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Hi-SIDE: Monitoring, Control and Test Software in a SpaceFibre Network

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www.star-dundee.com @STAR_Dundee

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- Hi-SIDE Project Overview
- STAR-Ultra PCIe Software
- Test Software
- Mass-Memory Software
- Control Software
- Integration and Final Demonstration
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Hi-SIDE Project Overview

- Project Objective:
  - Develop and demonstrate technologies that enable future high-speed on-board data-handling systems
  - Demonstrate the integrated data-chain:
    - Instruments for generating data
    - Processors for compressing and encrypting data
    - Mass-memory for storing and playing back data
    - Downlinks for transferring data to ground
- Received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776151

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Hi-SIDE Project Partners

AIRBUS

TESAT

STAR-Dundee

STAR-Barcelona

ISD S.A. Integrated Systems Development

ERZIA

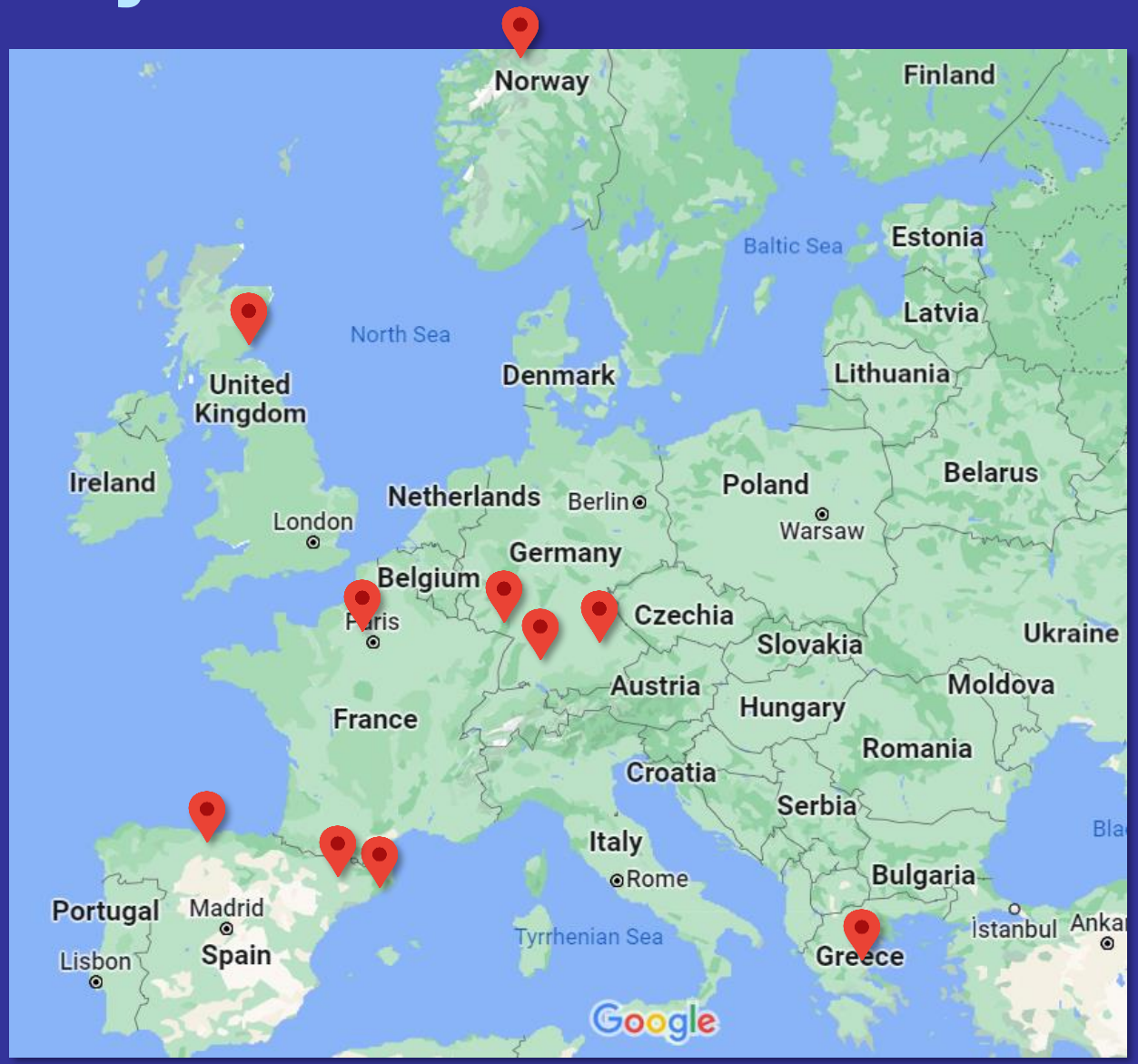
HELLENIC REPUBLIC
National and Kapodistrian University of Athens
EST. 1837

DLR

UAB Universitat Autònoma de Barcelona

KONGSBERG

MODUS Research and Innovation



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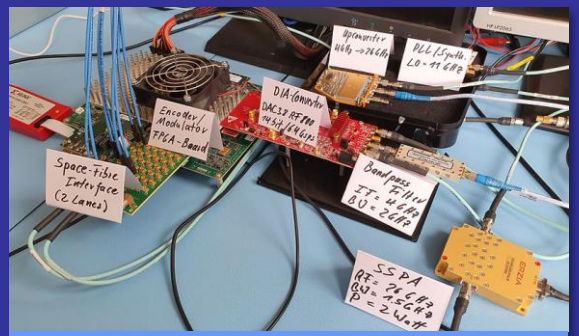
Hi-SIDE Systems

SpaceFibre Routing Switch

High-Performance Data Processor

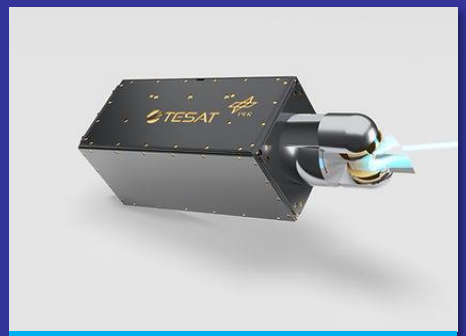
Data Compression Module

Ka-Band SSPA



RF Downlink

Ground Receiver



Optical Data-Link

Photographs from: https://www.hi-side.space/hi-sideproducts

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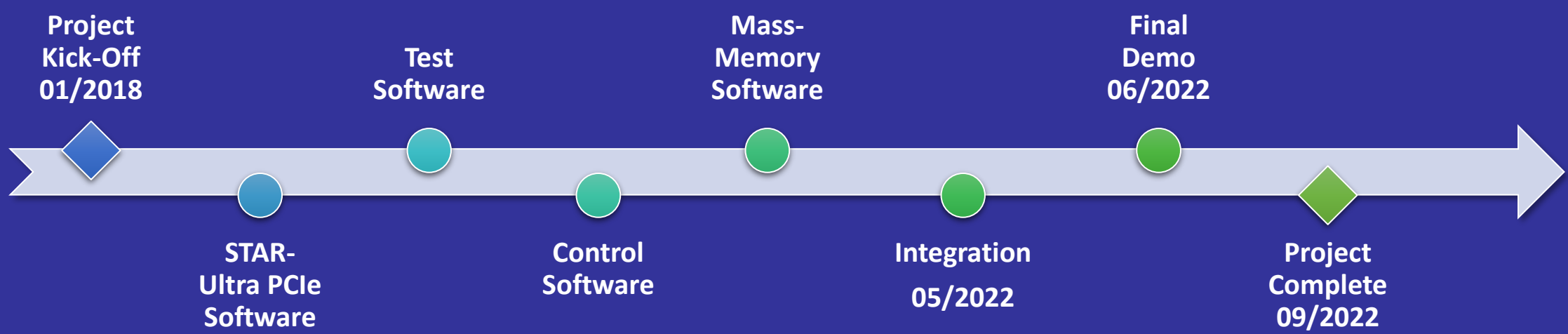
Hi-SIDE Project Timeline



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Test Equipment: STAR-Ultra PCIe

- 2 x quad-lane SpaceFibre interfaces:
  - 8 x VCs each
  - 1.25 to 6.125 Gbit/s lane signalling rate
- Eight-lane PCIe Gen3 interface (x16 connector)
- SpaceFibre interface and link analyser

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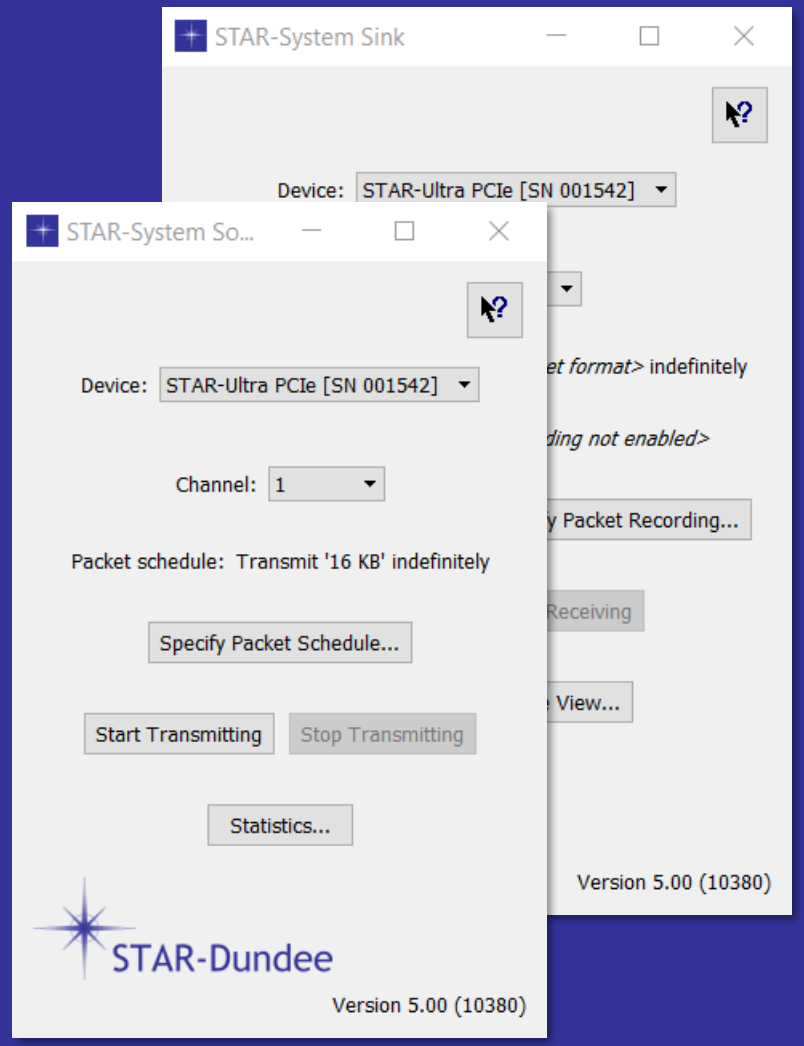
Software Support: STAR-System

- Software suite:
  - Device drivers
  - GUI applications
  - C, C++, Python APIs
- Send and receive packets and broadcast messages
- Packet Libraries:
  - RMAP
  - CCSDS Space Packet Protocol
  - CCSDS Transfer Frames
- Documentation and examples



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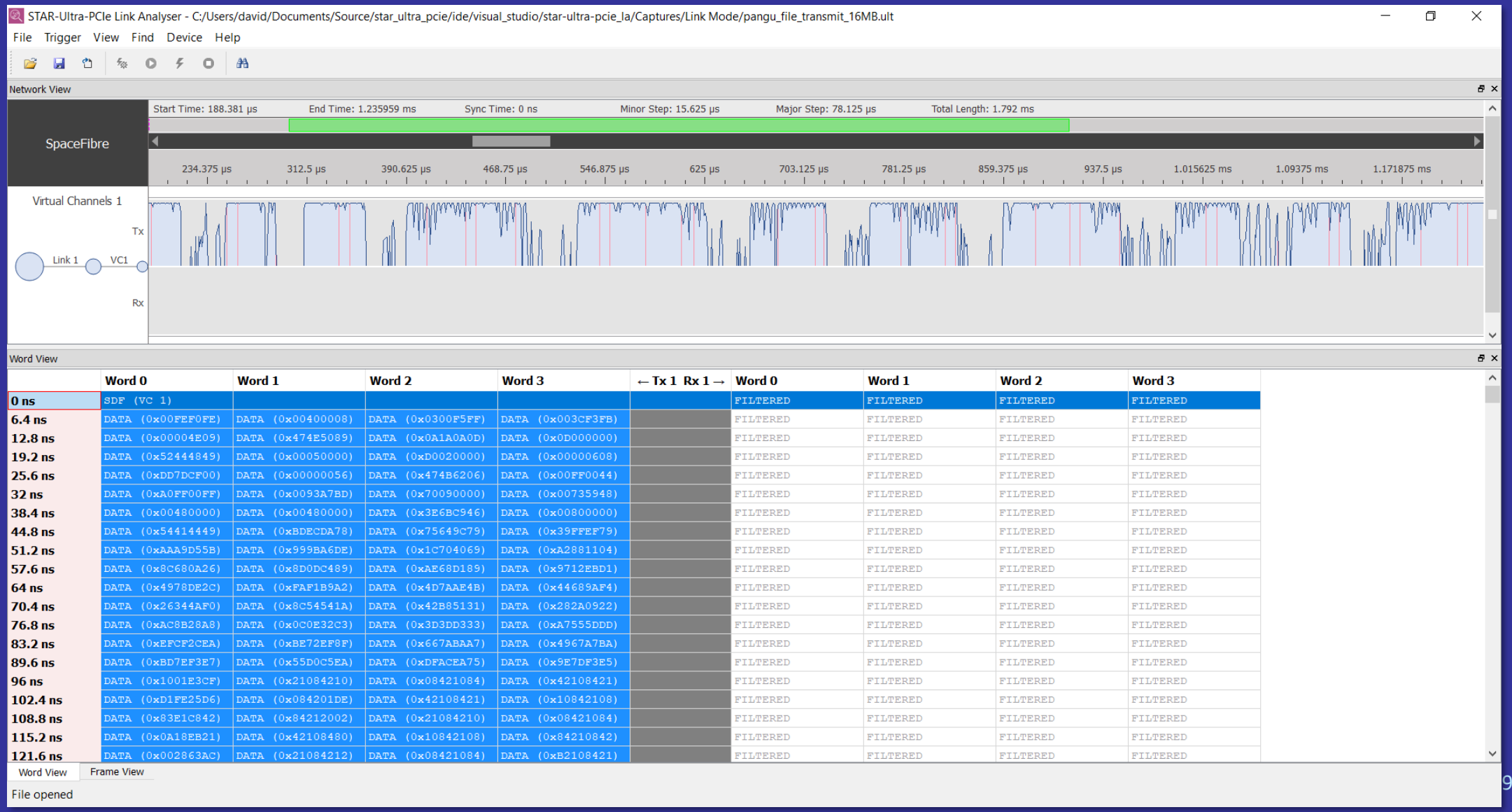
Software Support: Link Analyser



