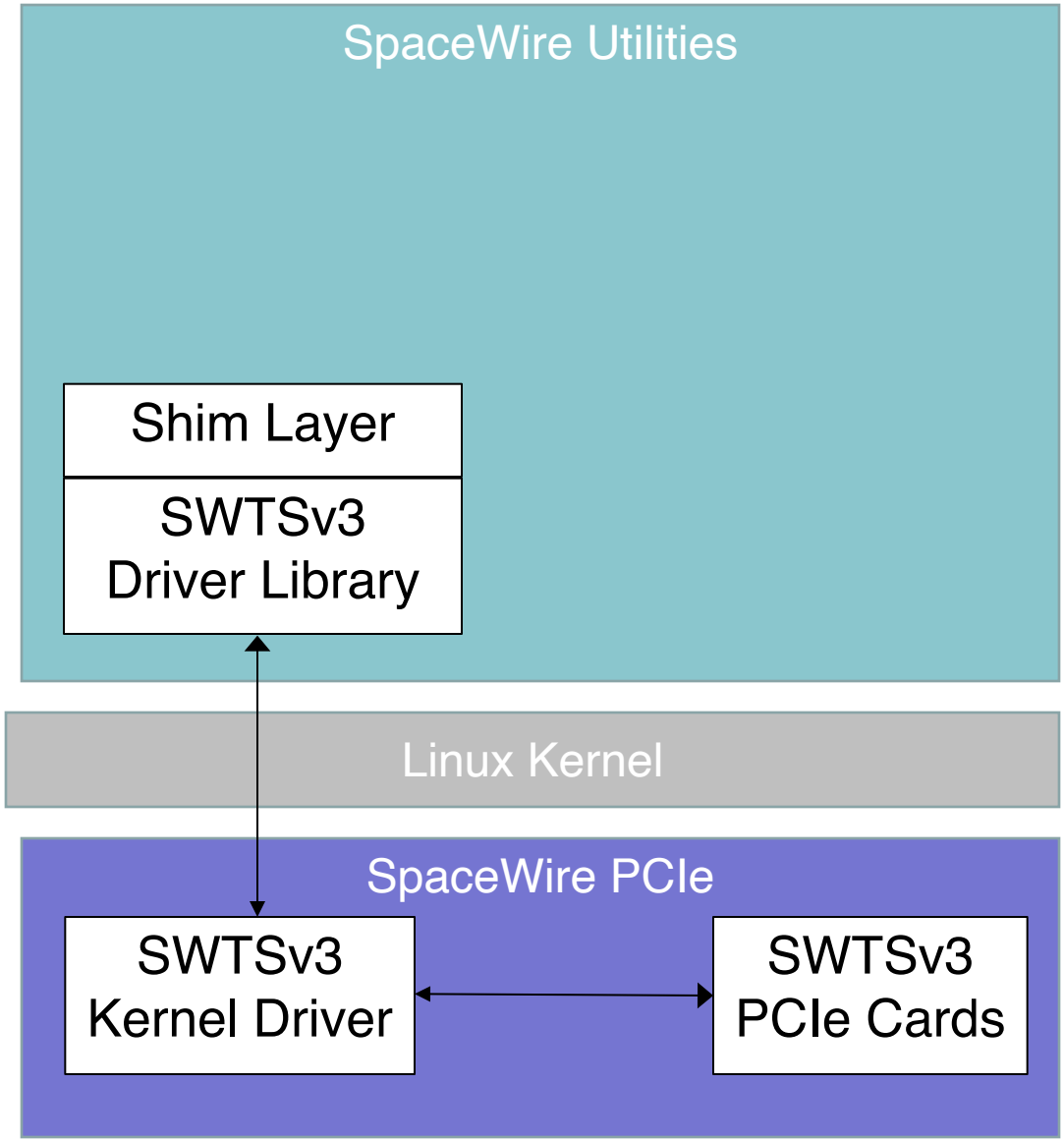
SpaceWire Architecture

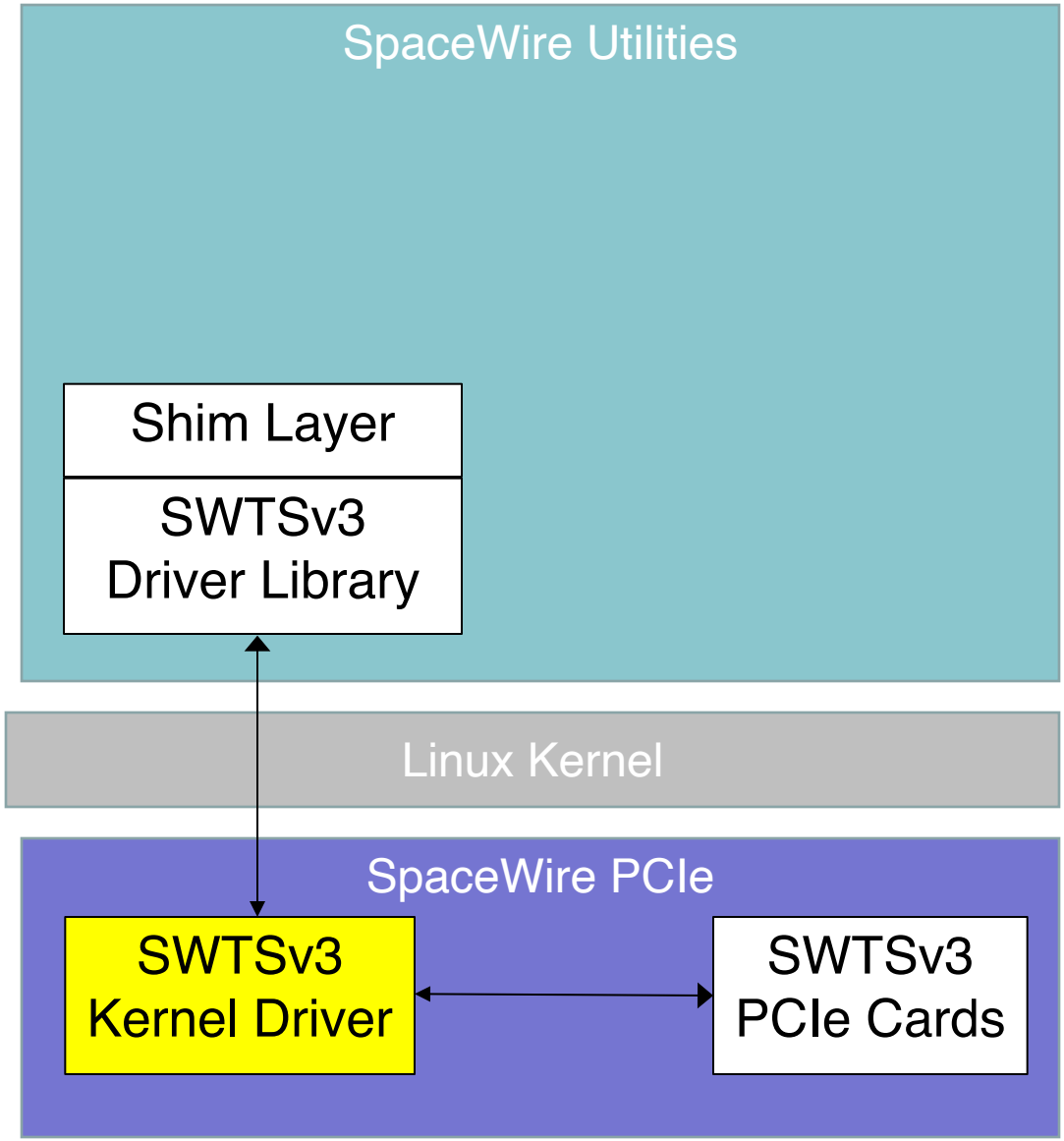


- RMAP Target Sim:
  - Simulates RMAP Targets
- RMAP Initiator Sim:
  - Simulates RMAP Initiators
- Hardware Status/Telemetry:
  - Retrieves Status from Driver Lib
  - Maps to Telemetry
  - Generates Hardware Events
- Hardware Configuration:
  - Actuates User Initiated Changes
- Data Gen:
  - Generates TX Packets/Buffers
    - Play from File with ns timing
    - Send from GUI
    - Generate Test Pattern
    - Forward from Simulator
- Data Rx:
  - Processes RX Packets/Buffers
    - Record to File with ns timing
    - Display to GUI
    - Compare w/ Test Pattern
    - Forward to Simulator
- Shim Layer
  - Moves Pkts/Buffers to/from Queues
  - Normalizes Driver Calls
- SWTSv3 Library APIs:
  - Hardware Init/Config/Status
  - Packet/Buffer TX/RX (Intr/DMA)
- SWTSv3 Kernel Driver:
  - PCI Discovery/Configuration
  - Register/Memory I/O Mapping
  - DMA Buffer Allocation and Mapping
  - Kernel-Level Interrupt Handling
- SWTSv3 PCIe Cards (Up to 3):
  - Xilinx Artix-7 FPGA
  - 8 SpaceWire Ports (or 4 redundant)
  - 4 GB SDRAM
  - DMA Controller
  - VCXO, Temp/Volt Sensors, etc.

