



STAR-Dundee

20 Years of Spacecraft Networking Innovation

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

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

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

Hi-SIDE Project Partners


AIRBUS

TESAT

 **STAR-Dundee**  **STAR-Barcelona**
a STAR-Dundee Company

ISD S.A.
Integrated Systems Development


ERZIA

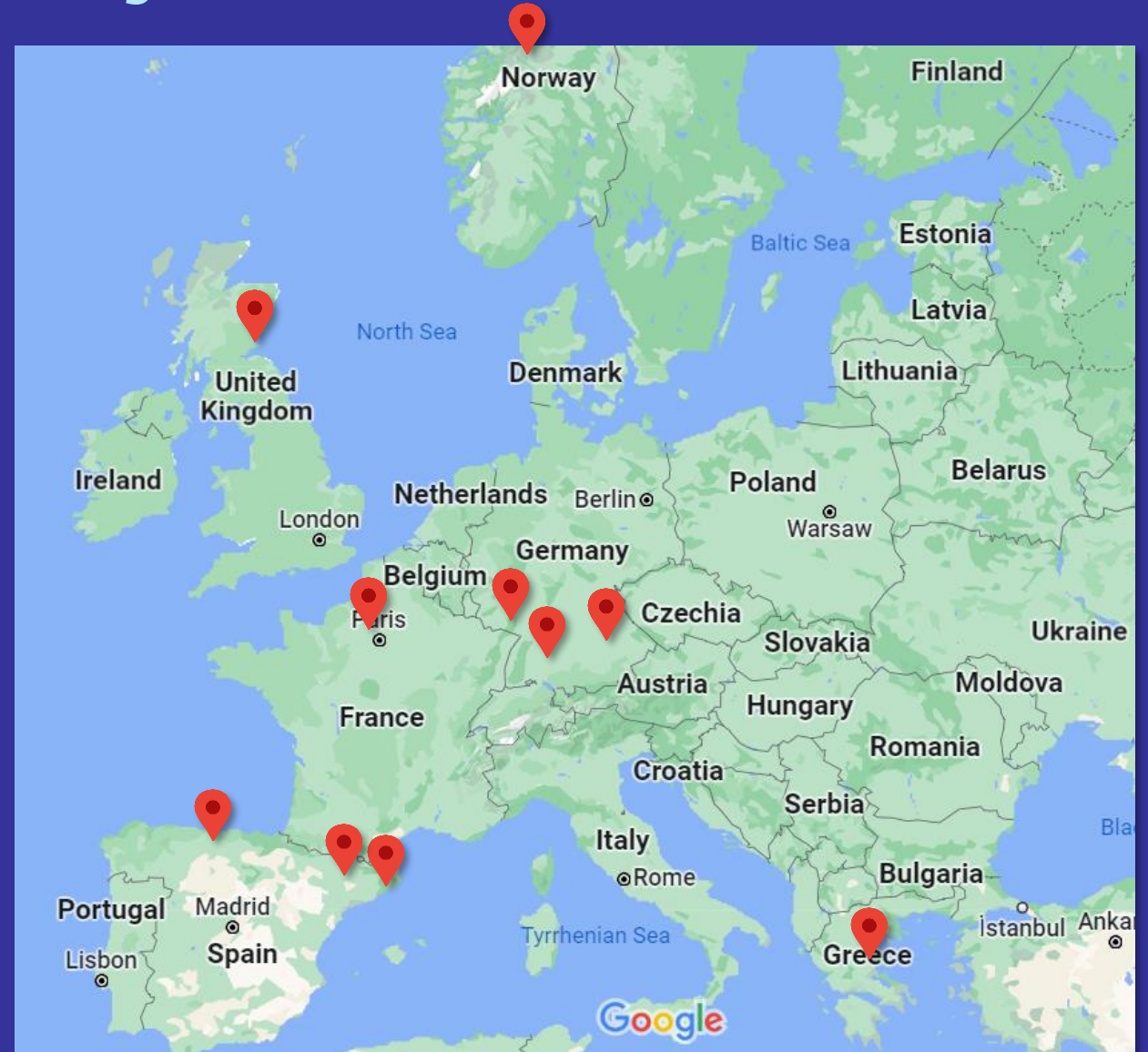
 **HELLENIC REPUBLIC**
National and Kapodistrian
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— EST. 1837 —