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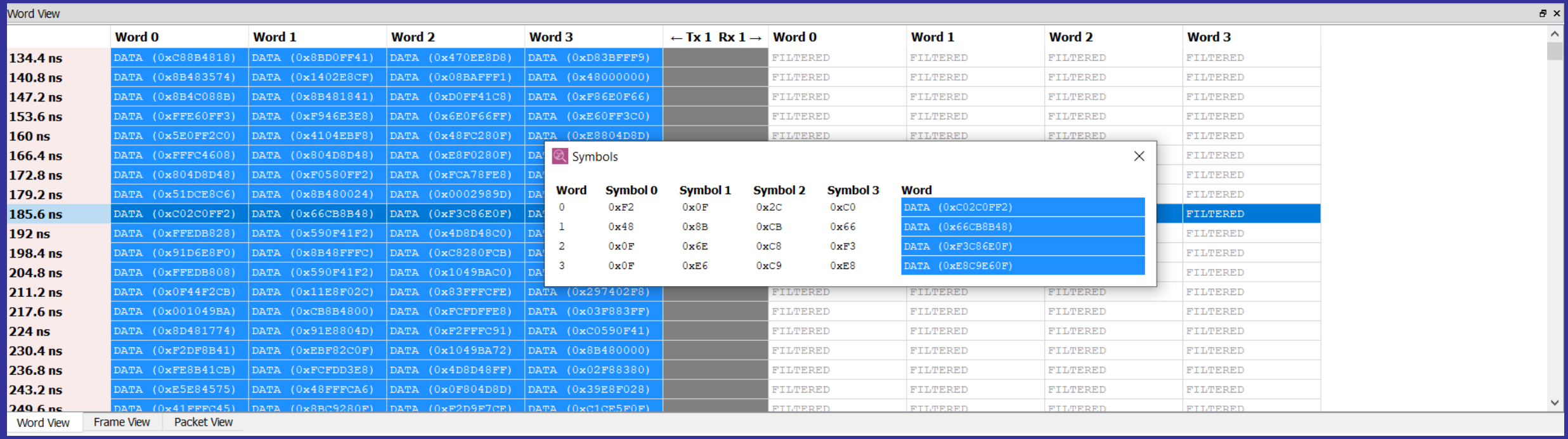
Link Analyser: Word View

- Displays SpaceFibre words and symbols
- Double-click any word to view the corresponding symbols



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Link Analyser: Frame/Packet Views

- Displays SpaceFibre frames and packets

Frame View

	VC1	← Tx 1
6.4883328 ms	SDF (256 words)	
6.4887488 ms	EDF (Seq +16)	
6.4887552 ms	SDF (256 words)	
6.489184 ms	EDF (Seq +17)	
6.4891904 ms	SDF (256 words)	
6.4896064 ms	EDF (Seq +18)	
6.4896128 ms	SDF (256 words)	
6.4900416 ms	EDF (Seq +19)	
6.490048 ms	SDF (256 words)	
6.490464 ms	EDF (Seq +20)	
6.4904704 ms	SDF (256 words)	
6.490848 ms	EOP	
6.4908992 ms	EDF (Seq +21)	
6.4909056 ms	SDF (256 words)	
6.491328 ms	EDF (Seq +22)	
6.4913344 ms	SDF (256 words)	
6.4917632 ms	EDF (Seq +23)	
6.4917696 ms	SDF (256 words)	

Word View | Frame View | Packet View

Packet View

	VC1	← Tx 1
99.9744 µs	Header: FE	
99.9744 µs	Cargo Size: 65545 bytes	
145.2992 µs	EOP	
145.3056 µs	Header: FE	
145.3056 µs	Cargo Size: 65545 bytes	
182.8352 µs	EOP	
182.8416 µs	Header: FE	
182.8416 µs	F0 FE 5D 08 00 00 19 FF	
182.8416 µs	FF 00 06 E7 57 35 00 14	
182.848 µs	72 00 00 00 49 83 C7 08	
182.848 µs	4C 3B FB 75 E3 44 8B FF	
182.8544 µs	48 8D 8D B0 00 00 00 FF	
182.8544 µs	15 40 51 20 00 44 3B FF	
182.8608 µs	0F 85 FE 00 00 00 48 8B	
182.8608 µs	CE E8 CF EB 01 00 48 8B	
182.8672 µs	44 24 38 48 C7 46 08 11	
182.8672 µs	00 00 00 8B 08 85 C9 74	
182.8736 µs	19 3B CF 74 53 48 8B 44	
182.8736 µs	24 38 8B CF F0 0F C1 08	

Word View | Frame View | Packet View

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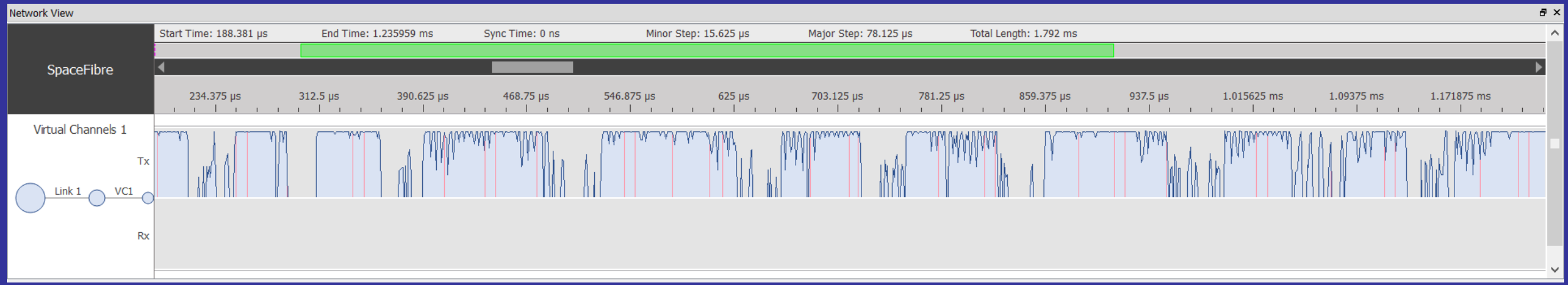
Link Analyser: Network View

- Displays summary of entire traffic capture
- Zoom/pan with the scrollbar and keyboard/mouse controls
- Rapidly navigate and select areas of interest



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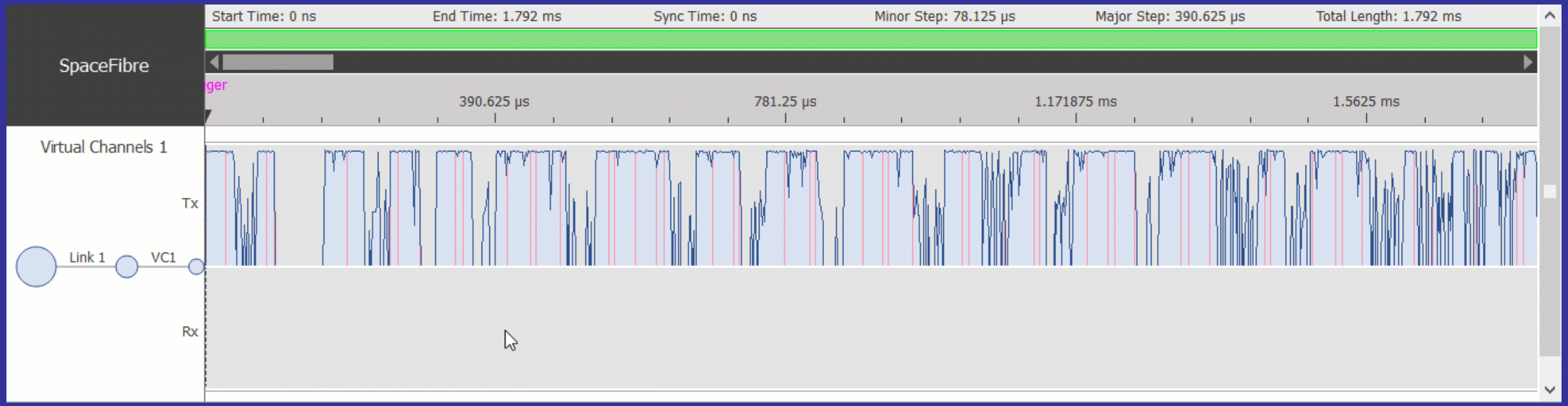
Link Analyser: Network View

- Select a region to load in detailed traffic
- View packet boundaries



STAR-Ultra PCIe: Performance Results

- All results were gathered on a mid-spec desktop PC
  - Intel i5-9600 Six-Core CPU
  - 8 GB Corsair Vengeance DDR4
  - 500 GB Samsung 860 EVO SSD
  - Windows 10 Pro 64-bit
- STAR-System Performance Tester application

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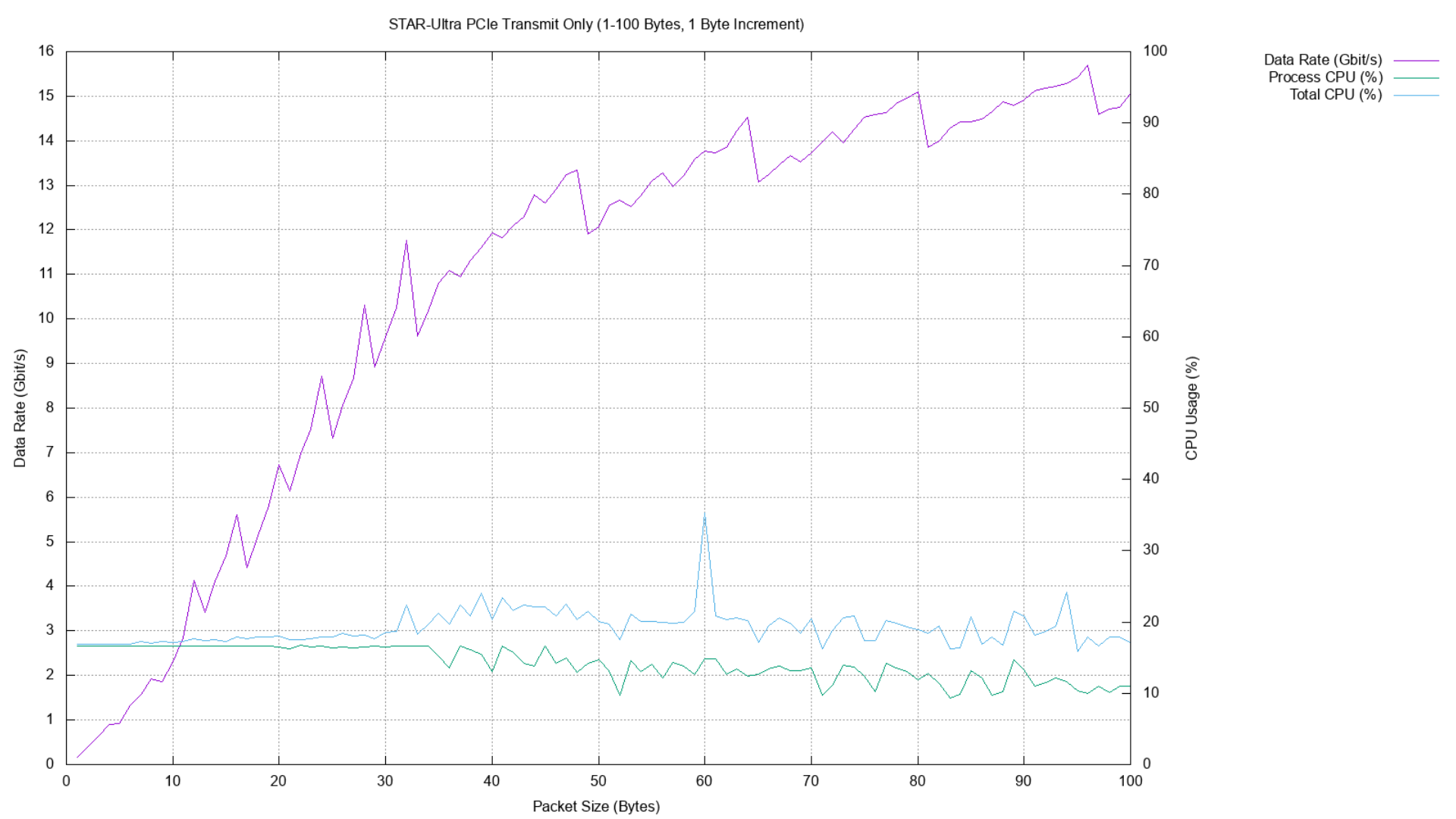
Perf. Results: Transmit Only (1-100 Bytes)



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Perf. Results: Transmit Only (100-20K Bytes)

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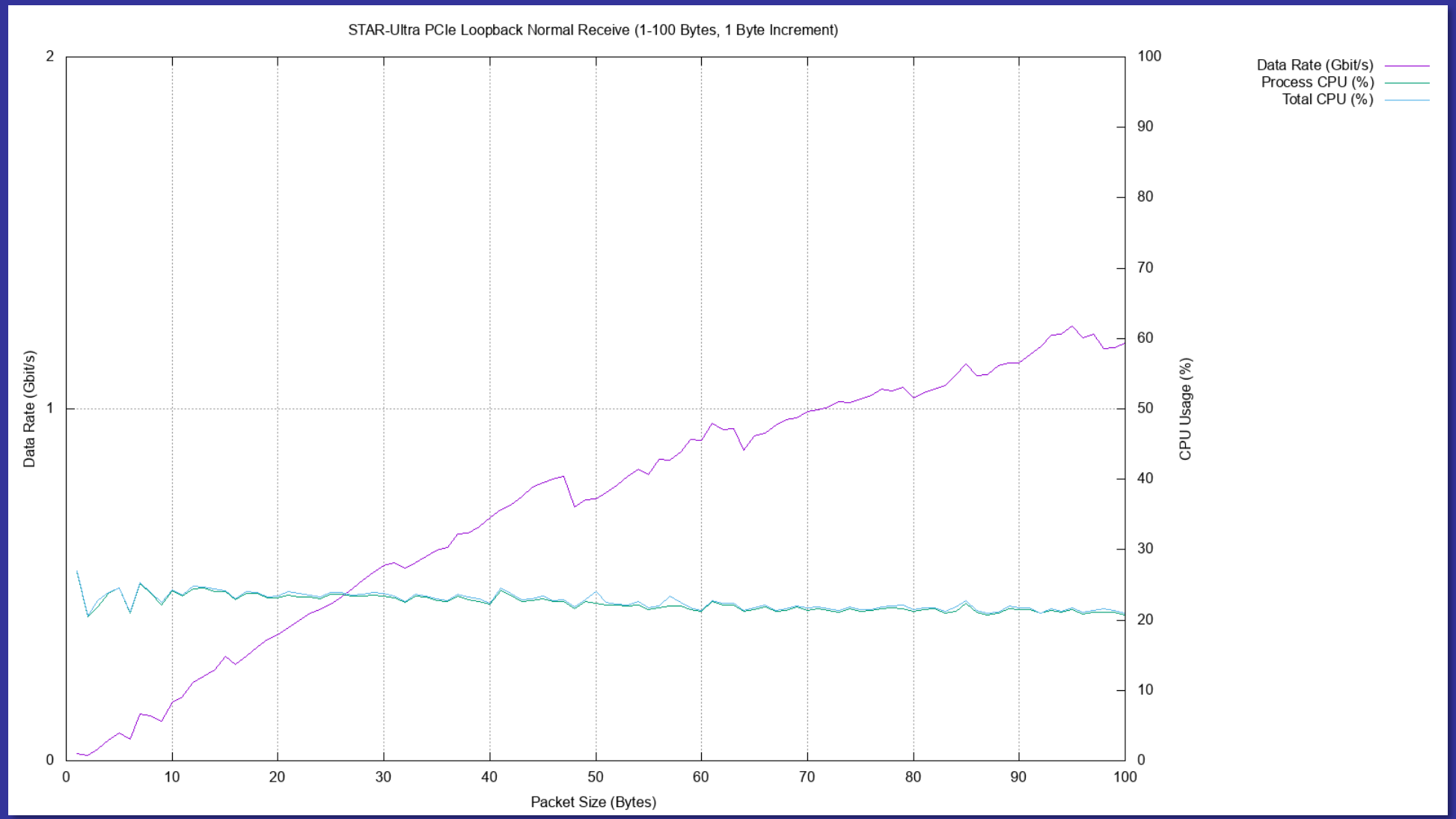
Perf. Results: Loopback Normal (1-100 Bytes)