SpaceWire Driver and Shim



SpaceWire Driver and Shim



SWTSv3 PCIe Kernel Driver

- **swts_init – called by OS on startup or module load.**
  - Initializes data structures
  - Calls ***alloc_chrdev_region*** to allocate character driver number
  - Calls ***cdev_add*** to add character driver to system
  - Calls ***pci_register_driver*** to inform OS which cards this module drives
- **swts_exit – called by OS on shutdown or driver unload**
  - Calls ***cdev_del*** to remove character driver from system
  - Calls ***unregister_chrdev_region*** to free character driver number
  - Calls ***pci_unregister_driver*** to inform OS this driver is no longer present

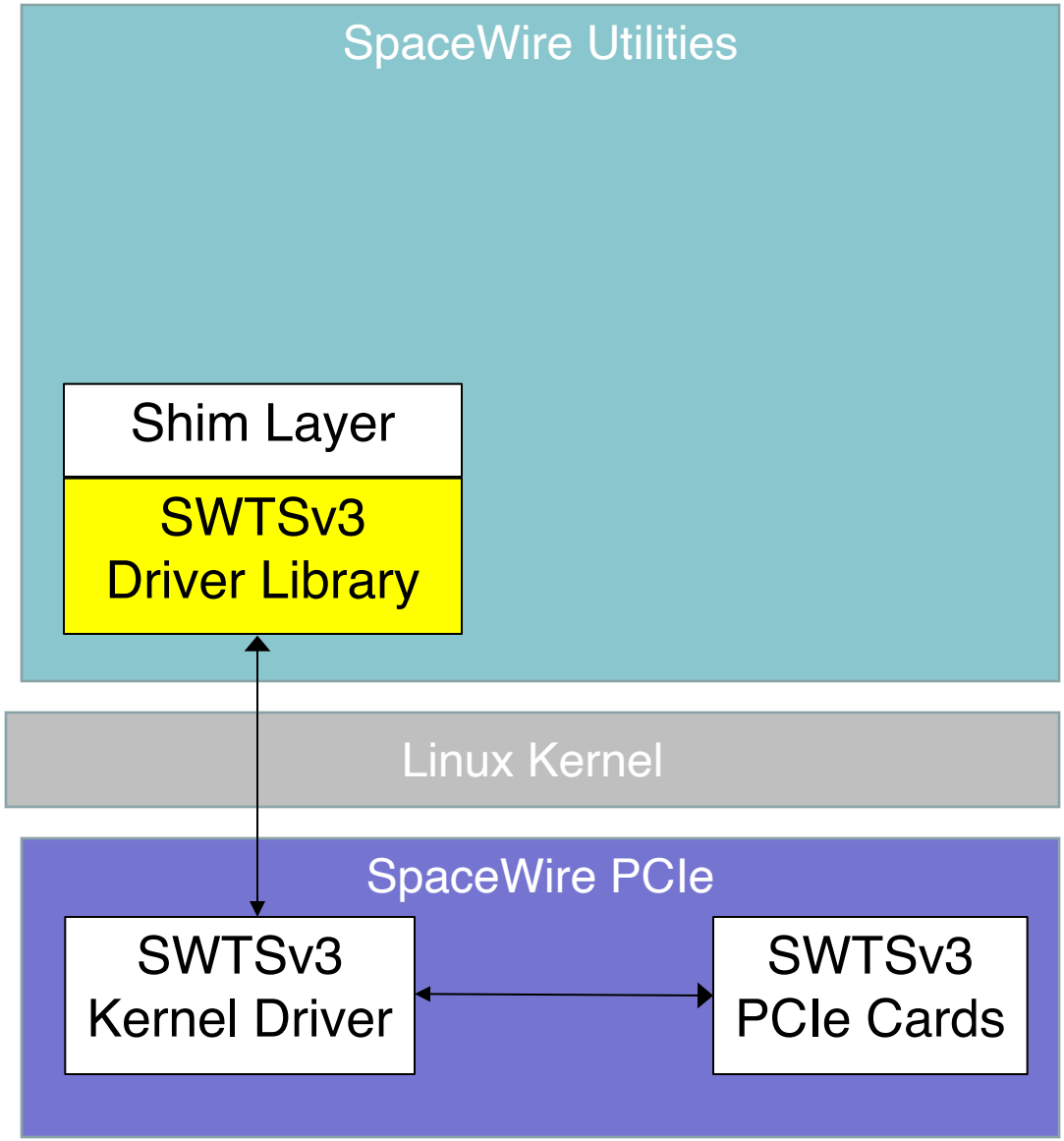
SWTSv3 PCIe Kernel Driver (cont.)

- **probe – called by OS once for each PCI card found in chassis**
  - Calls ***pci_resource_start, pci_resource_len, pci_resource_flags, request_mem_region, ioremap_nocache, pci_ioremap_bar, request_region, and ioremap_nocache*** to configure memory windows for each BAR on each card
  - Calls ***kmalloc, pci_map_single, pci_set_dma_mask*** to allocate and map DMA buffers
  - Calls ***pci_enable_device, pci_set_master*** to enable card
  - Calls ***pci_enable_msi, request_irq*** to configure and enable interrupts for card
- **remove – called by OS once for each PCI on shutdown (or card remove in hot-swap)**
  - Calls ***disable_irq, free_irq, pci_disable_msi*** to disable and free interrupts for card
  - Calls ***iounmap, release_mem_region*** to free memory windows for each BAR on card
  - Calls ***pci_unmap_single, kfree*** to unmap and deallocate DMA buffers for card
  - Calls ***pci_disable_device*** to shutdown device

SWTSv3 PCIe Kernel Driver (cont.)