DLR

UAB
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de Barcelona


KONGSBERG

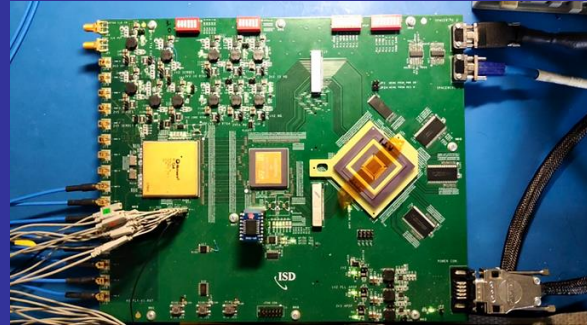

MODUS
Research and Innovation



Hi-SIDE Systems



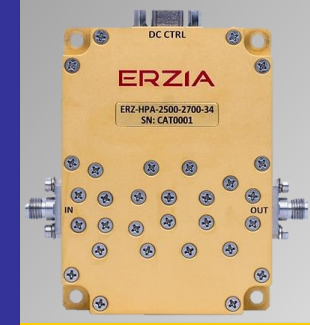
SpaceFibre Routing Switch



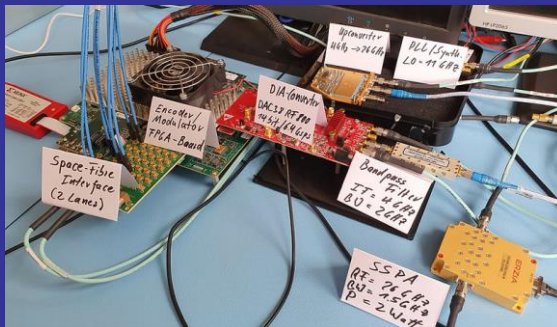
High-Performance Data Processor



Data Compression Module



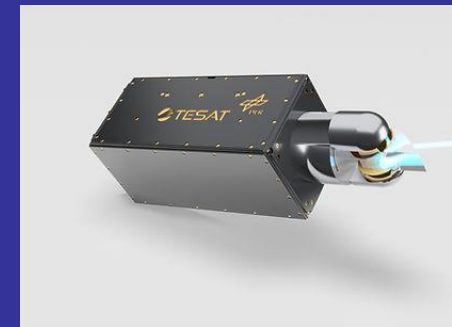
Ka-Band SSPA



RF Downlink

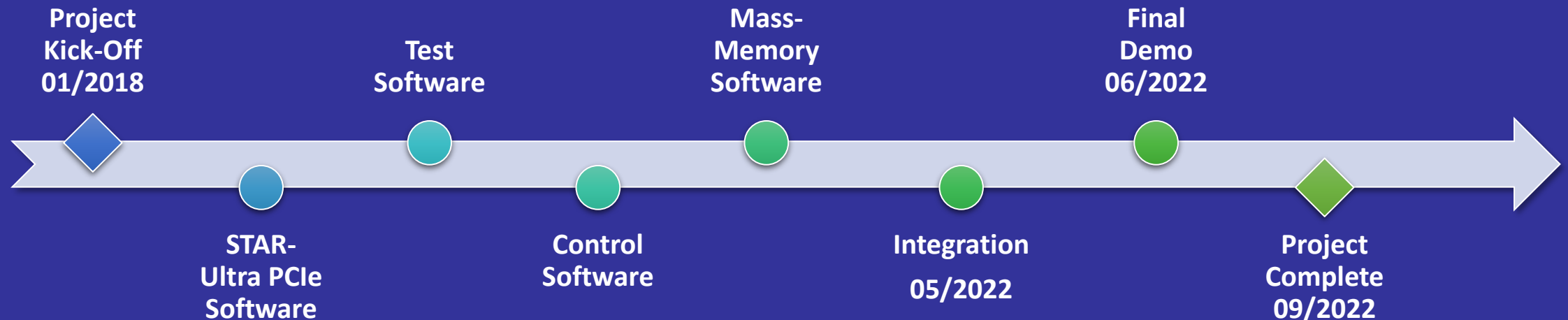


Ground Receiver



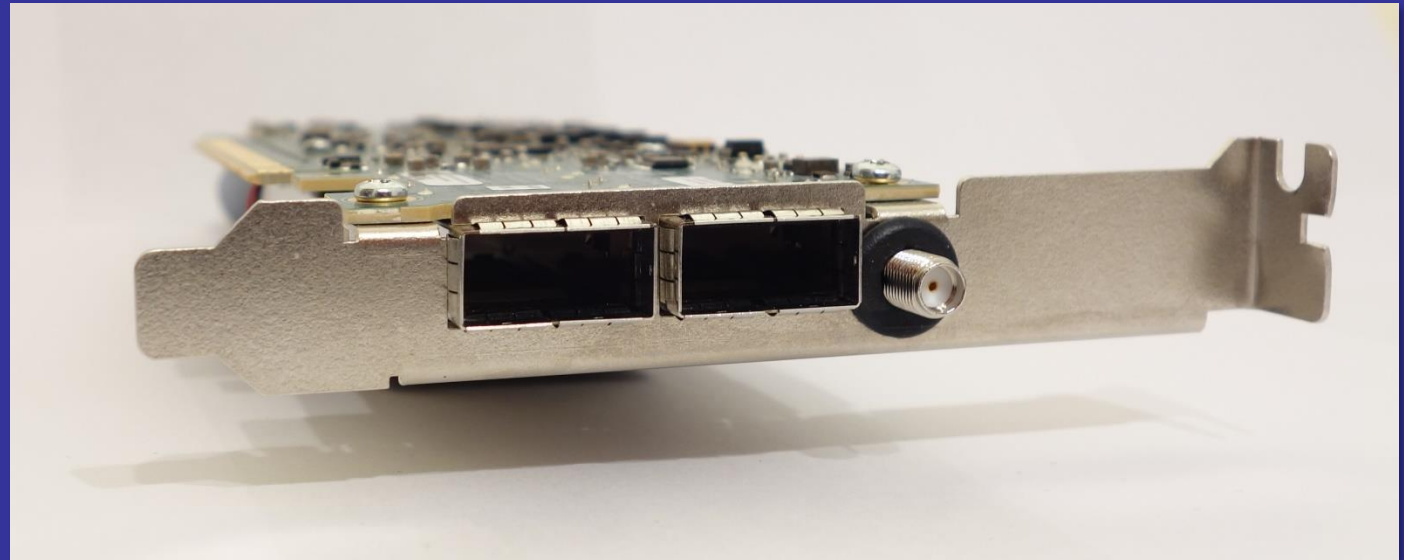
Optical Data-Link

Hi-SIDE Project Timeline



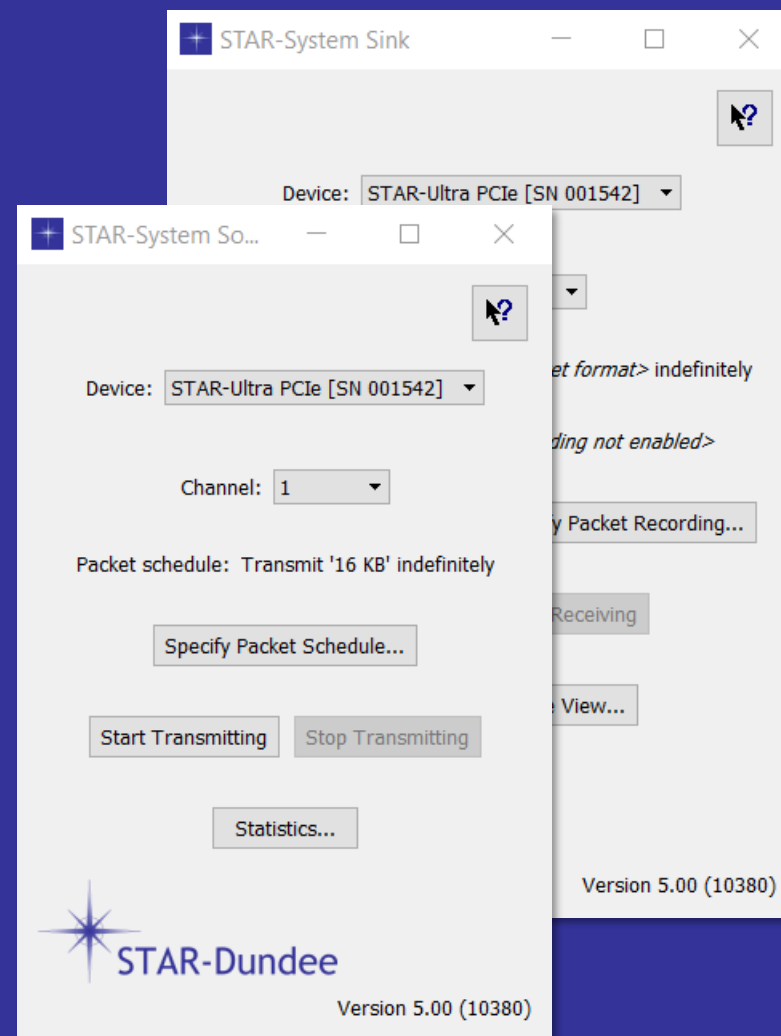
Test Equipment: STAR-Ultra PCIe

- 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

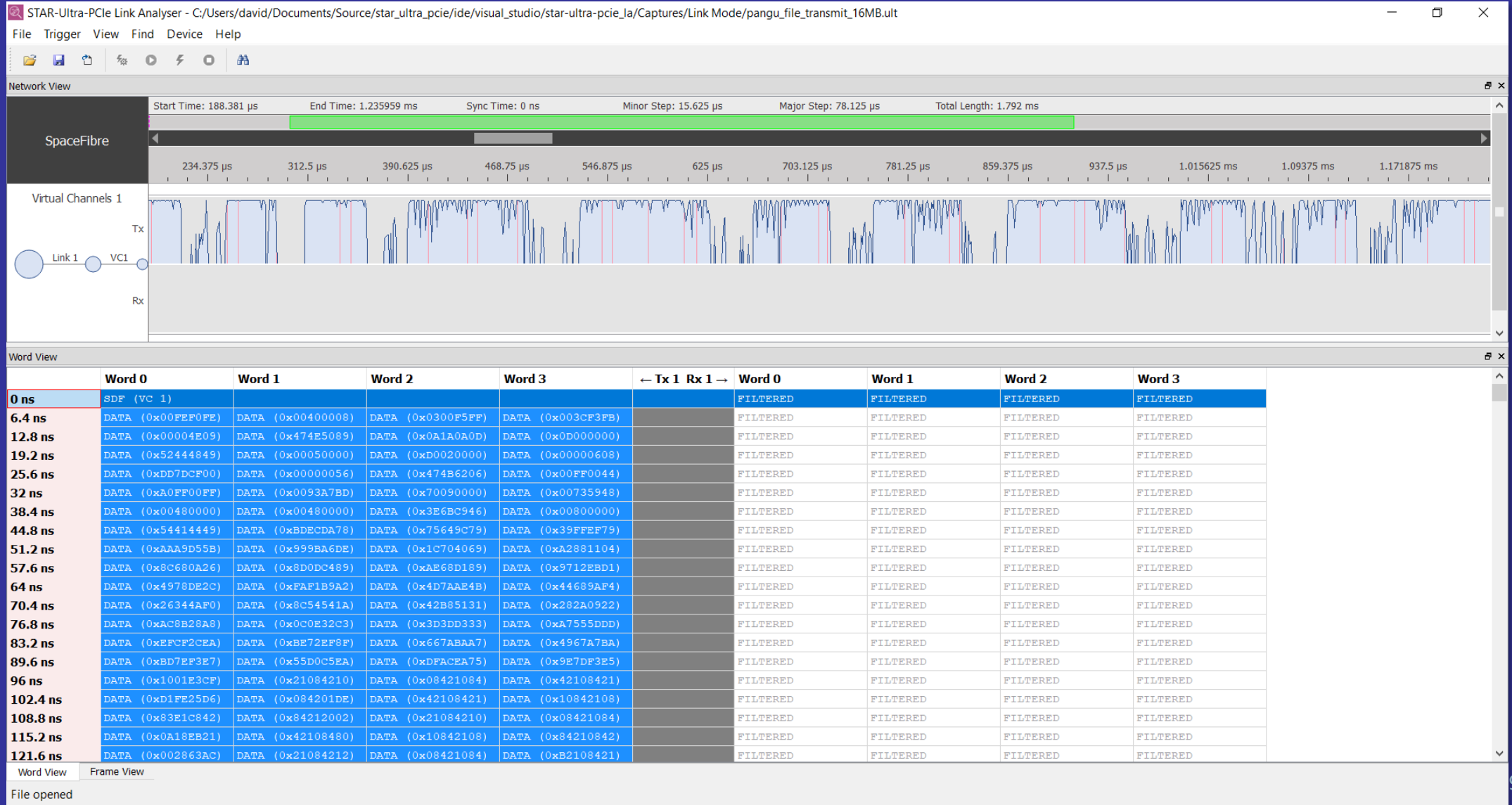


Software Support: STAR-System

- 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



Software Support: Link Analyser



Link Analyser: Word View

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

Word View									
	Word 0	Word 1	Word 2	Word 3	← Tx 1 Rx 1 →	Word 0	Word 1	Word 2	Word 3
134.4 ns	DATA (0xC88B4818)	DATA (0x8BD0FF41)	DATA (0x470EE8D8)	DATA (0xD83BFFF9)		FILTERED	FILTERED	FILTERED	FILTERED
140.8 ns	DATA (0x8B483574)	DATA (0x1402E8CF)	DATA (0x08BAFFF1)	DATA (0x48000000)		FILTERED	FILTERED	FILTERED	FILTERED
147.2 ns	DATA (0x8B4C088B)	DATA (0x8B481841)	DATA (0xD0FF41C8)	DATA (0xF86E0F66)		FILTERED	FILTERED	FILTERED	FILTERED
153.6 ns	DATA (0xFFE60FF3)	DATA (0xF946E3E8)	DATA (0x6E0F66FF)	DATA (0xE60FF3C0)		FILTERED	FILTERED	FILTERED	FILTERED
160 ns	DATA (0x5E0FF2C0)	DATA (0x4104EBF8)	DATA (0x48FC280F)	DATA (0xE8804D8D)		FILTERED	FILTERED	FILTERED	FILTERED
166.4 ns	DATA (0xFFFC4608)	DATA (0x804D8D48)	DATA (0xE8F0280F)	DATA (0x804D8D48)					FILTERED