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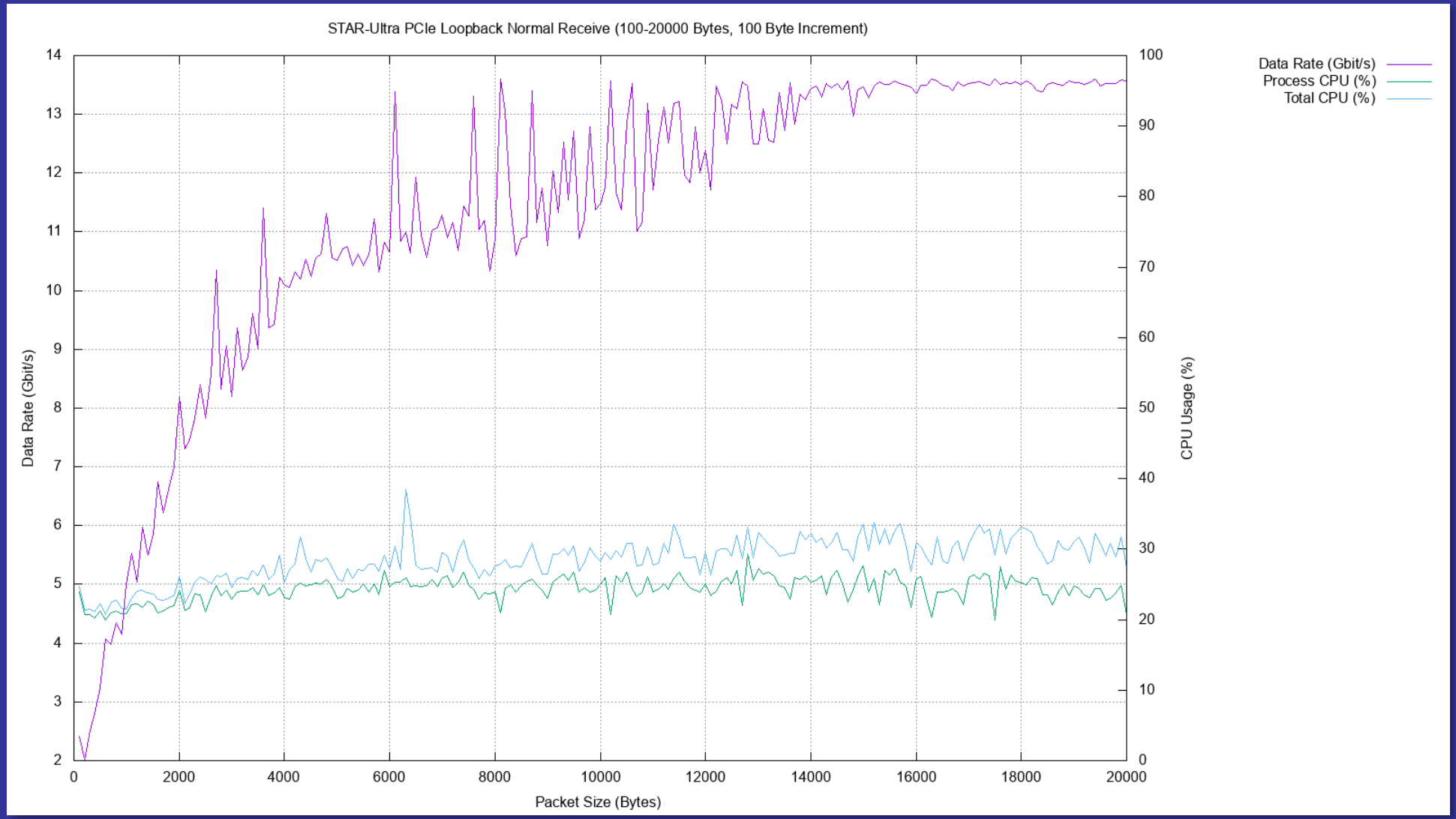
Perf. Results: Loopback Normal (100-20K Bytes)



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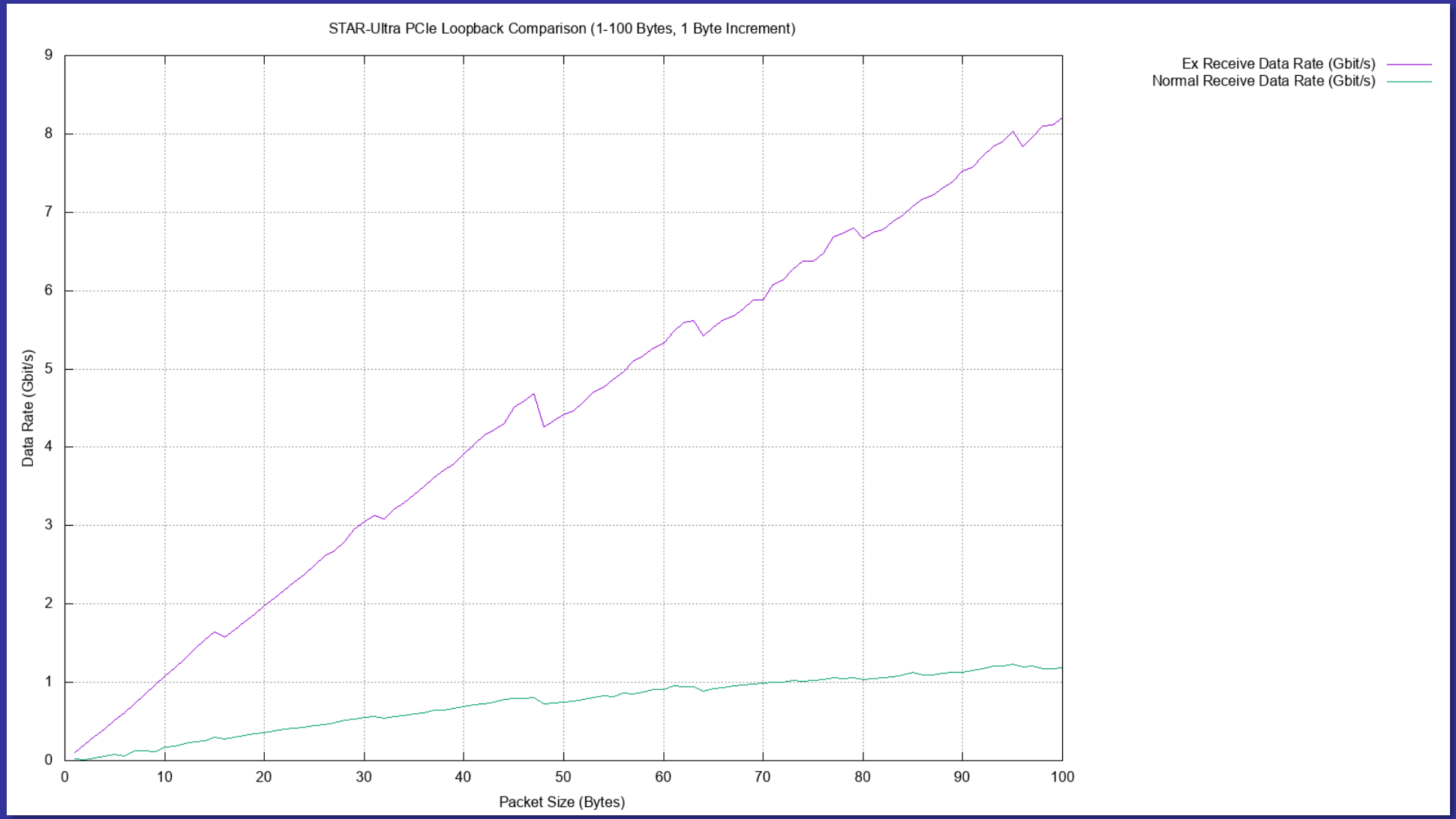
Perf. Results: Loopback Comparison (1-100 Bytes)



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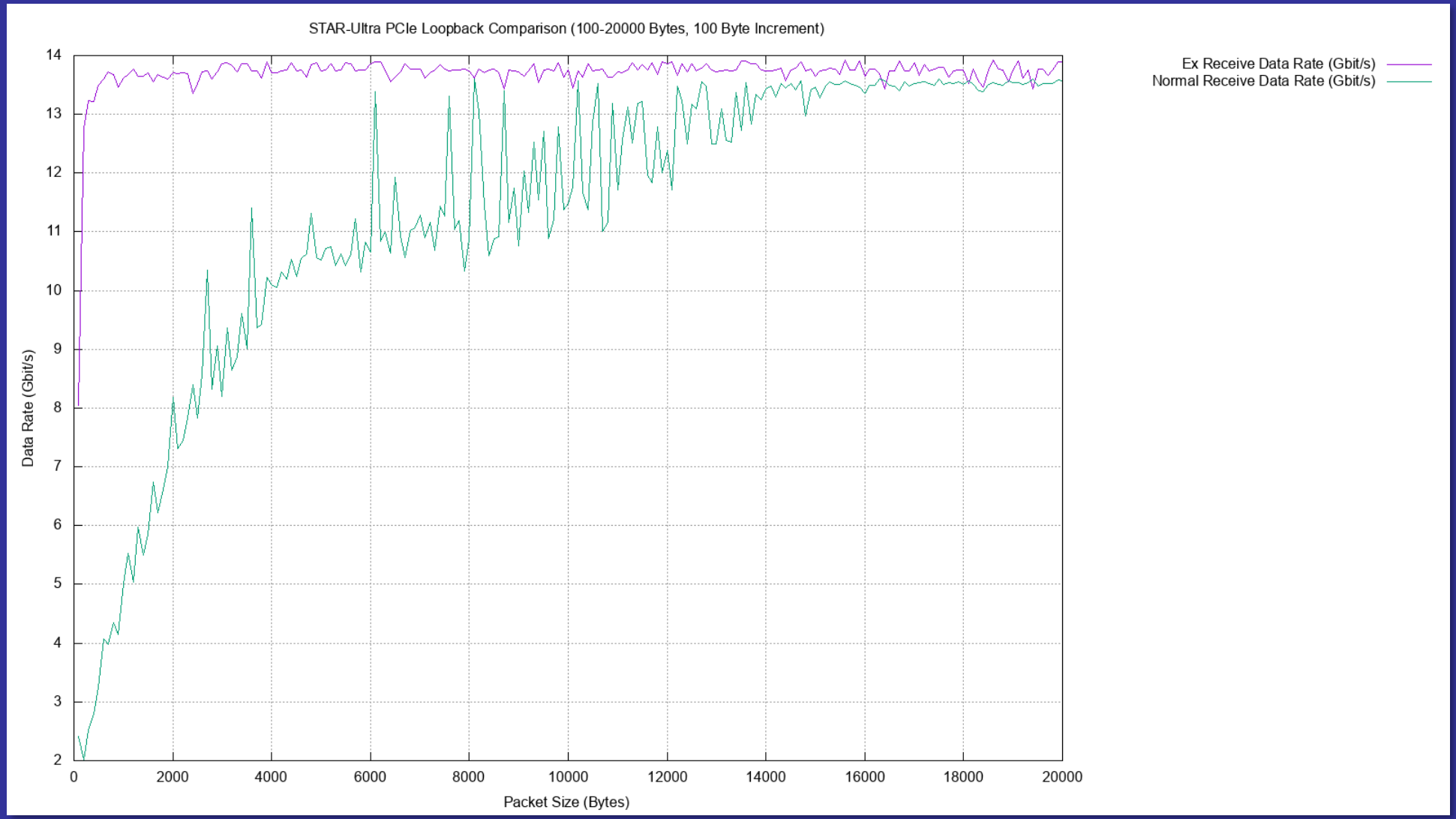
Perf. Results: Loopback Comparison (100-20K Bytes)



Test Software: CCSDS File Transfer

- Protocols used for transferring files in Hi-SIDE:
  - Payload Data Encapsulation Protocol (PDEP):
    - PDEP header (addresses, PID, seq. number)
    - CCSDS Space Packet Protocol (SPP) packet
  - Transfer Frame Encapsulation Protocol (TFEP):
    - TFEP header (addresses, PID, seq. number)
    - CCSDS AOS Transfer Frame (TF) packet containing SPP fragments(s)

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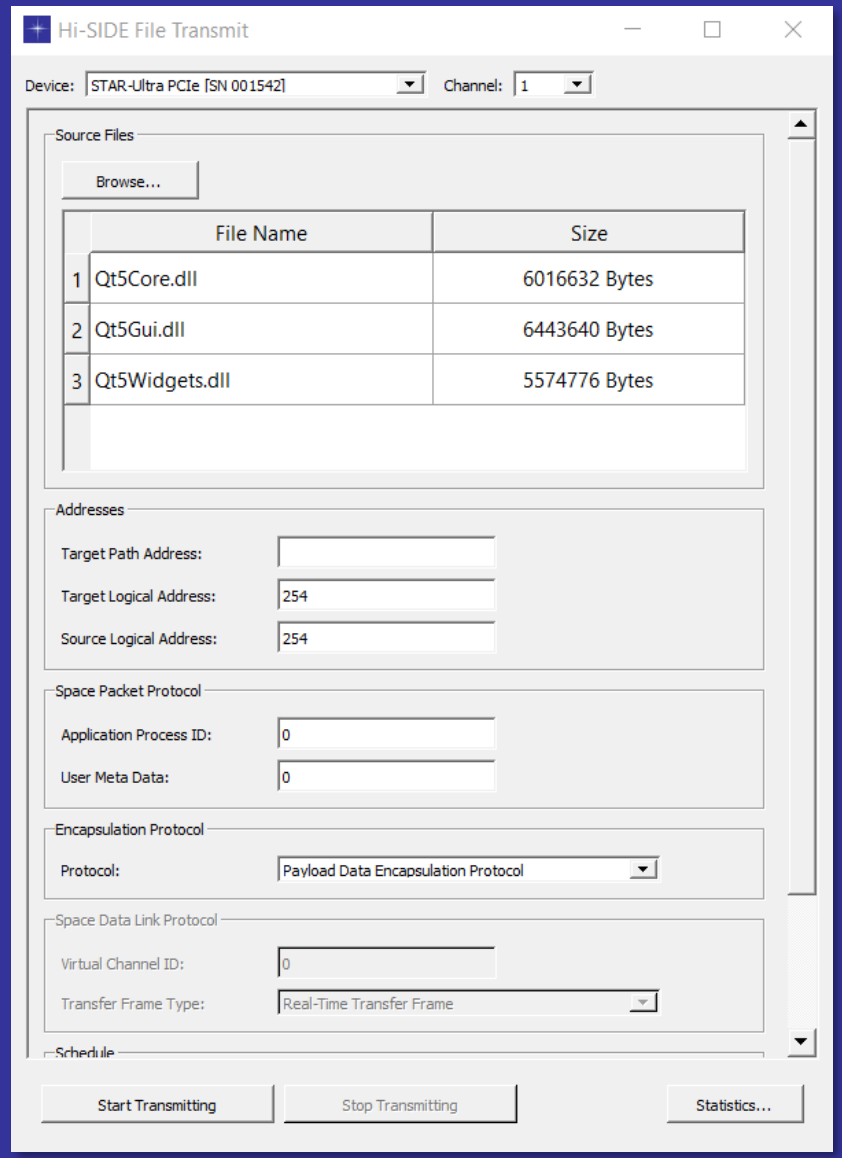
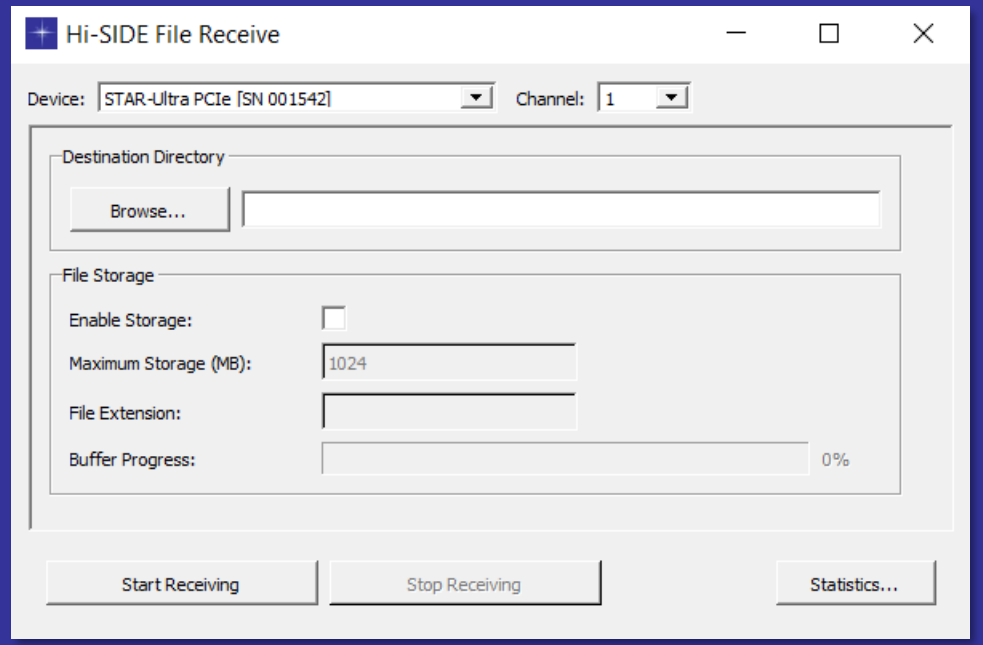
Test Software: CCSDS File Transfer