- **swts_ioctl – primary interface between library and kernel driver**
  - READ
    - Uses BAR information to Map Card address to System Address
    - Calls ***readl*** or ***readq***
  - WRITE
    - Uses BAR information to Map Card address to System Address
    - Calls ***writel*** or ***writeq***
  - GET_DMA_BUS_ADDRS _IO
    - Calls ***upper_32_bits, lower_32_bits*** to map DMA buffer addresses to PCI Bus Addresses (Note: this information is used by the application library to program the DMA controller)
  - GET_RXDMA_DATA
    - Calls ***copy_to_user*** to move data from DMA buffer to user space (Note: this is used by the application library to get the data after a RX DMA is completed)
  - SET_TXDMA_DATA
    - Calls ***copy_from_user*** to move data from user space to DMA buffer (Note: this is used by the application library to set the data before a TX DMA is started)
- **swts_read**
  - Used by application library interrupt service thread
  - Blocks until interrupt is received, and returns contents of interrupt status register

SpaceWire Driver and Shim



- Shim Layer
  - Moves Pkts/Buffers to/from Queues
  - Normalizes Driver Calls
- SWTSv3 Library:
  - Hardware Init/Config/Status calls
  - Packet/Buffer TX/RX (DMA)
- SWTSv3 Kernel Driver:
  - PCI Discovery/Configuration
  - Register/Memory I/O
  - DMA Buffer Allocation
  - Basic Interrupt Support
- SWTSv3 PCIe Cards (Up to 3):
  - 8 SpaceWire Ports
  - 1 GB SDRAM
  - DMA Controller
  - VCXO, Temp/Volt Sensors, etc.