172.8 ns	DATA (0x804D8D48)	DATA (0xF0580FF2)	DATA (0xFCA78FE8)	DATA (0x804D8D48)					FILTERED
179.2 ns	DATA (0x51DCE8C6)	DATA (0x8B480024)	DATA (0x0002989D)	DATA (0x8B480024)					FILTERED
185.6 ns	DATA (0xC02C0FF2)	DATA (0x66CB8B48)	DATA (0xF3C86E0F)	DATA (0x66CB8B48)					FILTERED
192 ns	DATA (0xFFEDB828)	DATA (0x590F41F2)	DATA (0x4D8D48C0)	DATA (0x590F41F2)					FILTERED
198.4 ns	DATA (0x91D6E8F0)	DATA (0x8B48FFFC)	DATA (0xC8280FCB)	DATA (0x8B48FFFC)					FILTERED
204.8 ns	DATA (0xFFEDB808)	DATA (0x590F41F2)	DATA (0x1049BAC0)	DATA (0x590F41F2)					FILTERED
211.2 ns	DATA (0x0F44F2CB)	DATA (0x11E8F02C)	DATA (0x83FFFCFE)	DATA (0x297402F8)		FILTERED	FILTERED	FILTERED	FILTERED
217.6 ns	DATA (0x001049BA)	DATA (0xCB8B4800)	DATA (0xFCDFFE8)	DATA (0x03F883FF)		FILTERED	FILTERED	FILTERED	FILTERED
224 ns	DATA (0x8D481774)	DATA (0x91E8804D)	DATA (0xF2FFFC91)	DATA (0xC0590F41)		FILTERED	FILTERED	FILTERED	FILTERED
230.4 ns	DATA (0xF2DF8B41)	DATA (0xEBF82C0F)	DATA (0x1049BA72)	DATA (0x8B480000)		FILTERED	FILTERED	FILTERED	FILTERED
236.8 ns	DATA (0xFE8B41CB)	DATA (0xFCFDD3E8)	DATA (0x4D8D48FF)	DATA (0x02F88380)		FILTERED	FILTERED	FILTERED	FILTERED
243.2 ns	DATA (0xE5E84575)	DATA (0x48FFFC A6)	DATA (0x0F804D8D)	DATA (0x39E8F028)		FILTERED	FILTERED	FILTERED	FILTERED
249.6 ns	DATA (0x41FFFC45)	DATA (0x8BC9280F)	DATA (0xF2D9F7CE)	DATA (0xC1CE5F0F)		FILTERED	FILTERED	FILTERED	FILTERED

Symbols

Word	Symbol 0	Symbol 1	Symbol 2	Symbol 3	Word
0	0xF2	0x0F	0x2C	0xC0	DATA (0xC02C0FF2)
1	0x48	0x8B	0xCB	0x66	DATA (0x66CB8B48)
2	0x0F	0x6E	0xC8	0xF3	DATA (0xF3C86E0F)
3	0x0F	0xE6	0xC9	0xE8	DATA (0xE8C9E60F)

Link Analyser: Frame/Packet Views

- Displays SpaceFibre frames and packets

	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)	