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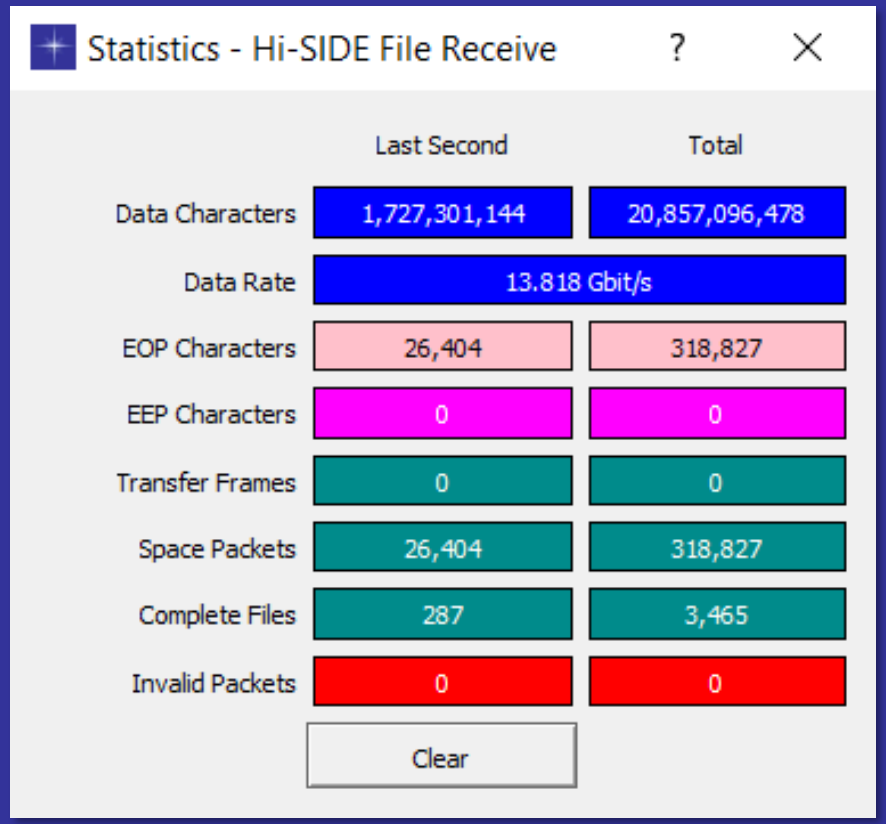
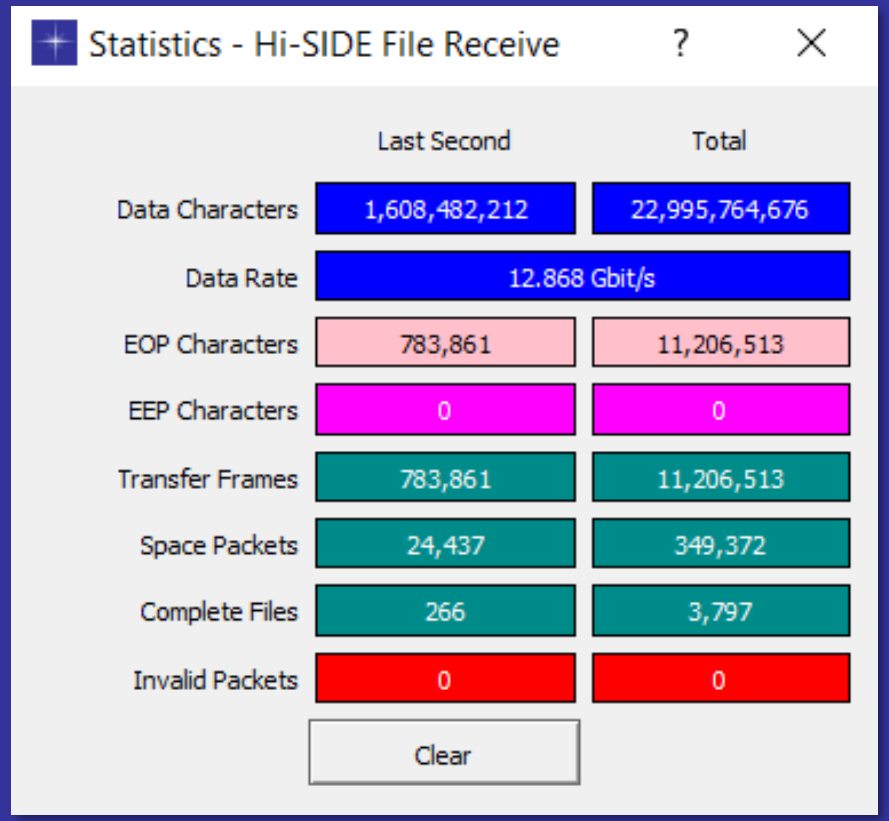
Test Software: CCSDS File Transfer

PDEP + CCSDS Space Packet Protocol



TFEP + CCSDS Transfer Frames



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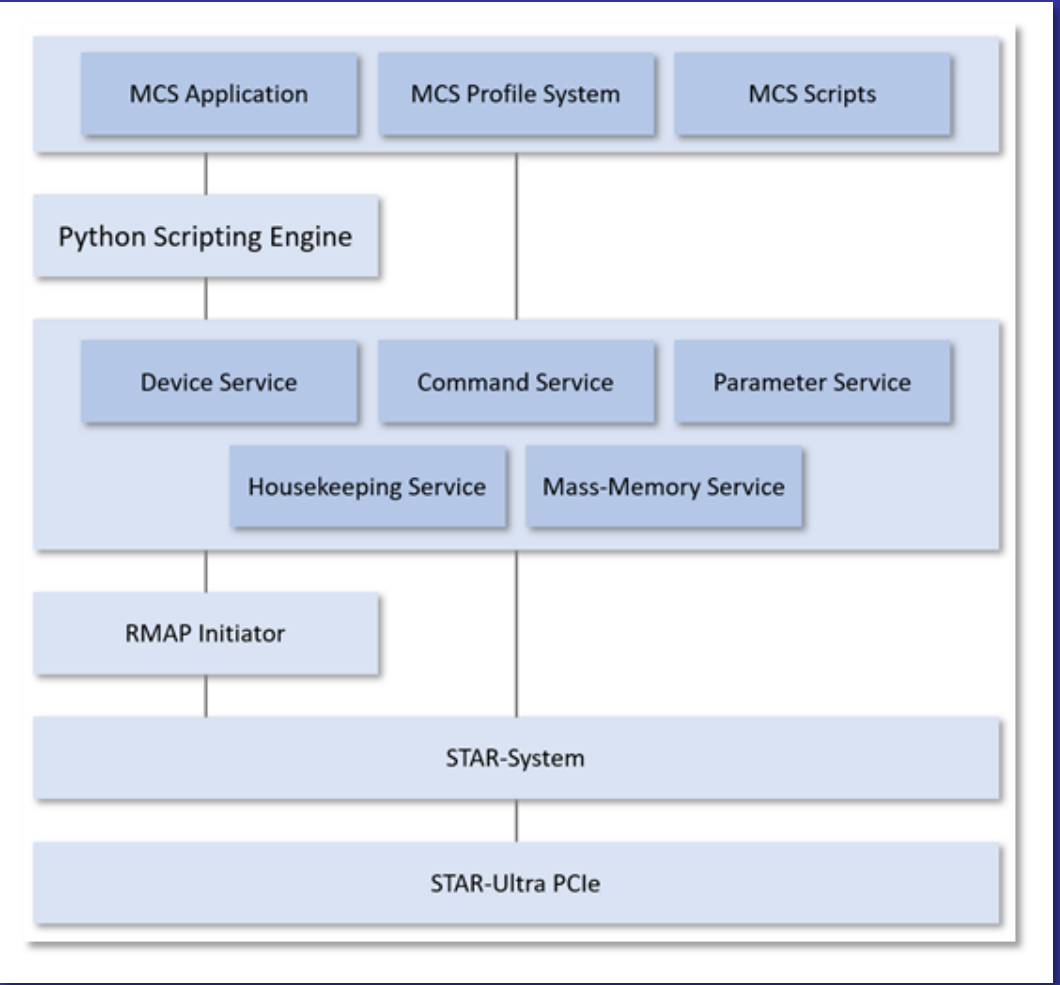
Control Software: Purpose

- Hi-SIDE Monitoring and Control System (MCS):
  - Configuration of the SpaceFibre network
  - Monitoring and control of the SpaceFibre network and elements
  - Automated scripting of demonstration scenarios



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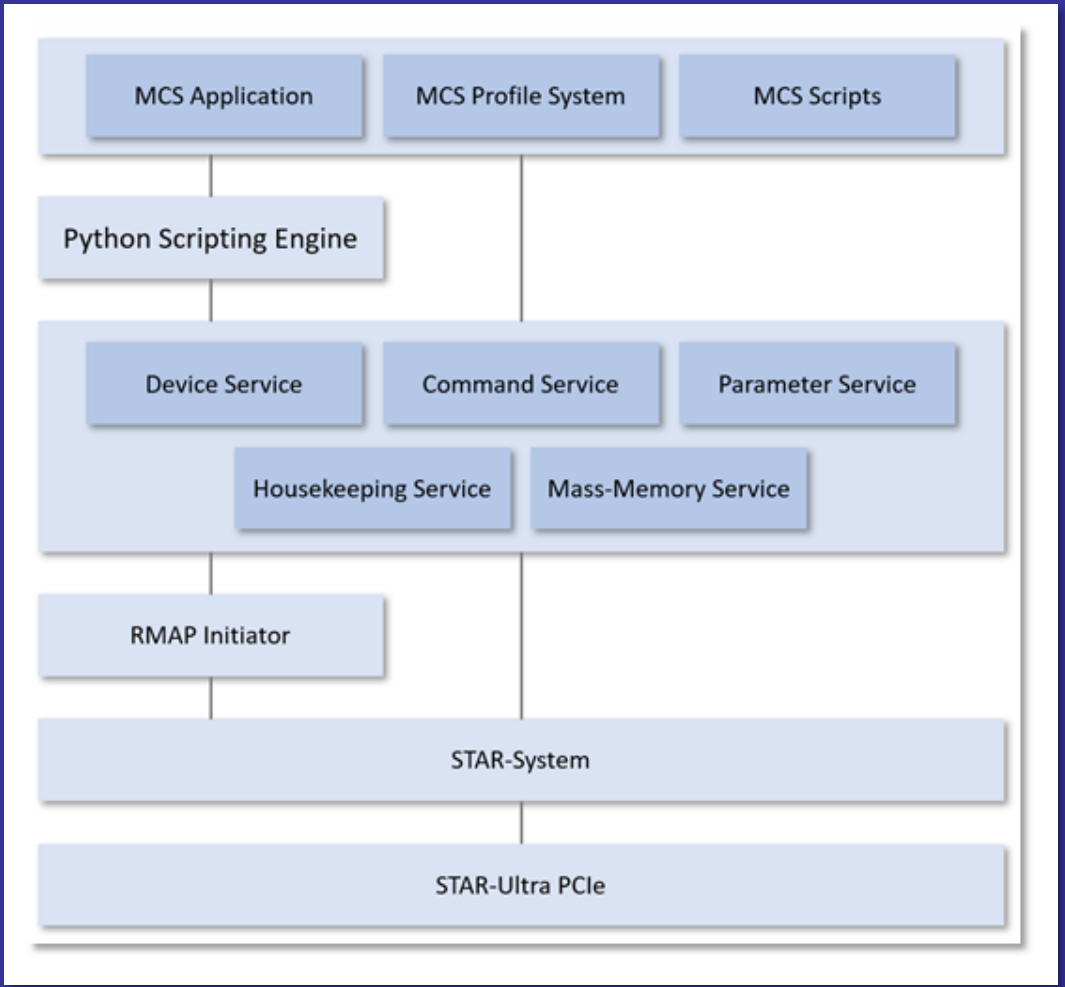
Control Software: Layers

- User Interface, MCS Profiles and MCS Scripts
- Python Scripting Engine
- Services:
  - Device Service
  - Command Service
  - Parameter Service
  - Housekeeping Service
  - Mass-Memory Service
- RMAP Initiator
- STAR-System and STAR-Ultra PCIe