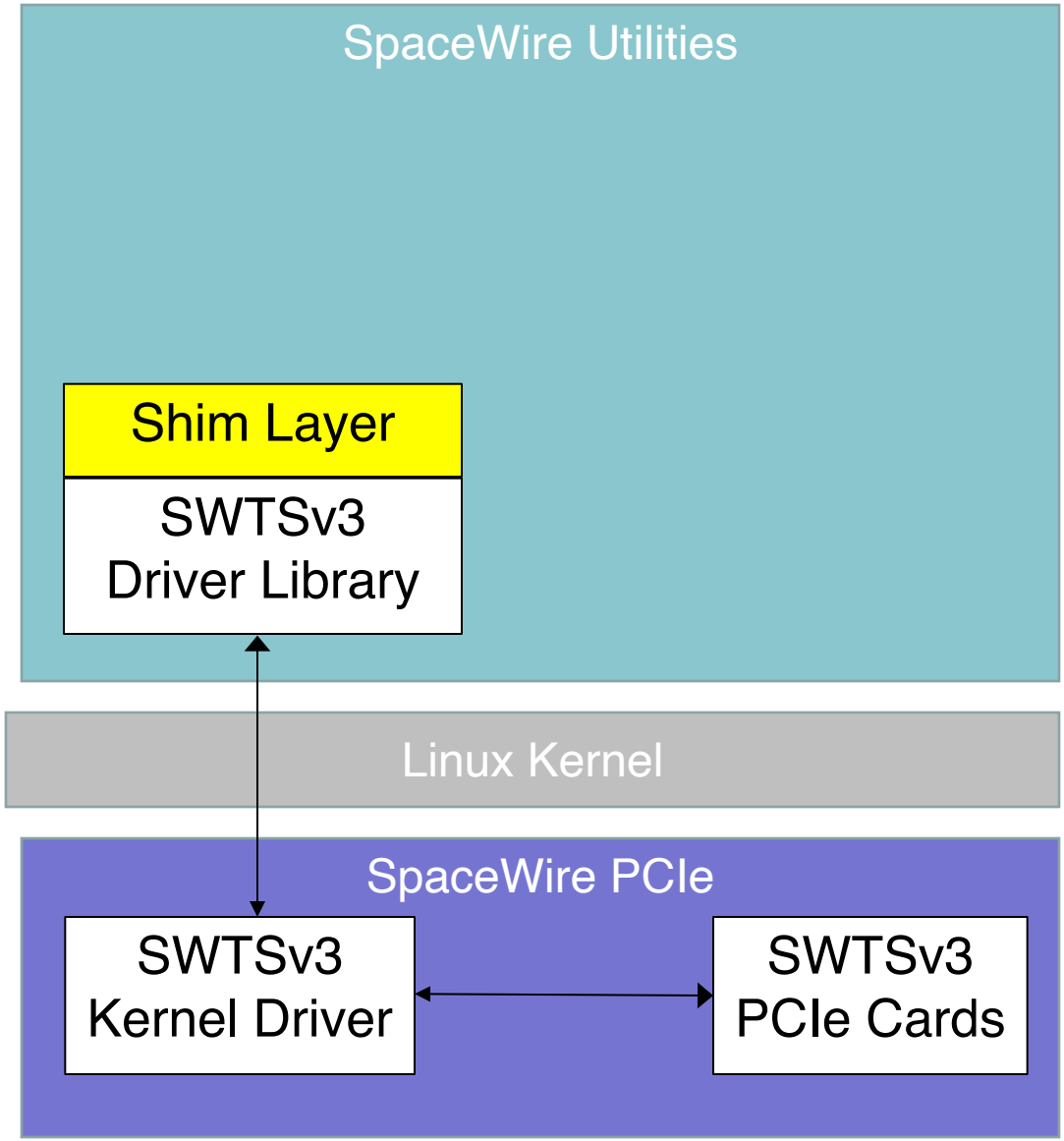
SWTSv3 Application Library

- **swts_lib_init**
  - Allocates memory, semaphores, pthreads, etc.
  - Initializes memory/data-structures
  - Initializes hardware via ioctl WRITEs
  - Gets DMA buffer PCI addresses via ioctl GET_DMA_BUS_ADDRS _IO
- **swts_lib_start**
  - starts swts lib receive threads
  - starts swts lib interrupt service threads
- **swts_lib_receive_thread**
  - Periodically polls swts hardware buffers for received data via ioctl READs
  - Reads data into user-space buffer from card via DMA using ioctl READs, WRITEs, and GET_RXDMA_DATA
  - Calls application-provided callback function to announce receipt of data
- **swts_lib_interrupt_thread**
  - blocks on device “read” until interrupt received
  - Uses contents of returned interrupt status register to announce interrupt to other library components (primarily DMA completion).

SWTSv3 Application Library (cont.)

- **swts_lib_tx_space_available**
  - Returns amount of space available on card for TX via ioctl READs
- **swts_lib_tx_buffer**
  - Transfers data from user-space buffer to card via DMA using ioctl READs, WRITEs, and SET_TXDMA_DATA
- **swts_lib_config_board**
  - Passes in data structure of board-level configuration information
- **swts_lib_conf_port**
  - Passes in data structure of port-level configuration information
- **swts_lib_status**
  - Fills out data structure with complete board status (counters, link state, etc.)
- **swts_lib_write_pkt_hdr/ftr**
  - Used by application to write packets to buffer
- **swts_lib_extract_pkt**
  - Used by application to extract packet from buffer