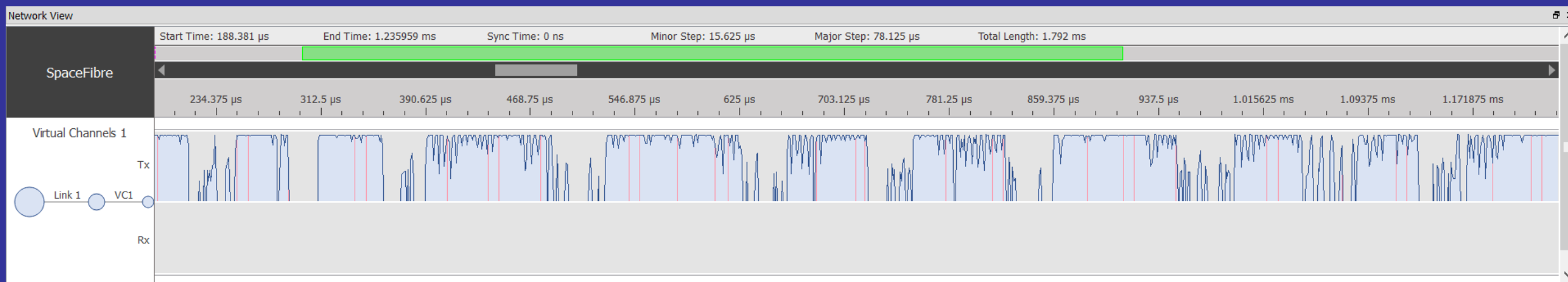
Word View Frame View Packet View

	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

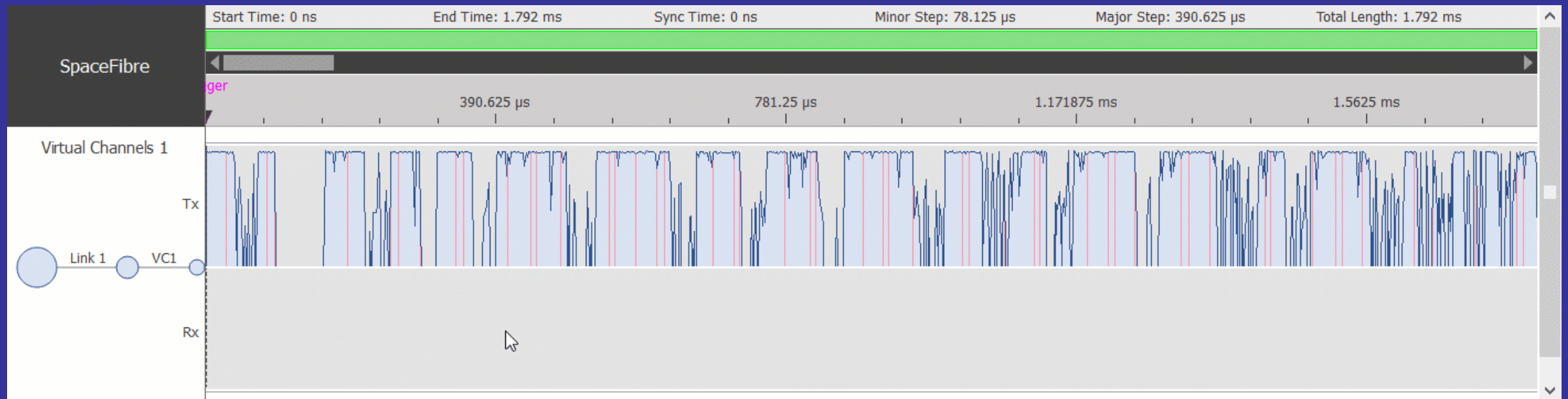
Link Analyser: Network View

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



Link Analyser: Network View

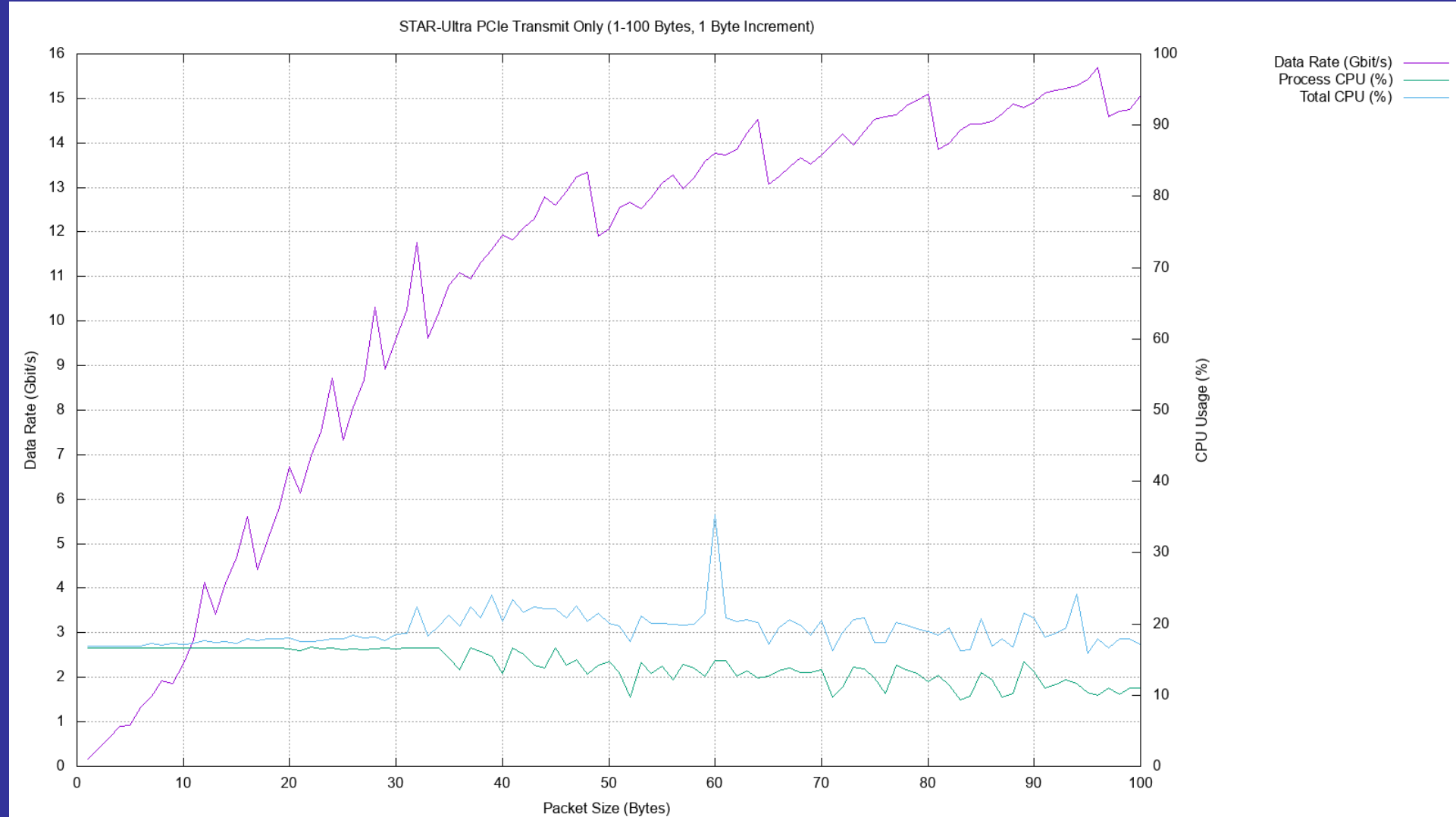
- Select a region to load in detailed traffic
- View packet boundaries



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

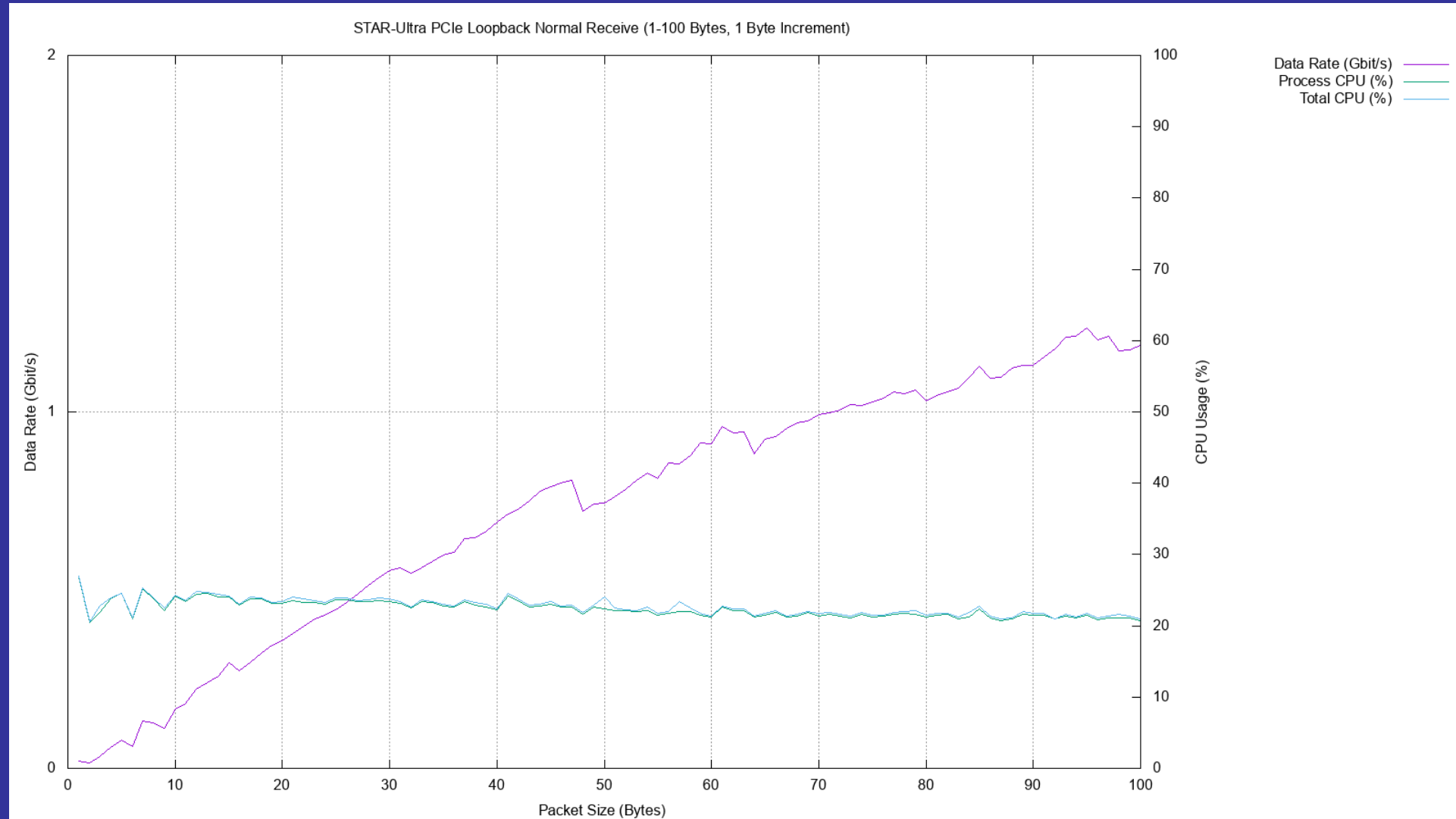
Perf. Results: Transmit Only (1-100 Bytes)



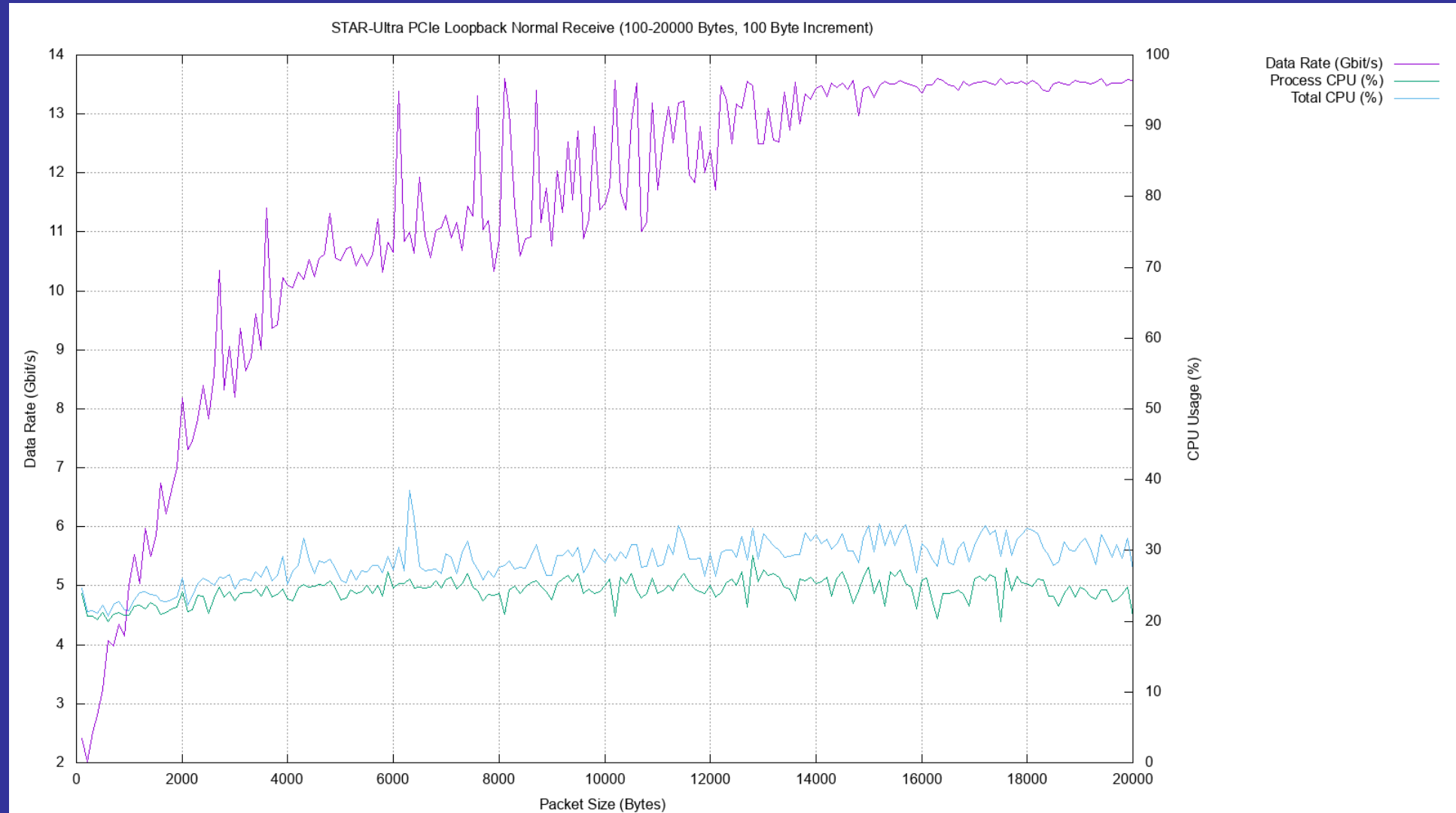
Perf. Results: Transmit Only (100-20K Bytes)