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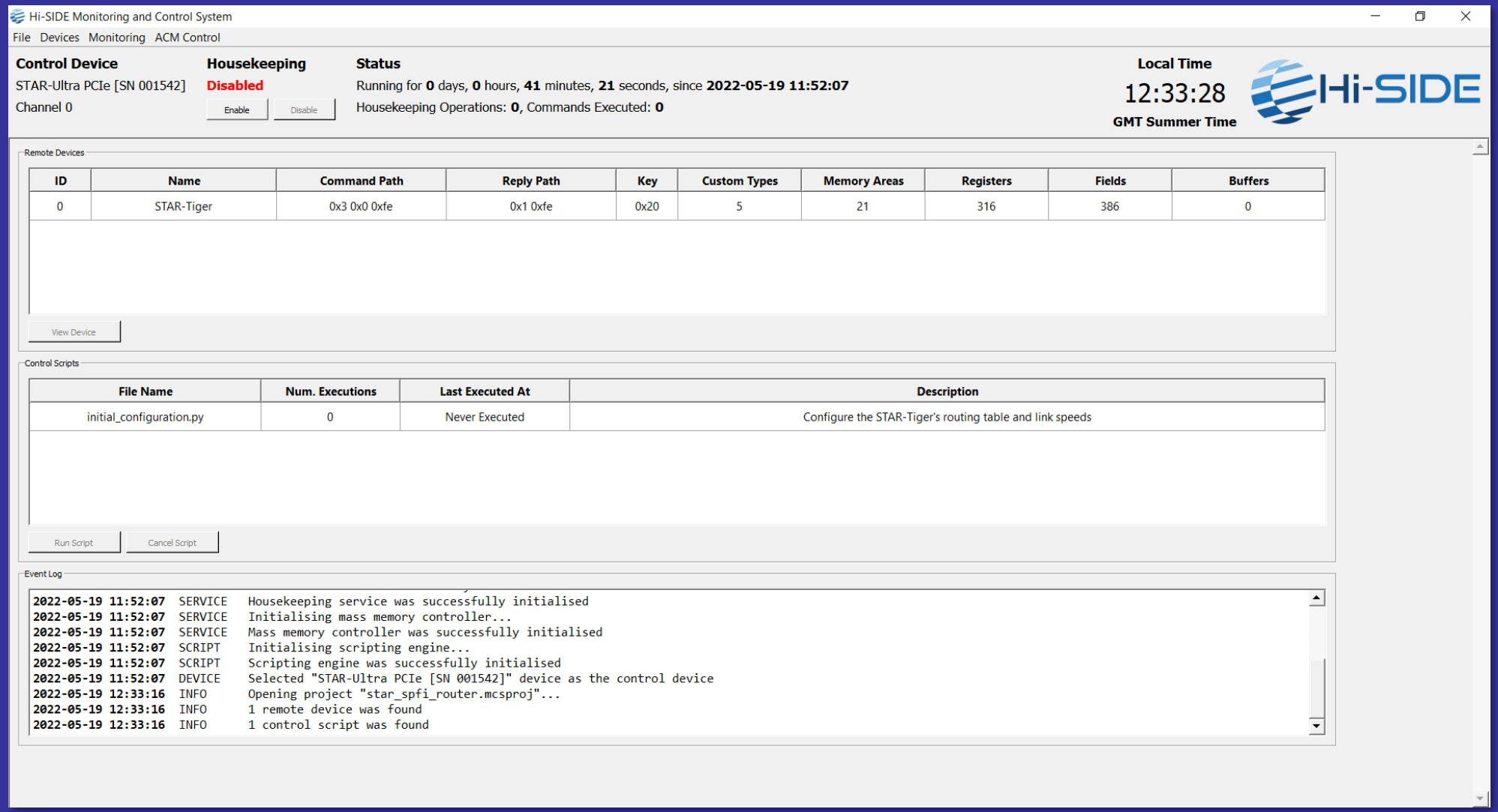
Control Software: GUI



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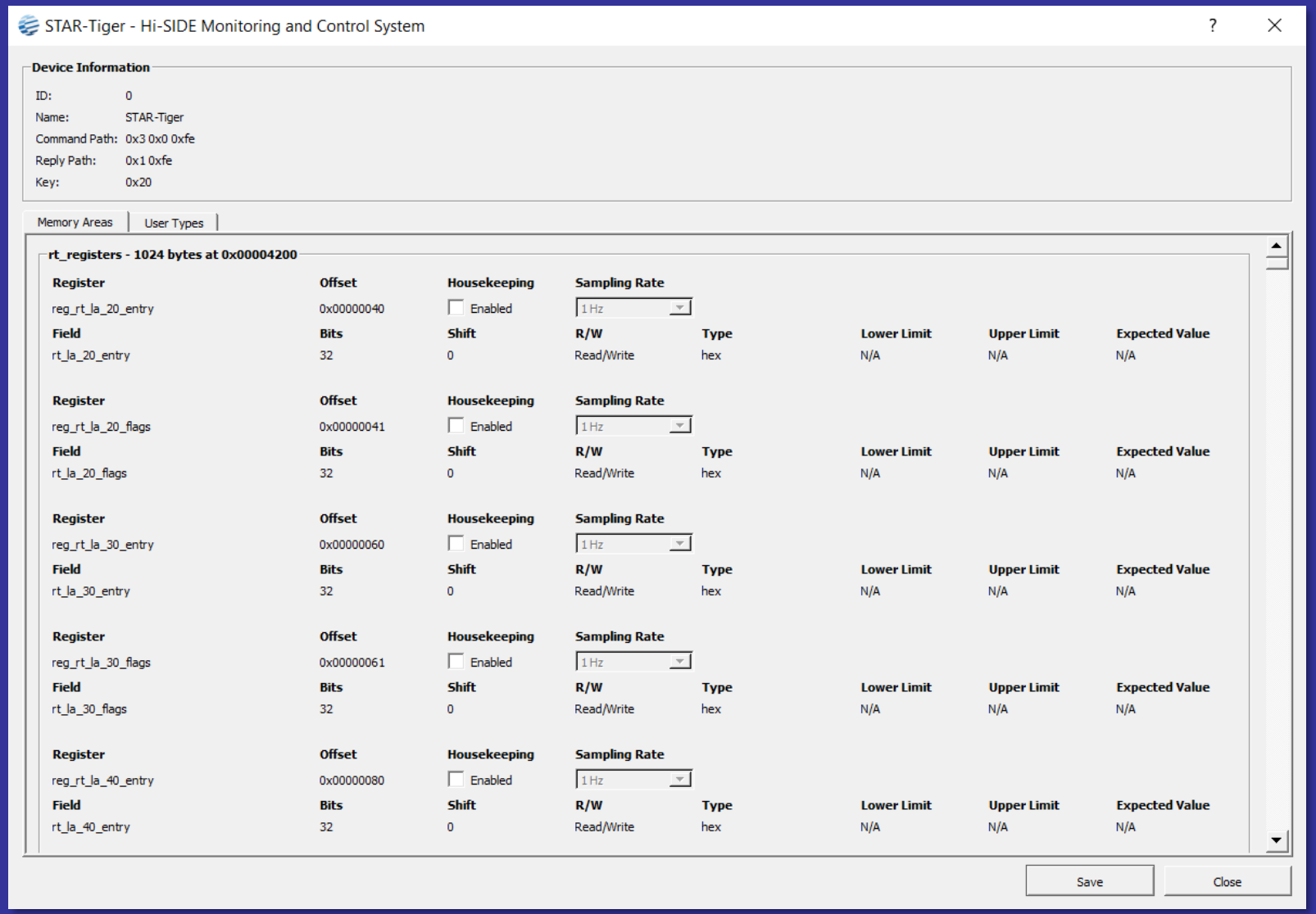
Control Software: Device Information



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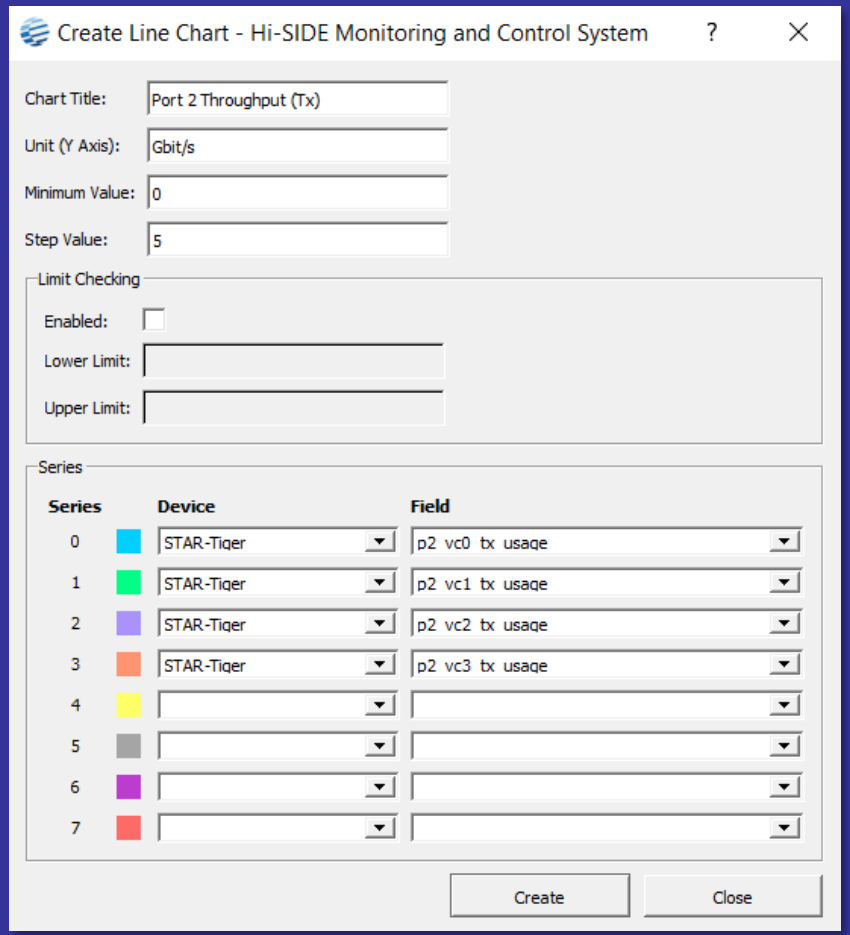
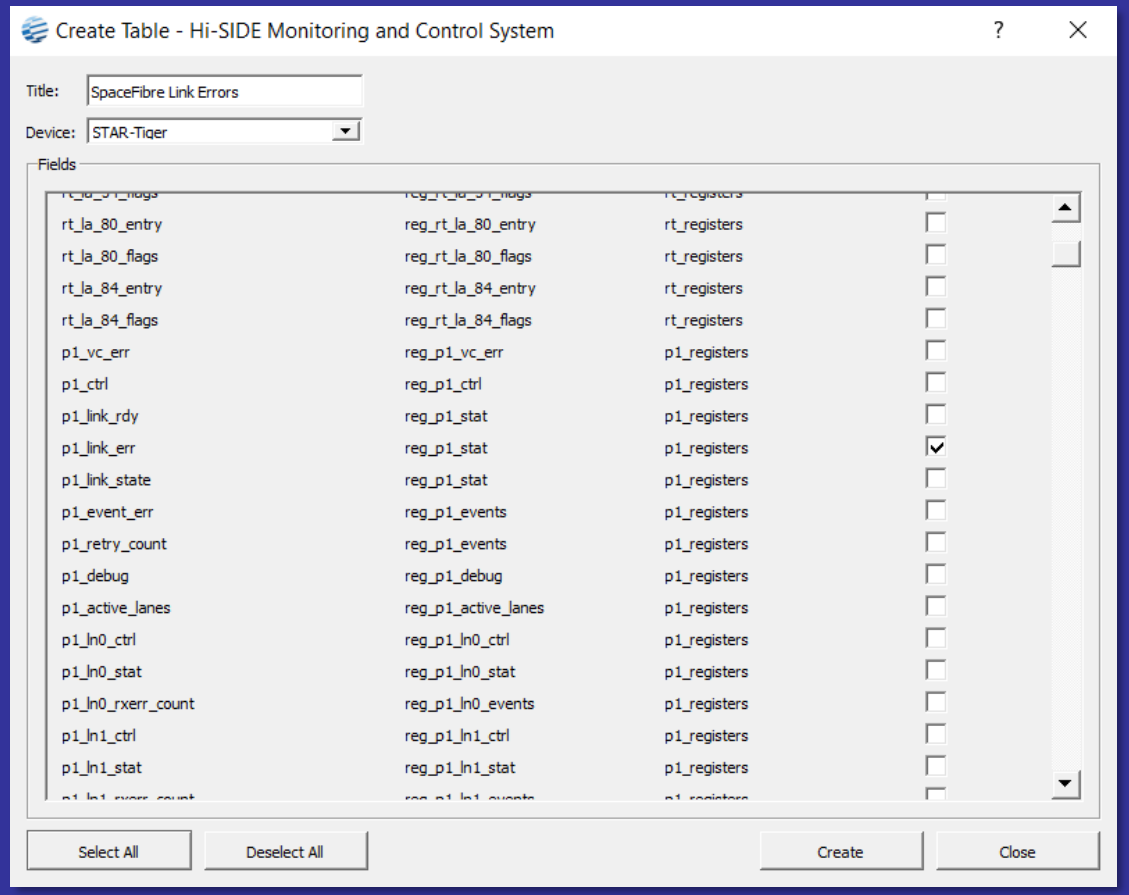
Control Software: Monitoring





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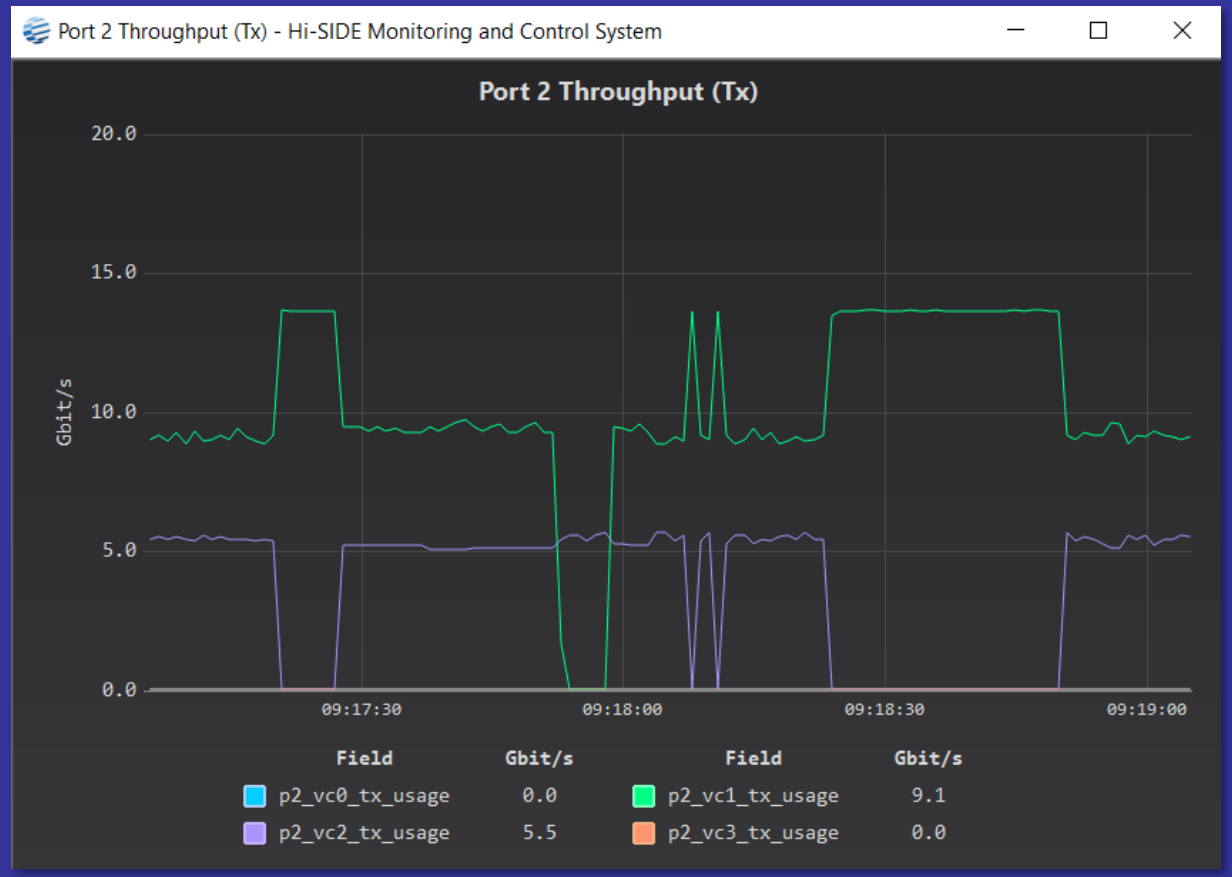
Control Software: Monitoring