SpaceWire Driver and Shim



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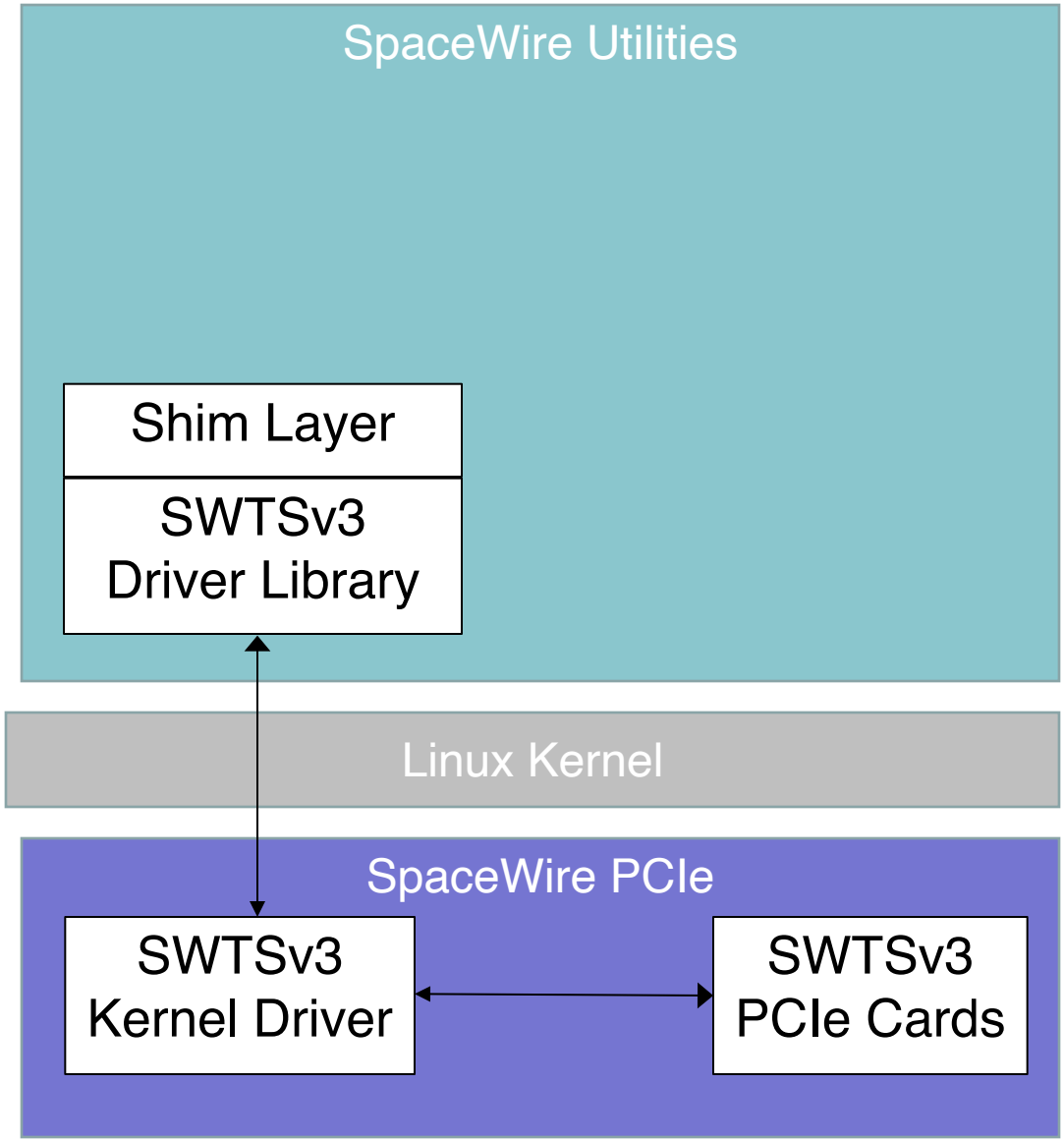
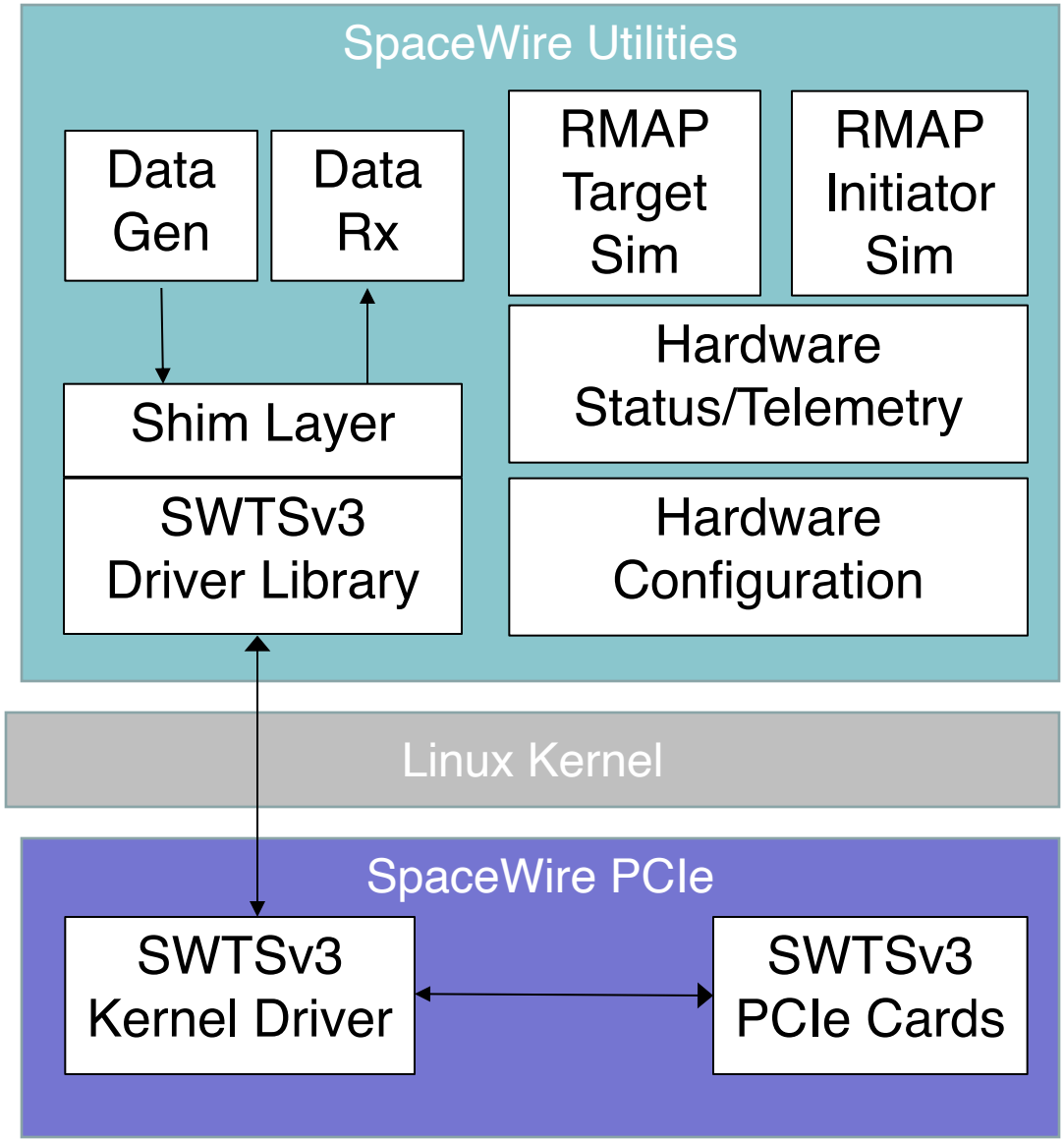
Shim Layer