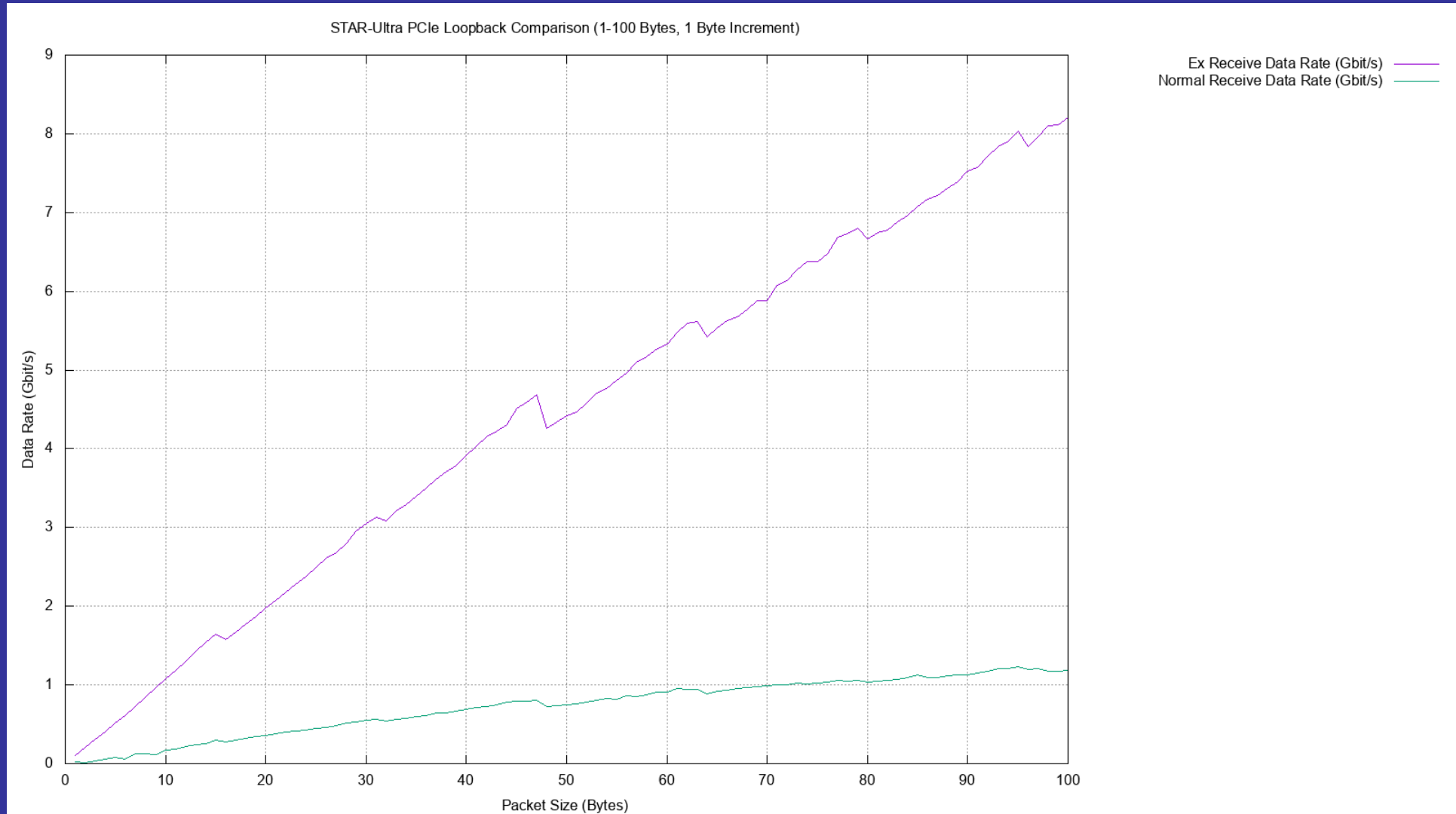
Perf. Results: Loopback Normal (1-100 Bytes)



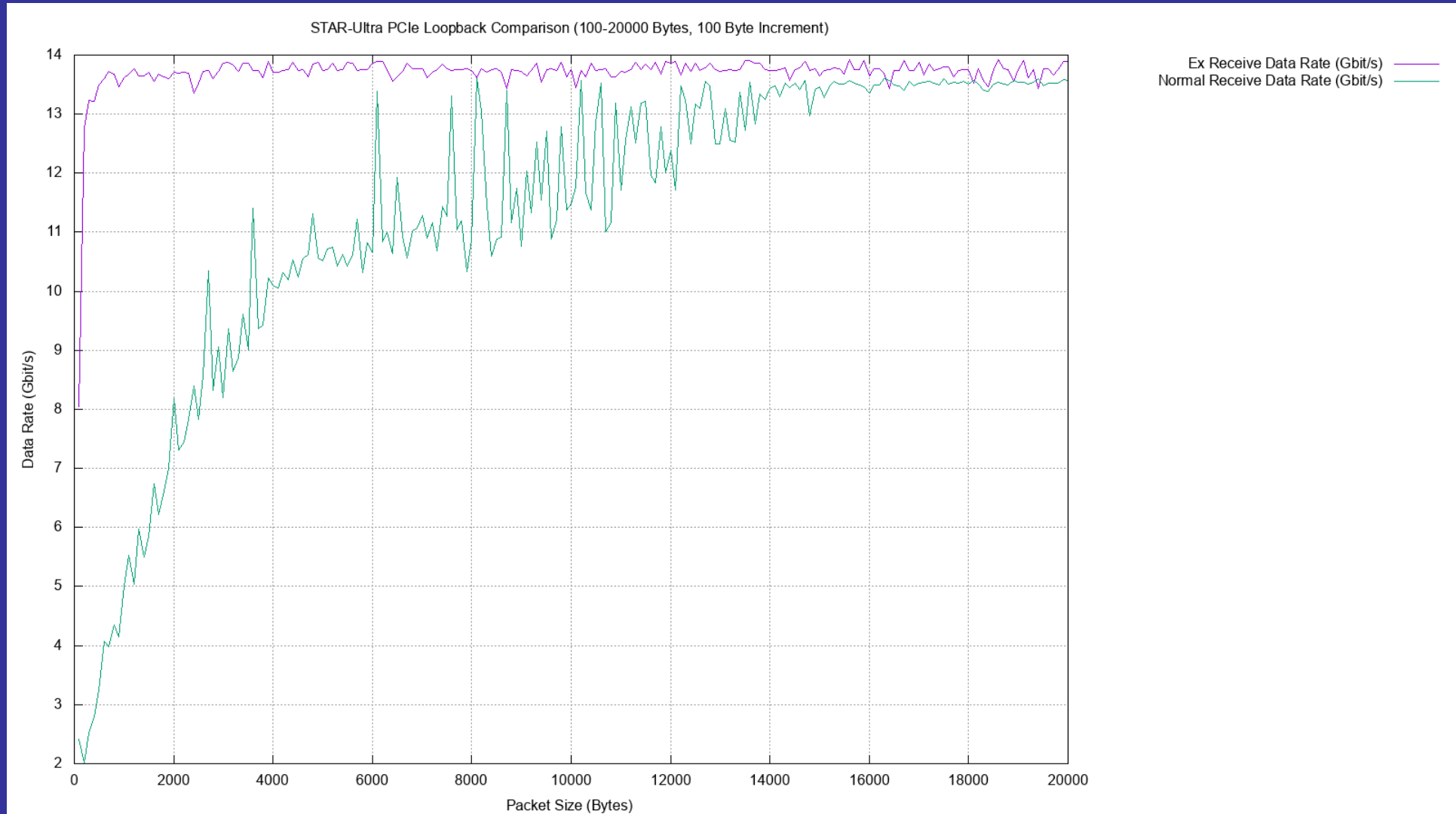
Perf. Results: Loopback Normal (100-20K Bytes)



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



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)

Test Software: CCSDS File Transfer

Hi-SIDE File Transmit

Device: STAR-Ultra PCIe [SN 001542] Channel: 1

Source Files

Browse...