SpaceFibre Link Errors - Hi-SIDE Monitoring and Control System

Field	Device	Sample Time	Lower	Upper	Expected	Actual
p1_link_err	STAR-Tiger	15:14:37.510	N/A	N/A	0	NO ERRORS
p2_link_err	STAR-Tiger	15:14:37.511	N/A	N/A	0	NO ERRORS
p3_link_err	STAR-Tiger	15:14:37.512	N/A	N/A	0	NO ERRORS
p4_link_err	STAR-Tiger	15:14:37.513	N/A	N/A	0	NO ERRORS
p5_link_err	STAR-Tiger	15:14:37.514	N/A	N/A	0	NO ERRORS
p6_link_err	STAR-Tiger	15:14:37.514	N/A	N/A	0	NO ERRORS
p7_link_err	STAR-Tiger	15:14:37.515	N/A	N/A	0	NO ERRORS
p8_link_err	STAR-Tiger	15:14:37.516	N/A	N/A	0	NO ERRORS
p9_link_err	STAR-Tiger	15:14:37.517	N/A	N/A	0	NO ERRORS
p10_link_err	STAR-Tiger	15:14:37.507	N/A	N/A	0	NO ERRORS

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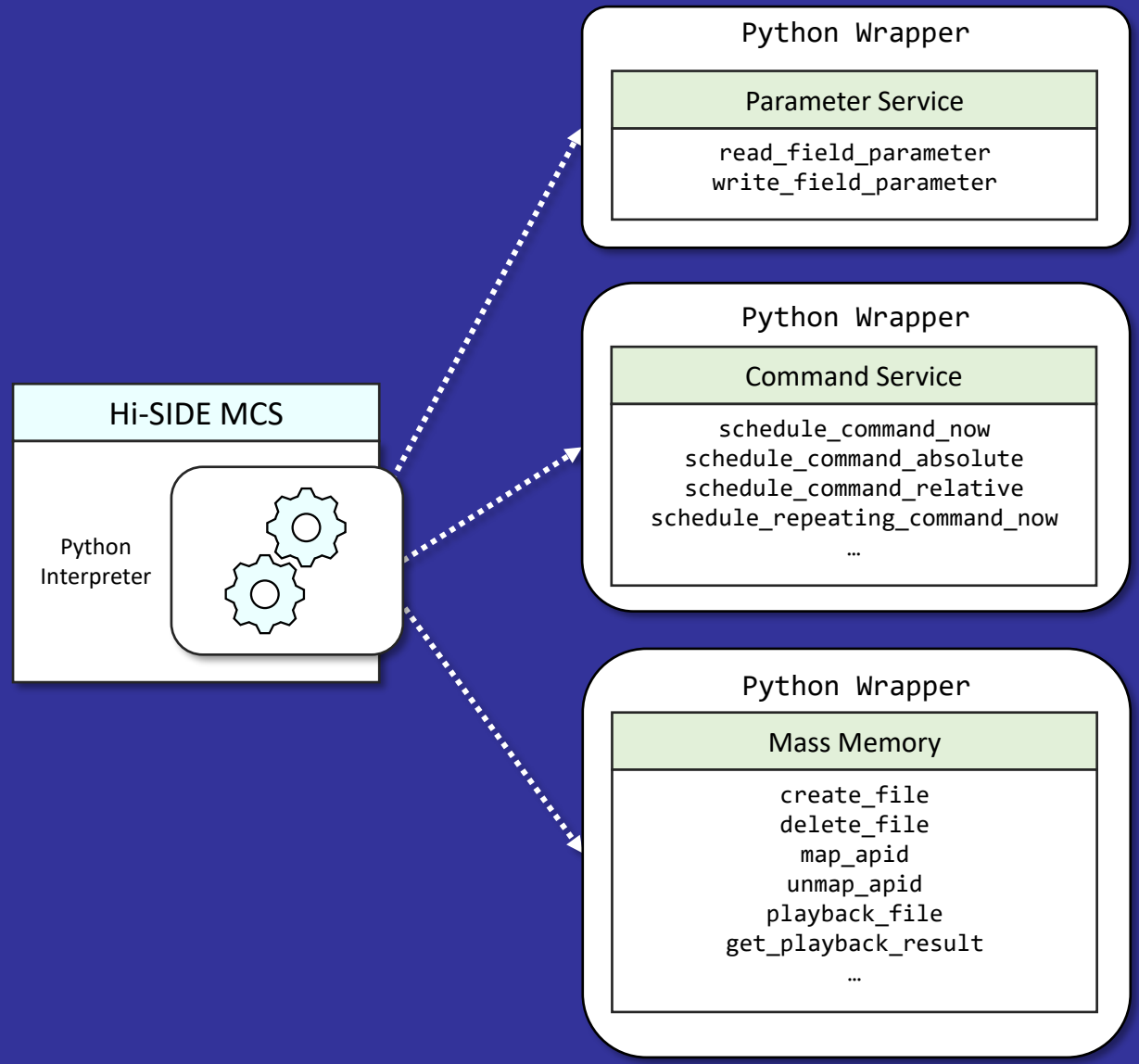
Control Software: Scripting

- Each service has a Python wrapper
- Embedded Python interpreter is used to execute control scripts



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Control Software: Scripting

- Each service has a Python wrapper
- Embedded Python interpreter is used to execute control scripts

```
***** START OF SCRIPT *****
File Name: vt-10.py

0: create_file("test_file_000"): service_status=SUCCESS
1: get_file_operation_result(): service_status=SUCCESS, fop_status=SUCCESS, fop_data=0

***** END OF SCRIPT *****
```

```
***** START OF SCRIPT *****
File Name: vt-70.py

0: create_file("test_file_000"): service_status=SUCCESS
1: get_file_operation_result(): service_status=SUCCESS, fop_status=SUCCESS, fop_data=0
2: map_apid(123, "test_file_000"): service_status=SUCCESS
3: get_file_operation_result(): service_status=SUCCESS, fop_status=SUCCESS, fop_data=0
4: playback_file("test_file_000", 0x54, PlaybackMode.TFEP, 1): service_status=SUCCESS
5: get_playback_result(1):
   service_status=SUCCESS, async_op_status=BUSY, async_op_progress=STARTED
   service_status=SUCCESS, async_op_status=BUSY, async_op_progress=STARTED
   service_status=SUCCESS, async_op_status=BUSY, async_op_progress=STARTED
   service_status=SUCCESS, async_op_status=BUSY, async_op_progress=STARTED
   service_status=SUCCESS, async_op_status=BUSY, async_op_progress=STARTED
   service_status=SUCCESS, async_op_status=IDLE, async_op_progress=COMPLETED

***** END OF SCRIPT *****
```

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Mass-Memory Software

- Software implementation of a Mass-Memory
- Running in a desktop PC:
  - Intel Core i9-9900K 3.6 GHz 8-Core CPU
  - 128 GB Corsair Vengeance LPX 3200 MHz DDR4
  - STAR-Ultra PCIe

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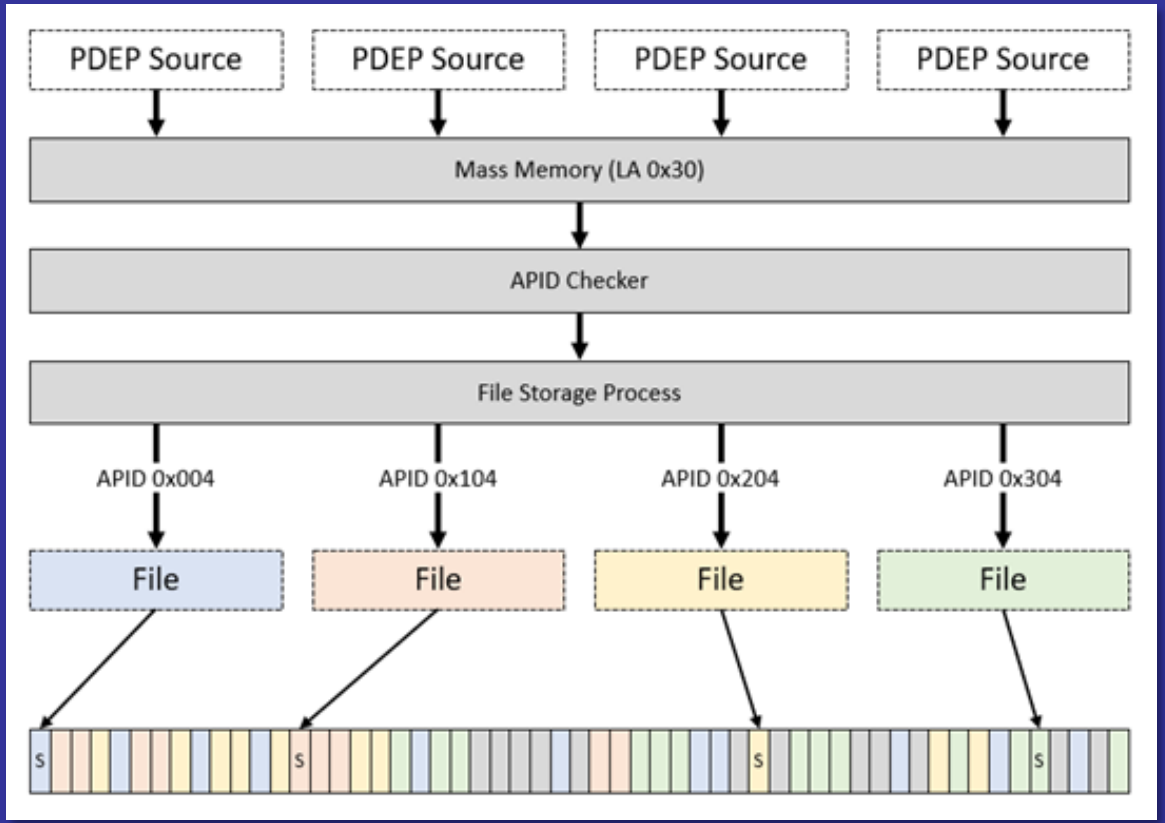
Mass-Memory Software

- Storage:
  - Receive PDEP packets
  - Extract and check APIDs
  - Add packets to the file system
- Playback:
  - Extract stored packets from the file system
  - Encode extracted packets in PDEP or TFEP mode
  - Transmit encoded packets to the intended receiver
- Integrated with File Protection Scheme
- Controlled via RMAP commands



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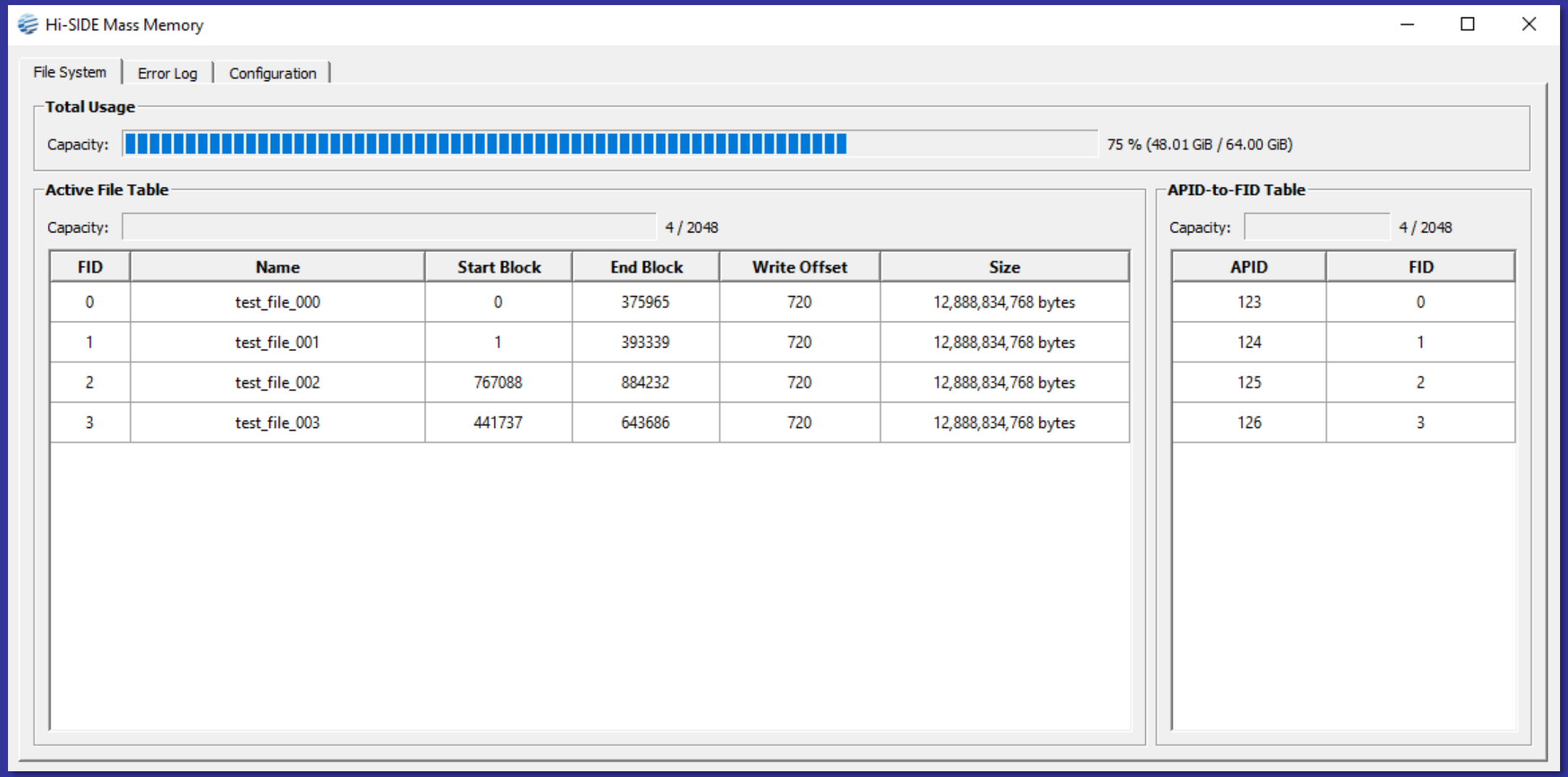
Mass-Memory Software