- **Shim layer is “software connector” that simplifies future additional SpW hardware**
  - Implemented with jump table structure for
    - Tx_space_available
    - Tx_buffer
    - Config_board
    - Config_port
    - Status
- **swts_shim_tx_thread**
  - Monitors system TX queues for outgoing traffic
  - Monitors Hardware queues for space via tx_space_available
  - When there’s a match, transmit buffer via tx_buffer
- **Swts_shim_rx**
  - Callback provided to swts_lib_receive_thread
  - Forwards received buffers into RX queue

SpaceWire Driver and Shim



SpaceWire Architecture



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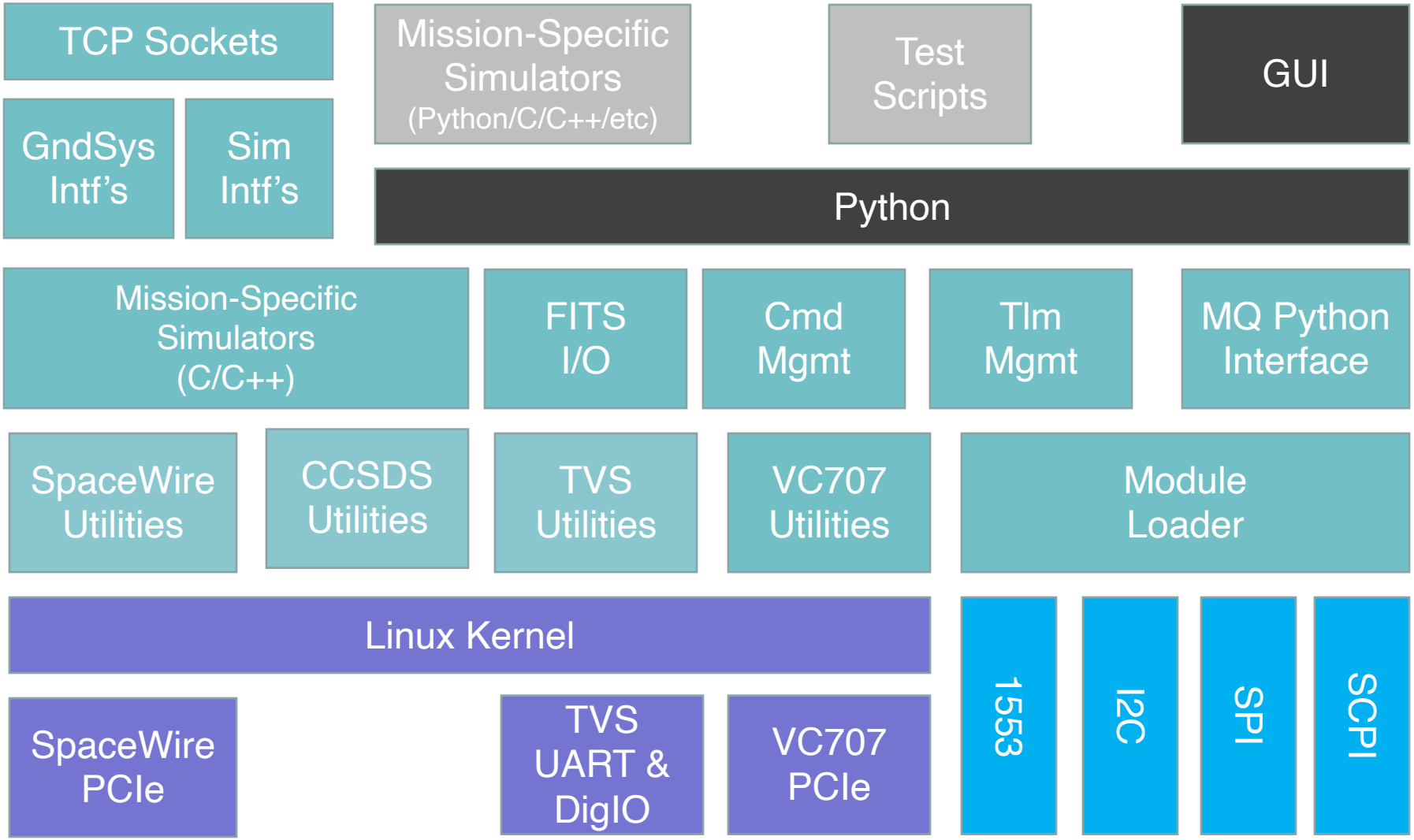