	File Name	Size
1	Qt5Core.dll	6016632 Bytes
2	Qt5Gui.dll	6443640 Bytes
3	Qt5Widgets.dll	5574776 Bytes

Addresses

Target Path Address:

Target Logical Address:

Source Logical Address:

Space Packet Protocol

Application Process ID:

User Meta Data:

Encapsulation Protocol

Protocol: Payload Data Encapsulation Protocol

Space Data Link Protocol

Virtual Channel ID:

Transfer Frame Type: Real-Time Transfer Frame

Schedule

Start Transmitting Stop Transmitting Statistics...

Hi-SIDE File Receive

Device: STAR-Ultra PCIe [SN 001542] Channel: 1

Destination Directory

Browse...

File Storage

Enable Storage: ☐

Maximum Storage (MB):

File Extension:

Buffer Progress:

Start Receiving Stop Receiving Statistics...

Test Software: CCSDS File Transfer

PDEP + CCSDS Space Packet Protocol

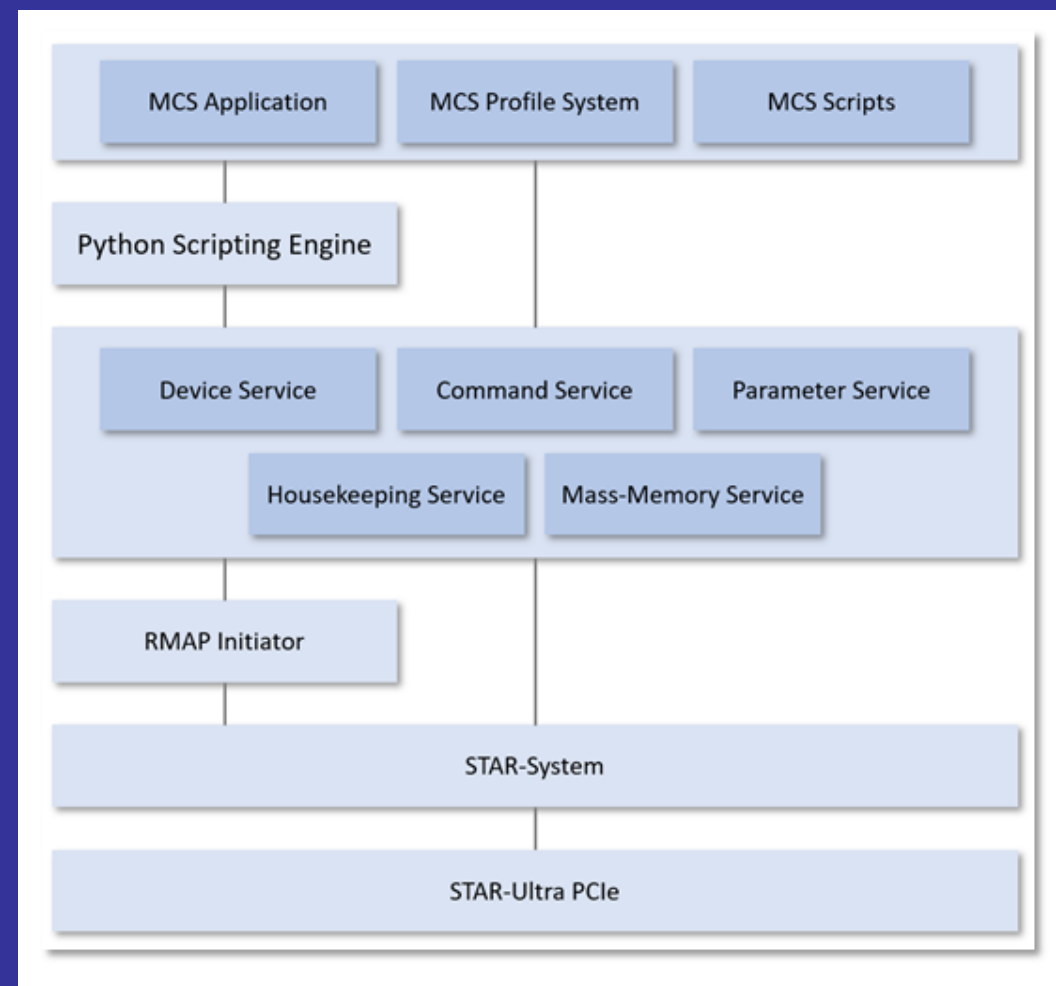
Statistics - Hi-SIDE File Receive ? X		
	Last Second	Total
Data Characters	1,727,301,144	20,857,096,478
Data Rate	13.818 Gbit/s	
EOP Characters	26,404	318,827
EEP Characters	0	0
Transfer Frames	0	0
Space Packets	26,404	318,827
Complete Files	287	3,465
Invalid Packets	0	0
Clear		

TFEP + CCSDS Transfer Frames

Statistics - Hi-SIDE File Receive ? X		
	Last Second	Total
Data Characters	1,608,482,212	22,995,764,676
Data Rate	12.868 Gbit/s	
EOP Characters	783,861	11,206,513
EEP Characters	0	0
Transfer Frames	783,861	11,206,513
Space Packets	24,437	349,372
Complete Files	266	3,797
Invalid Packets	0	0
Clear		

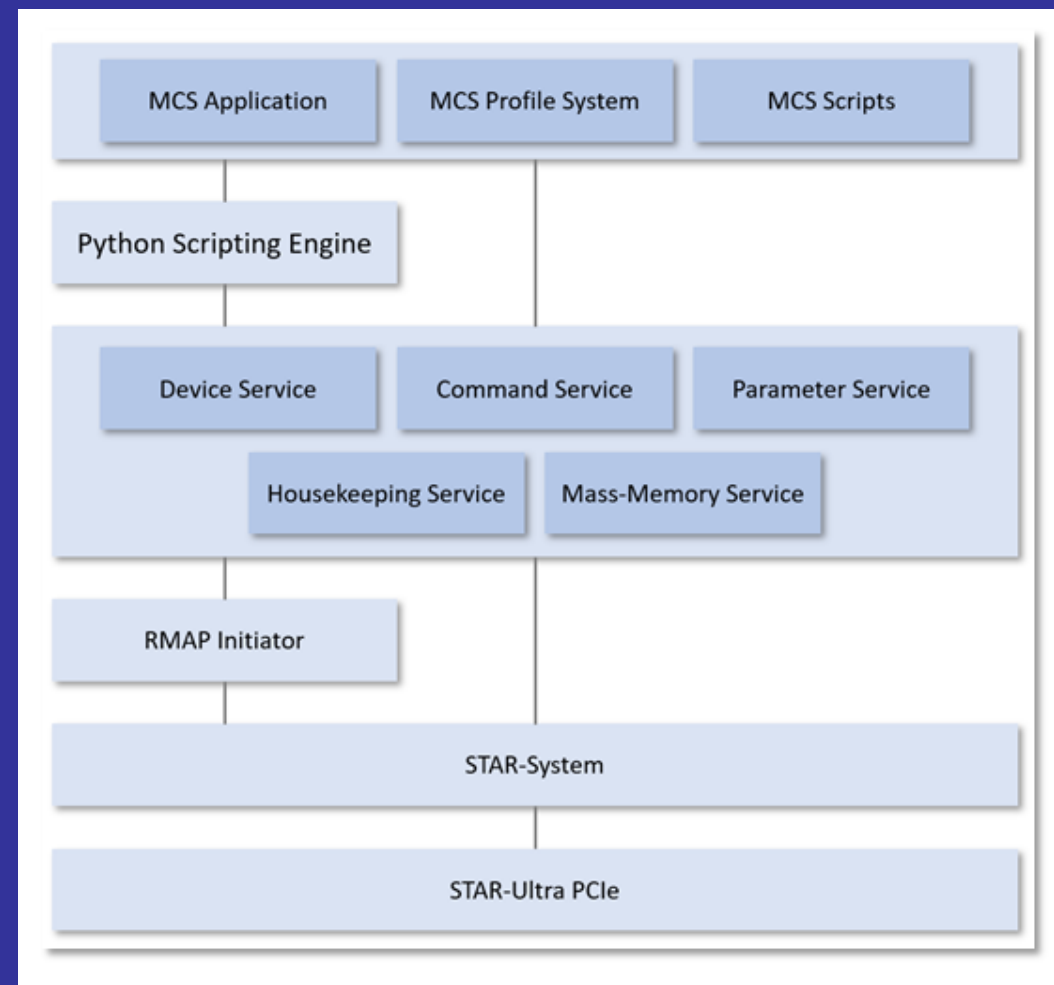
Control Software: Purpose

- 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



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



Control Software: GUI

Hi-SIDE Monitoring and Control System
File Devices Monitoring ACM Control


Control Device
STAR-Ultra PCIe [SN 001542]
Channel 0

Housekeeping
Disabled

Enable
Disable

Status
Running for 0 days, 0 hours, 41 minutes, 21 seconds, since 2022-05-19 11:52:07
Housekeeping Operations: 0, Commands Executed: 0