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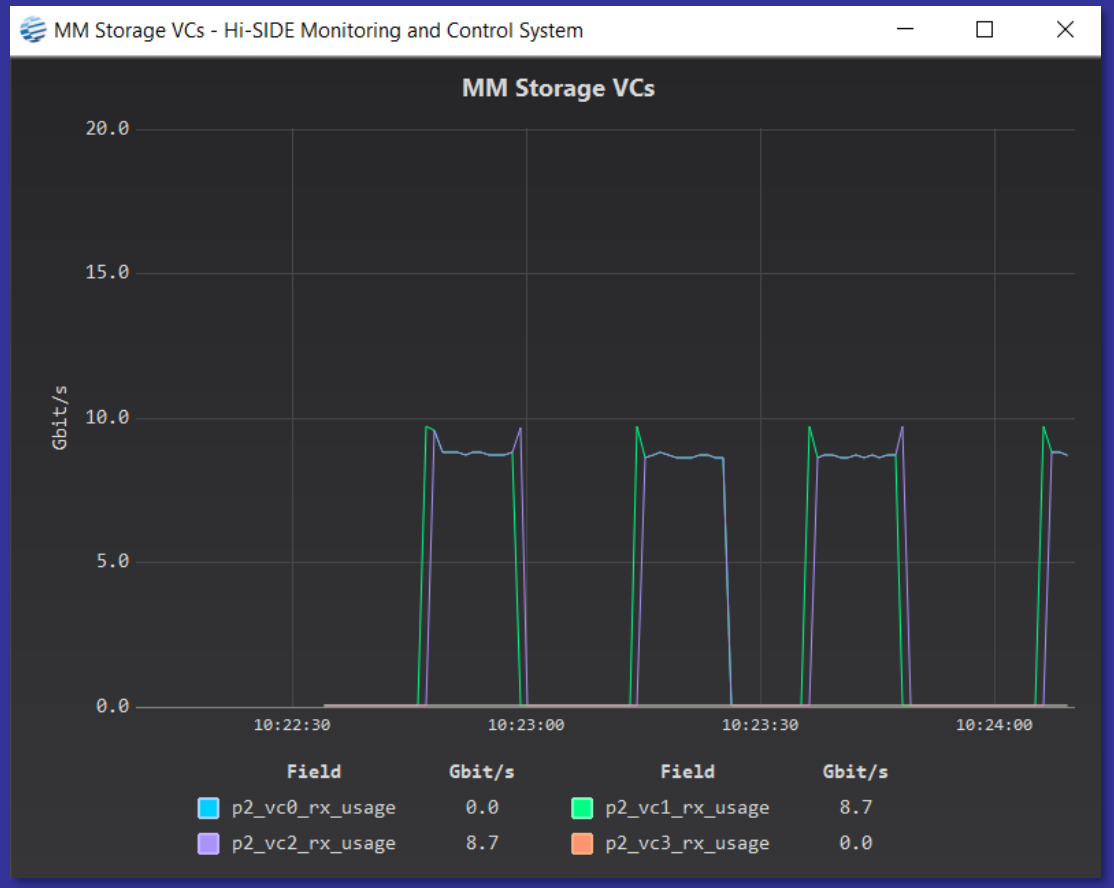
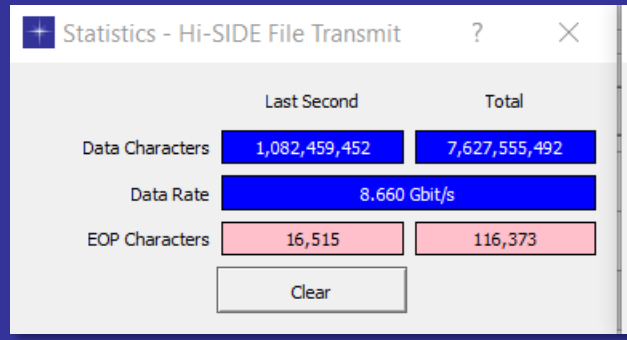
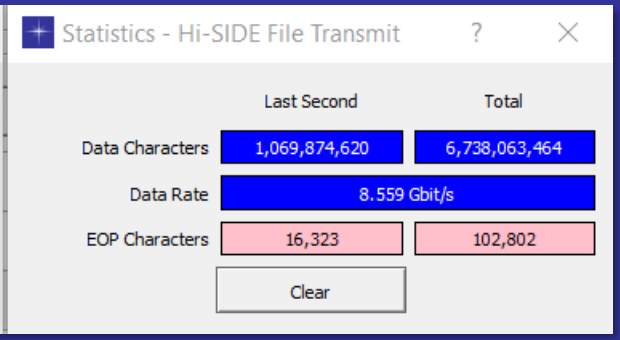
Mass-Memory Software: Performance

- Storing two files from two PDEP sources at approximately 8.5 Gbit/s on two VCs (17 Gbit/s total)







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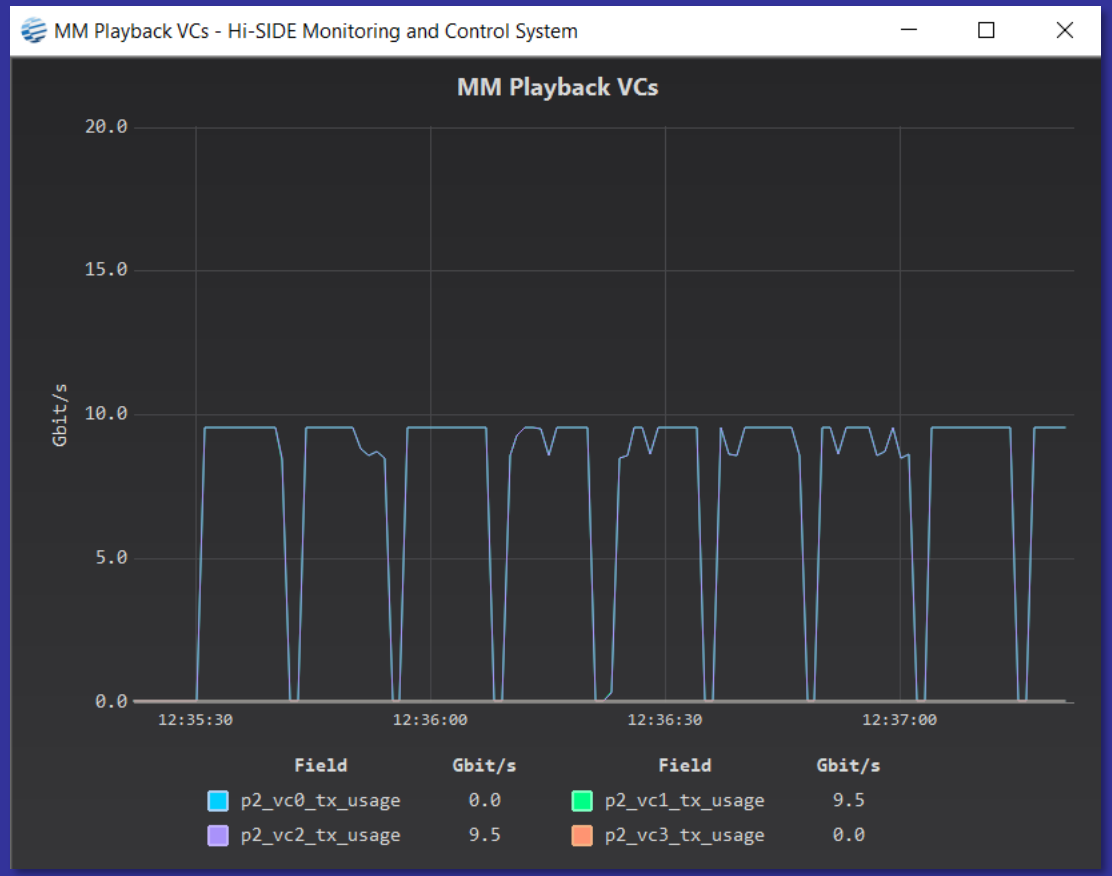
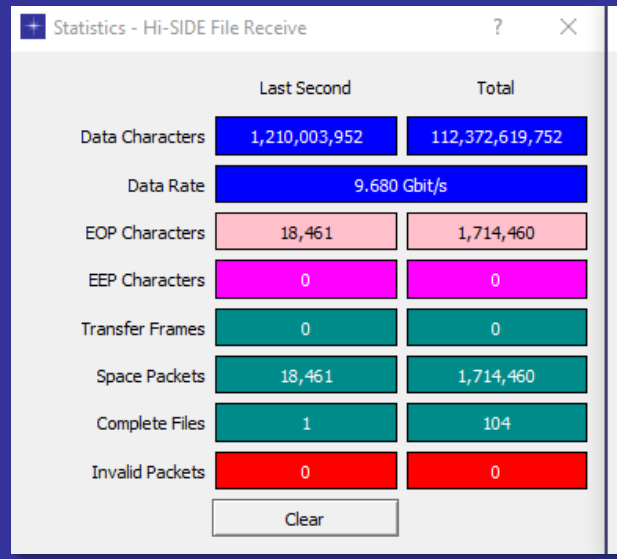
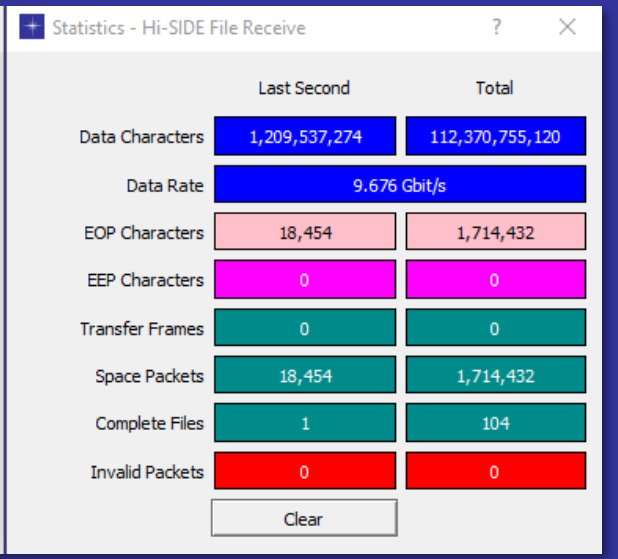
Mass-Memory Software: Performance

- Playing back two files in PDEP mode to two receivers at approximately 9.6 Gbit/s on two VCs (19.2 Gbit/s total)







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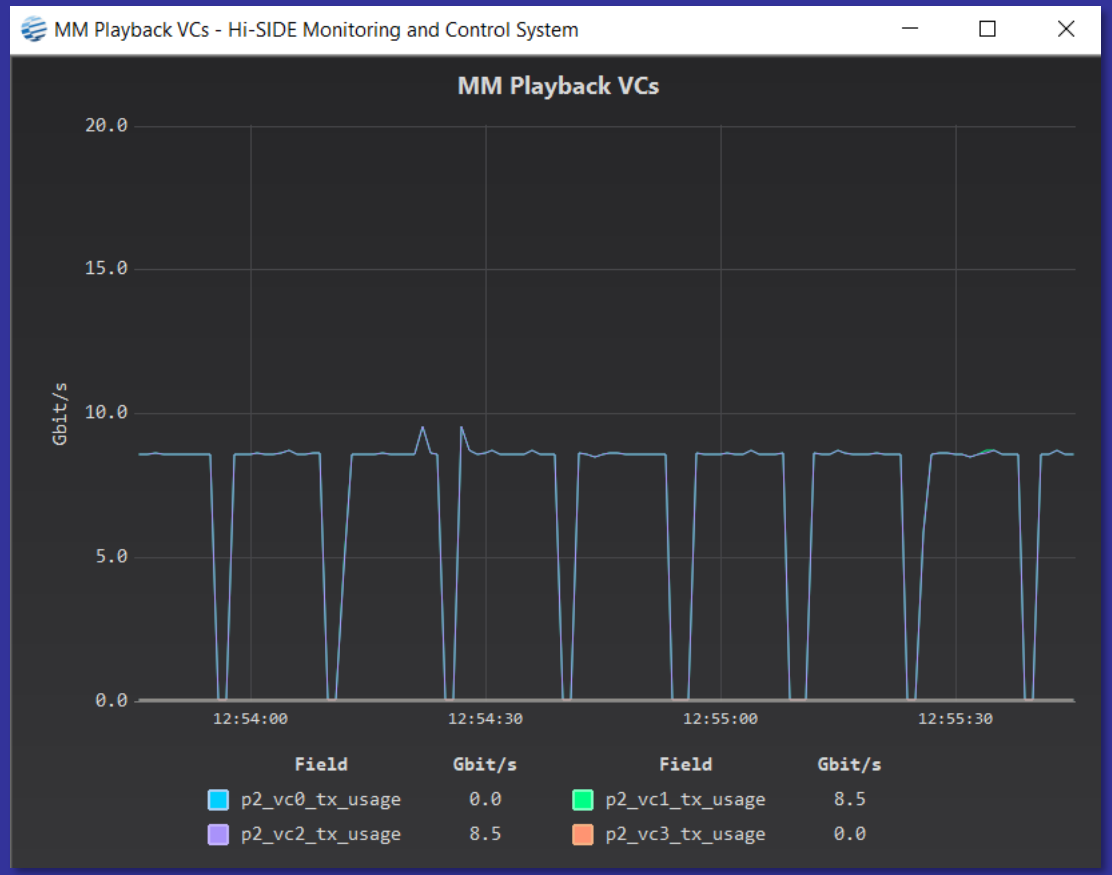
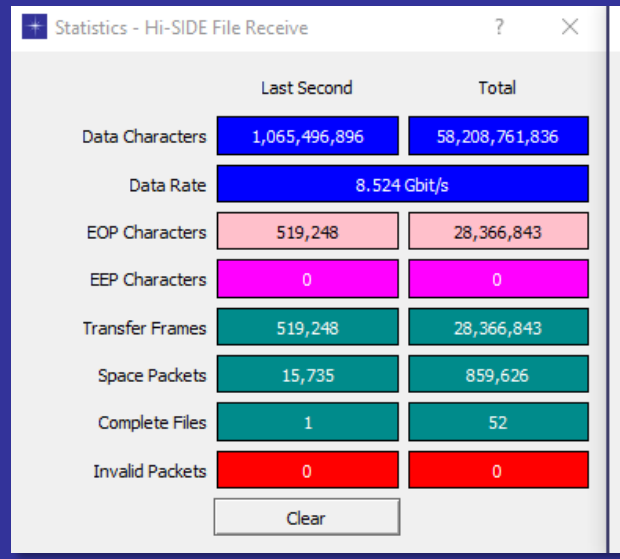
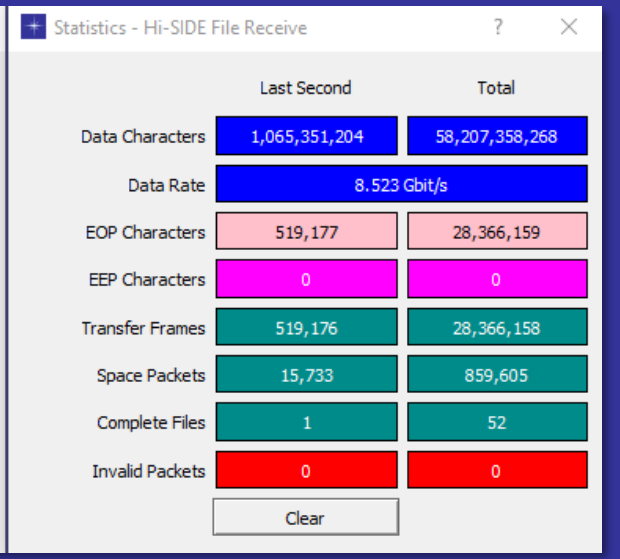
Mass-Memory Software: Performance

- Playing back two files in TFEP mode to two receivers at approximately 8.5 Gbit/s on two VCs (17 Gbit/s total)