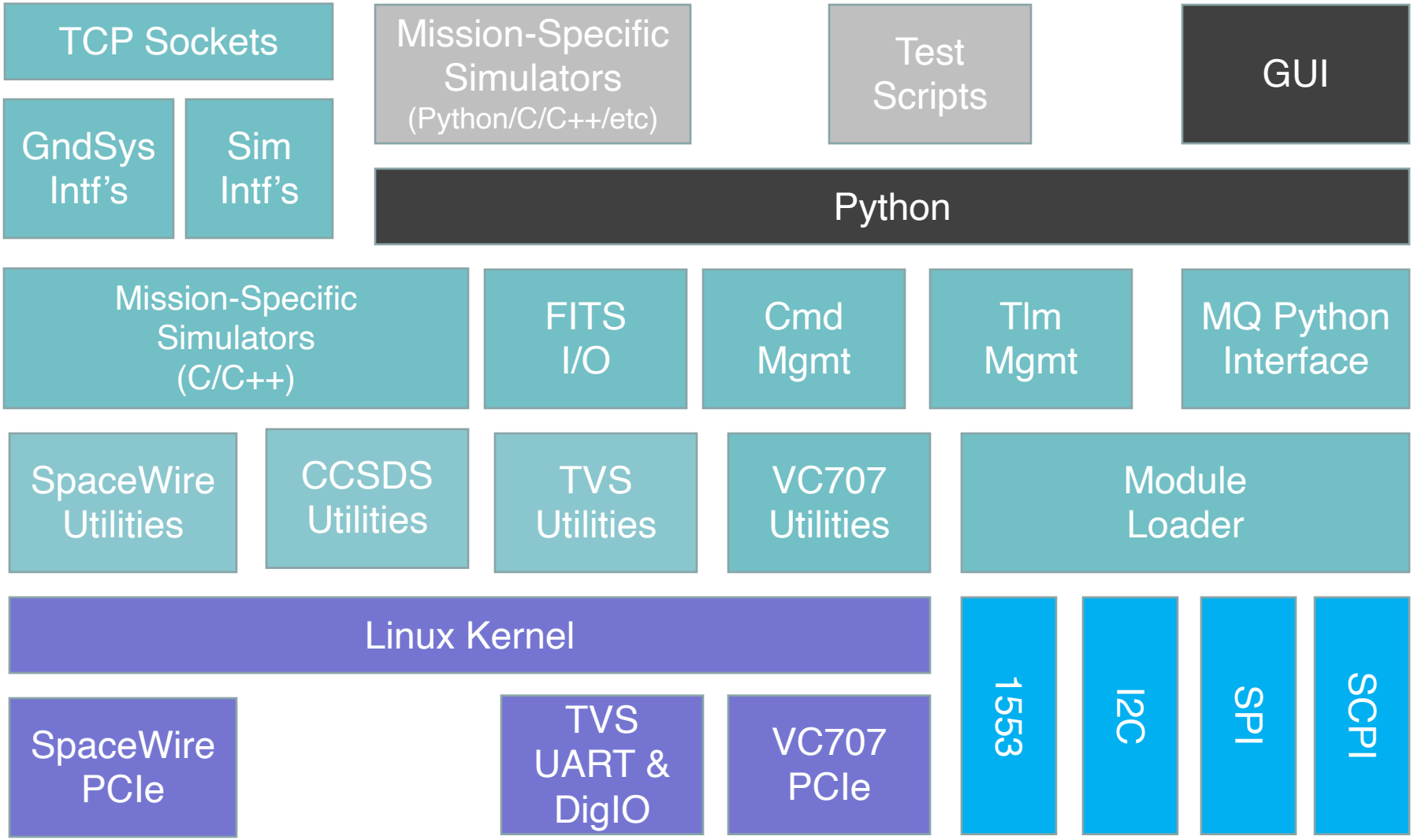


SWTSv3 Software Architecture

Note: can provide equally detailed breakdowns of other software components



Summary

- **SWTSv3 is the 3rd Generation SpaceWire Test Set**
  - Direct port of SWTSv2 code used on almost every mission at Goddard since 2003
    - ASTRO-H, ATLAS, GPM, JPSS, JWST, LCRD, LRO, MMS, MOMA, and others
  - SWTSv3 is currently deployed on almost every mission at Goddard today
    - JWST, OCI, PACE, RESTORE-L, WFIRST, and others
  - Active development on-going
  - Increased flexibility via new hardware and software APIs
  - Available for new missions/applications today