Local Time
12:33:28
GMT Summer Time



Remote Devices

ID	Name	Command Path	Reply Path	Key	Custom Types	Memory Areas	Registers	Fields	Buffers
0	STAR-Tiger	0x3 0x0 0xfe	0x1 0xfe	0x20	5	21	316	386	0

View Device

Control Scripts

File Name	Num. Executions	Last Executed At	Description
initial_configuration.py	0	Never Executed	Configure the STAR-Tiger's routing table and link speeds

Run Script
Cancel Script


Event Log

```

2022-05-19 11:52:07 SERVICE Housekeeping service was successfully initialised
2022-05-19 11:52:07 SERVICE Initialising mass memory controller...
2022-05-19 11:52:07 SERVICE Mass memory controller was successfully initialised
2022-05-19 11:52:07 SCRIPT Initialising scripting engine...
2022-05-19 11:52:07 SCRIPT Scripting engine was successfully initialised
2022-05-19 11:52:07 DEVICE Selected "STAR-Ultra PCIe [SN 001542]" device as the control device
2022-05-19 12:33:16 INFO Opening project "star_spfi_router.mcsproj"...
2022-05-19 12:33:16 INFO 1 remote device was found
2022-05-19 12:33:16 INFO 1 control script was found

```

Control Software: Device Information


STAR-Tiger - Hi-SIDE Monitoring and Control System

?

×

Device Information

ID: 0
Name: STAR-Tiger
Command Path: 0x3 0x0 0xfe
Reply Path: 0x1 0xfe
Key: 0x20

Memory Areas

User Types

rt_registers - 1024 bytes at 0x00004200

Register	Offset	Housekeeping	Sampling Rate				
reg_rt_la_20_entry	0x00000040	<input type="checkbox"/> Enabled	1 Hz				
Field	Bits	Shift	R/W	Type	Lower Limit	Upper Limit	Expected Value
rt_la_20_entry	32	0	Read/Write	hex	N/A	N/A	N/A
Register	Offset	Housekeeping	Sampling Rate				
reg_rt_la_20_flags	0x00000041	<input type="checkbox"/> Enabled	1 Hz				
Field	Bits	Shift	R/W	Type	Lower Limit	Upper Limit	Expected Value
rt_la_20_flags	32	0	Read/Write	hex	N/A	N/A	N/A
Register	Offset	Housekeeping	Sampling Rate				
reg_rt_la_30_entry	0x00000060	<input type="checkbox"/> Enabled	1 Hz				
Field	Bits	Shift	R/W	Type	Lower Limit	Upper Limit	Expected Value
rt_la_30_entry	32	0	Read/Write	hex	N/A	N/A	N/A
Register	Offset	Housekeeping	Sampling Rate				
reg_rt_la_30_flags	0x00000061	<input type="checkbox"/> Enabled	1 Hz				
Field	Bits	Shift	R/W	Type	Lower Limit	Upper Limit	Expected Value
rt_la_30_flags	32	0	Read/Write	hex	N/A	N/A	N/A
Register	Offset	Housekeeping	Sampling Rate				
reg_rt_la_40_entry	0x00000080	<input type="checkbox"/> Enabled	1 Hz				
Field	Bits	Shift	R/W	Type	Lower Limit	Upper Limit	Expected Value
rt_la_40_entry	32	0	Read/Write	hex	N/A	N/A	N/A

Save

Close

Control Software: Monitoring

Create Line Chart - Hi-SIDE Monitoring and Control System

Chart Title: Port 2 Throughput (Tx)

Unit (Y Axis): Gbit/s

Minimum Value: 0

Step Value: 5

Limit Checking

Enabled: ☐

Lower Limit:

Upper Limit:

Series

Series	Device	Field
0	STAR-Tiqer	p2_vc0_tx_usage
1	STAR-Tiqer	p2_vc1_tx_usage
2	STAR-Tiqer	p2_vc2_tx_usage
3	STAR-Tiqer	p2_vc3_tx_usage
4		
5		
6		
7		