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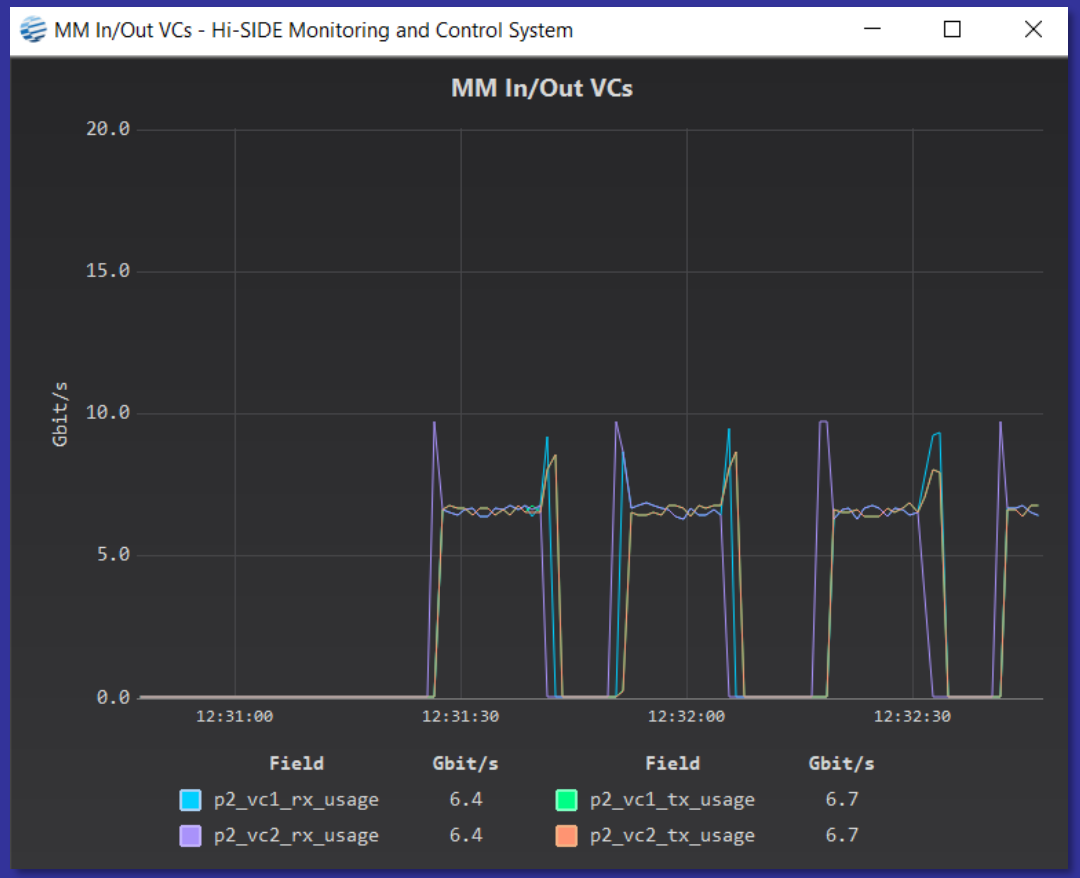
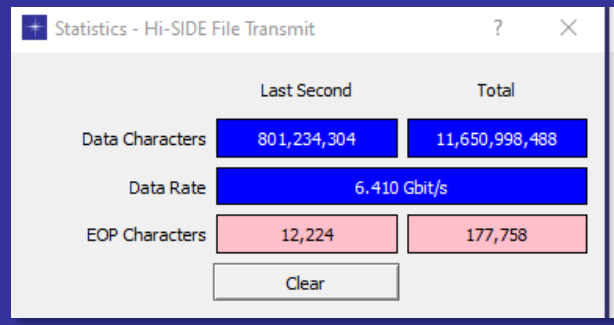
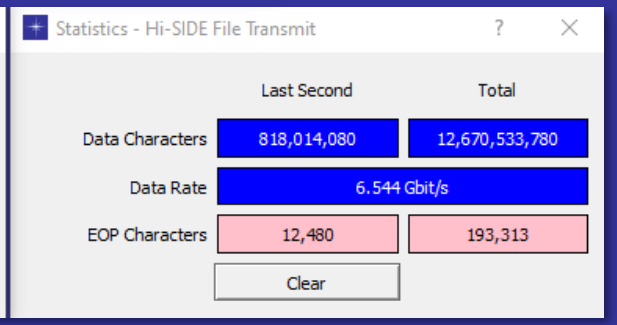
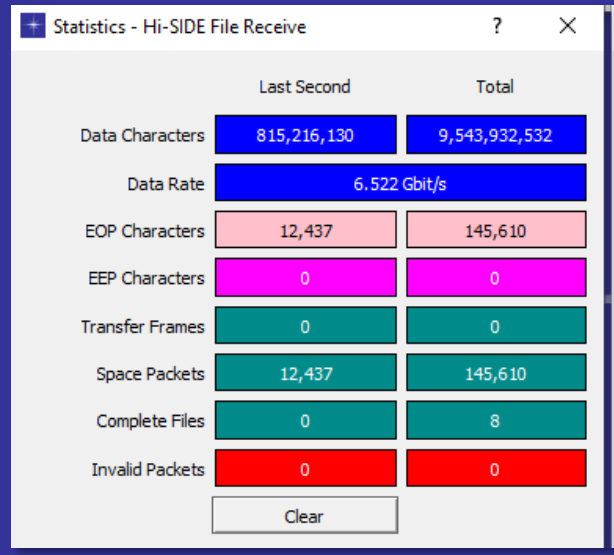
Mass-Memory Software: Performance

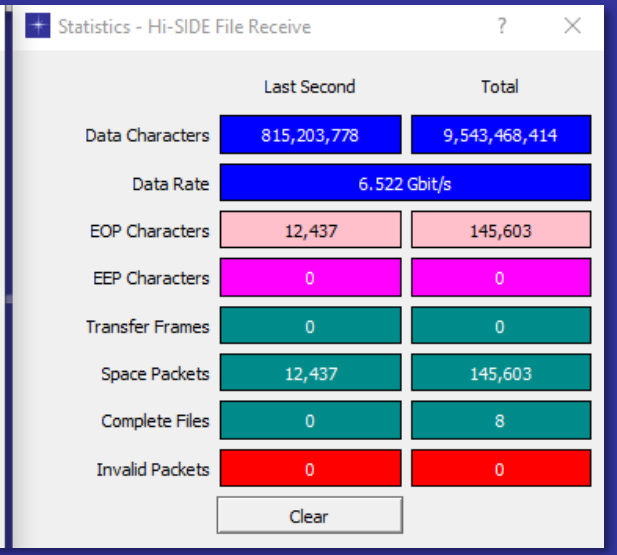
- Simultaneously storing and playing back two files in PDEP mode to two receivers at approximately 13 Gbit/s in each direction











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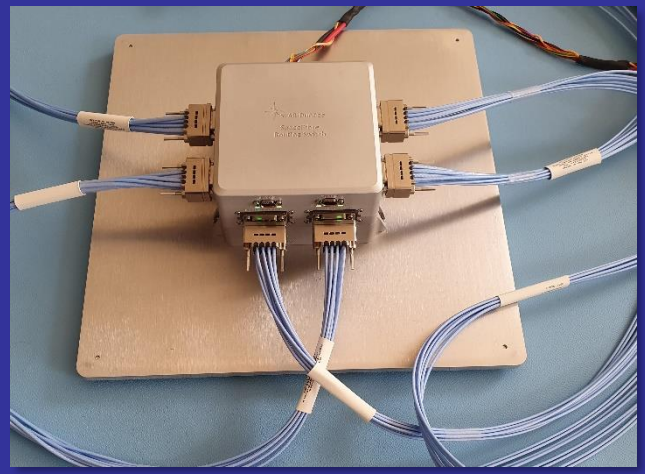
Integration and Final Demonstration



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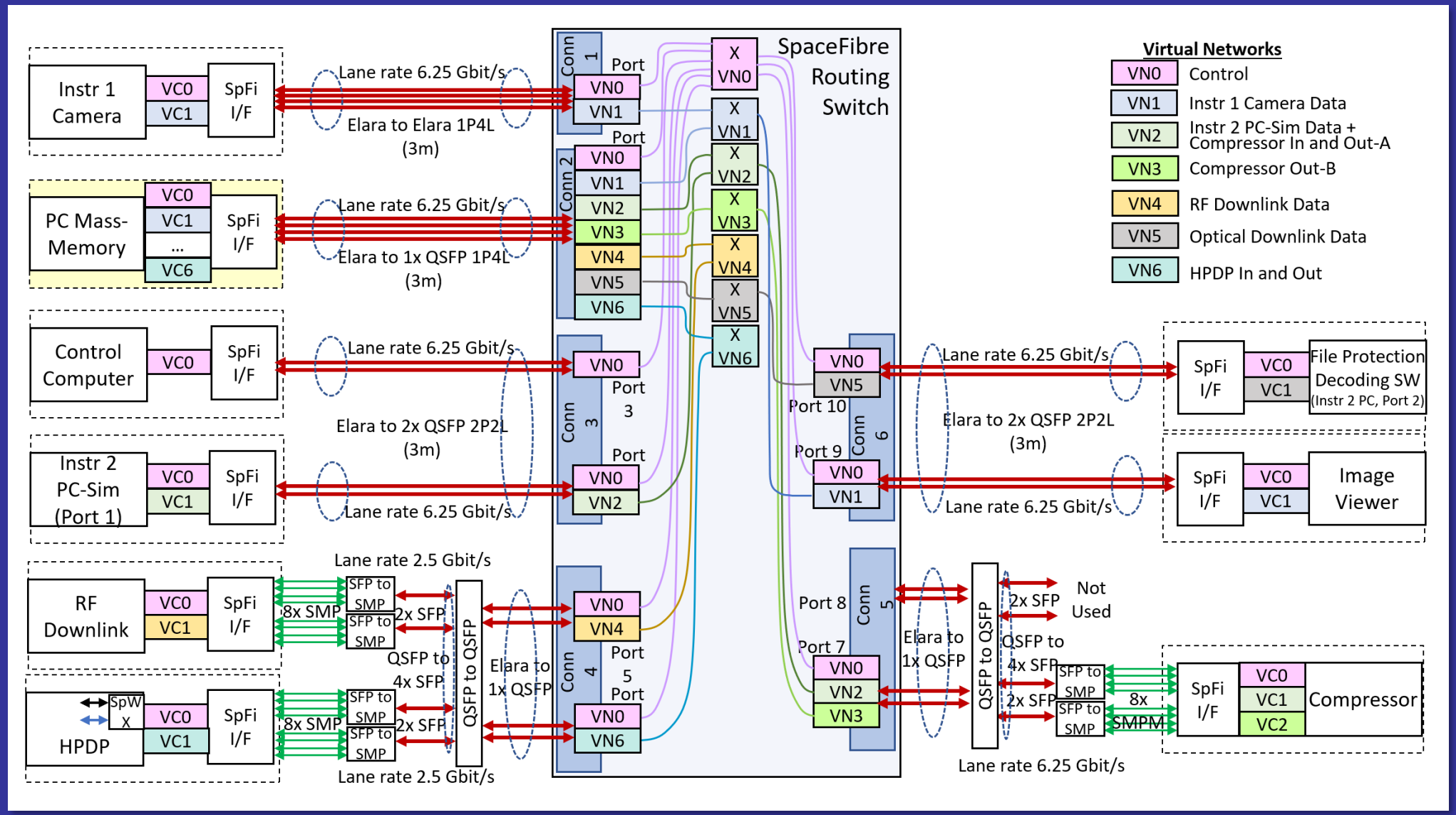
Integration and Final Demonstration



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Integration and Final Demonstration

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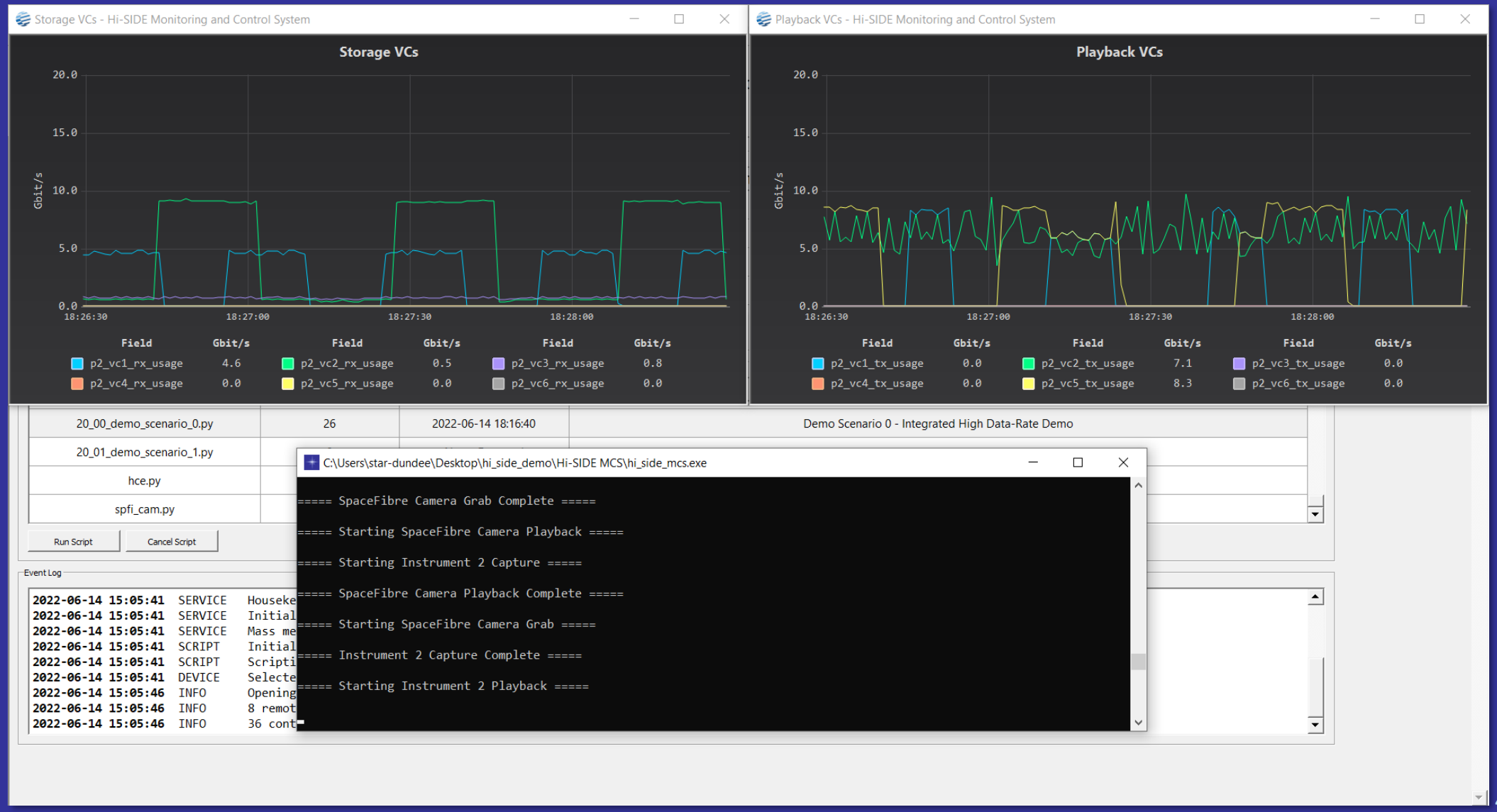
Integration and Final Demonstration



Conclusions

- Hi-SIDE was a Horizon 2020 project to develop and demonstrate technologies to enable future high-speed on-board data-handling systems
- STAR-Dundee developed software to test, control and monitor the Hi-SIDE network and systems:
  - STAR-Ultra PCIe driver and applications
  - Hi-SIDE File Transfer applications
  - Hi-SIDE Monitoring and Control System
  - Hi-SIDE PC-Based Mass-Memory
  - Additional support utilities
- Hi-SIDE integration and final demonstration took place successfully at STAR-Dundee's office in June 2022
- More information at: https://www.hi-side.space/

Any questions?