Create Close

Create Table - Hi-SIDE Monitoring and Control System

Title: SpaceFibre Link Errors

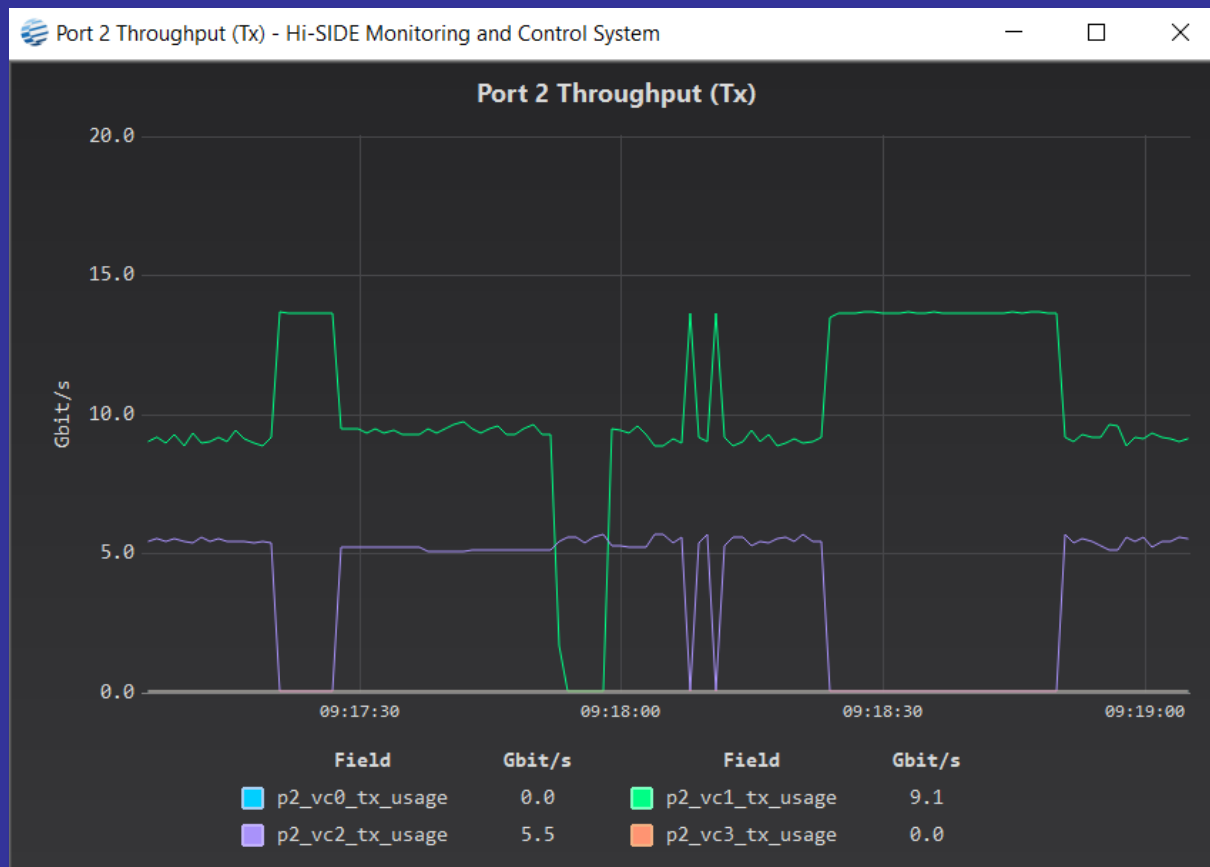
Device: STAR-Tiqer

Fields

Field	Register	Register	Register	Register
rt_la_80_entry	reg_rt_la_80_entry	rt_registers	<input type="checkbox"/>	
rt_la_80_flags	reg_rt_la_80_flags	rt_registers	<input type="checkbox"/>	
rt_la_84_entry	reg_rt_la_84_entry	rt_registers	<input type="checkbox"/>	
rt_la_84_flags	reg_rt_la_84_flags	rt_registers	<input type="checkbox"/>	
p1_vc_err	reg_p1_vc_err	p1_registers	<input type="checkbox"/>	
p1_ctrl	reg_p1_ctrl	p1_registers	<input type="checkbox"/>	
p1_link_rdy	reg_p1_stat	p1_registers	<input type="checkbox"/>	
p1_link_err	reg_p1_stat	p1_registers	<input checked="" type="checkbox"/>	
p1_link_state	reg_p1_stat	p1_registers	<input type="checkbox"/>	
p1_event_err	reg_p1_events	p1_registers	<input type="checkbox"/>	
p1_retry_count	reg_p1_events	p1_registers	<input type="checkbox"/>	
p1_debug	reg_p1_debug	p1_registers	<input type="checkbox"/>	
p1_active_lanes	reg_p1_active_lanes	p1_registers	<input type="checkbox"/>	
p1_in0_ctrl	reg_p1_in0_ctrl	p1_registers	<input type="checkbox"/>	
p1_in0_stat	reg_p1_in0_stat	p1_registers	<input type="checkbox"/>	
p1_in0_rxerr_count	reg_p1_in0_events	p1_registers	<input type="checkbox"/>	
p1_in1_ctrl	reg_p1_in1_ctrl	p1_registers	<input type="checkbox"/>	
p1_in1_stat	reg_p1_in1_stat	p1_registers	<input type="checkbox"/>	
p1_in1_err_count	reg_p1_in1_events	p1_registers	<input type="checkbox"/>	

Select All Deselect All Create Close

Control Software: Monitoring

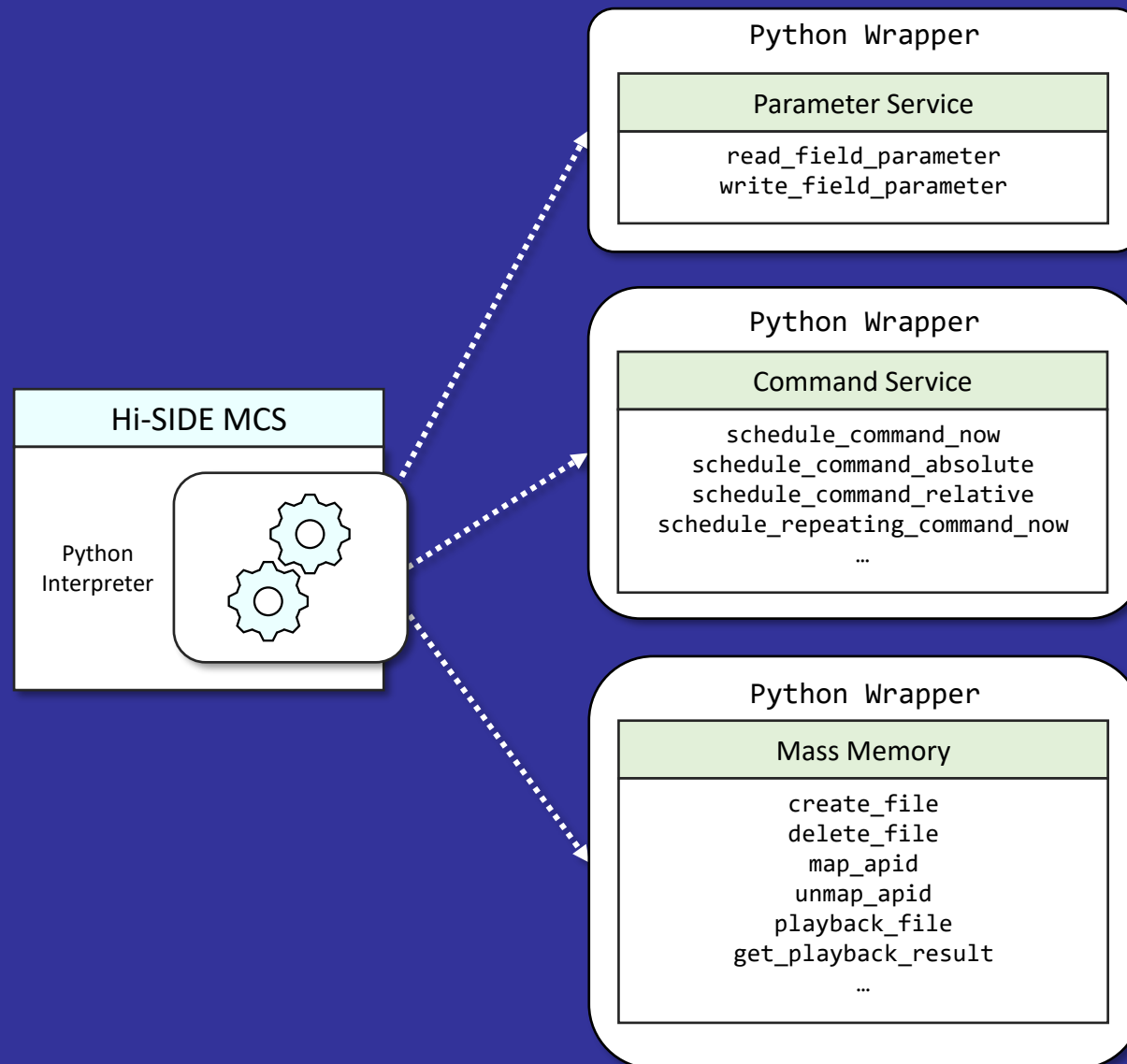


SpaceFibre Link Errors - Hi-SIDE Monitoring and Control System

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

Control Software: Scripting

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



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 *****
```

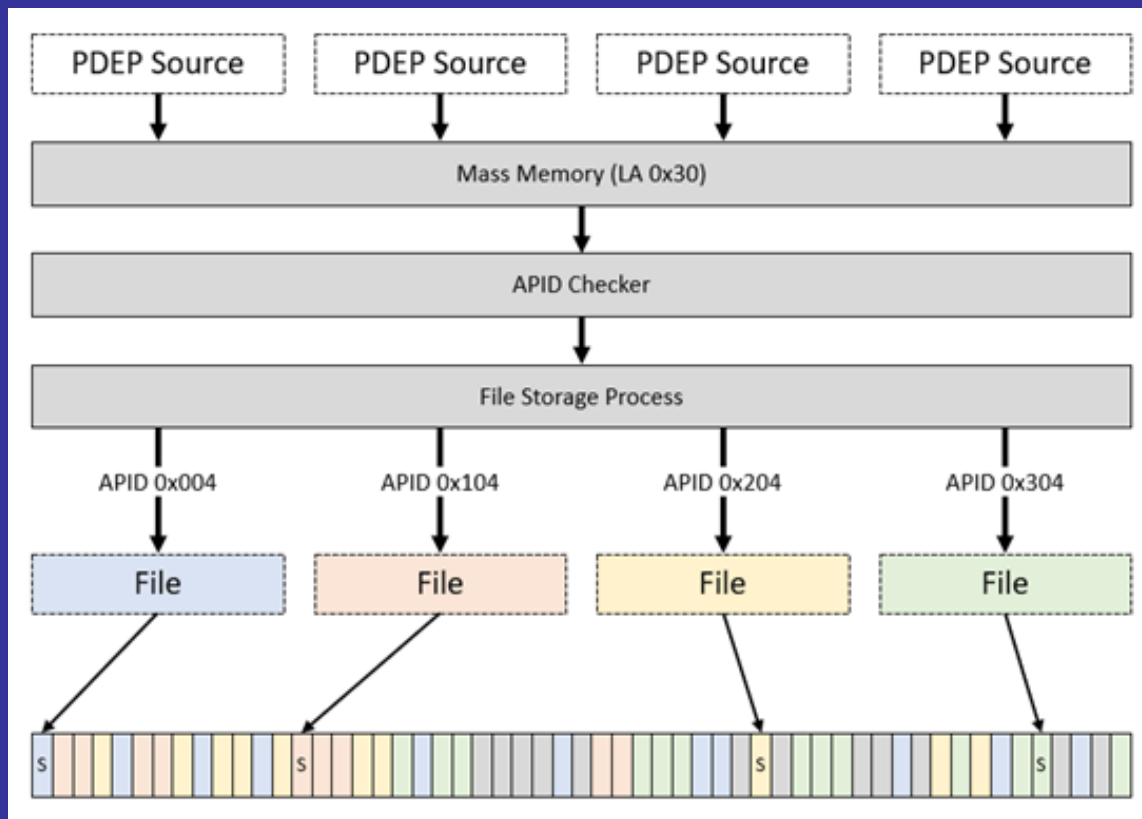

Mass-Memory Software

- 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

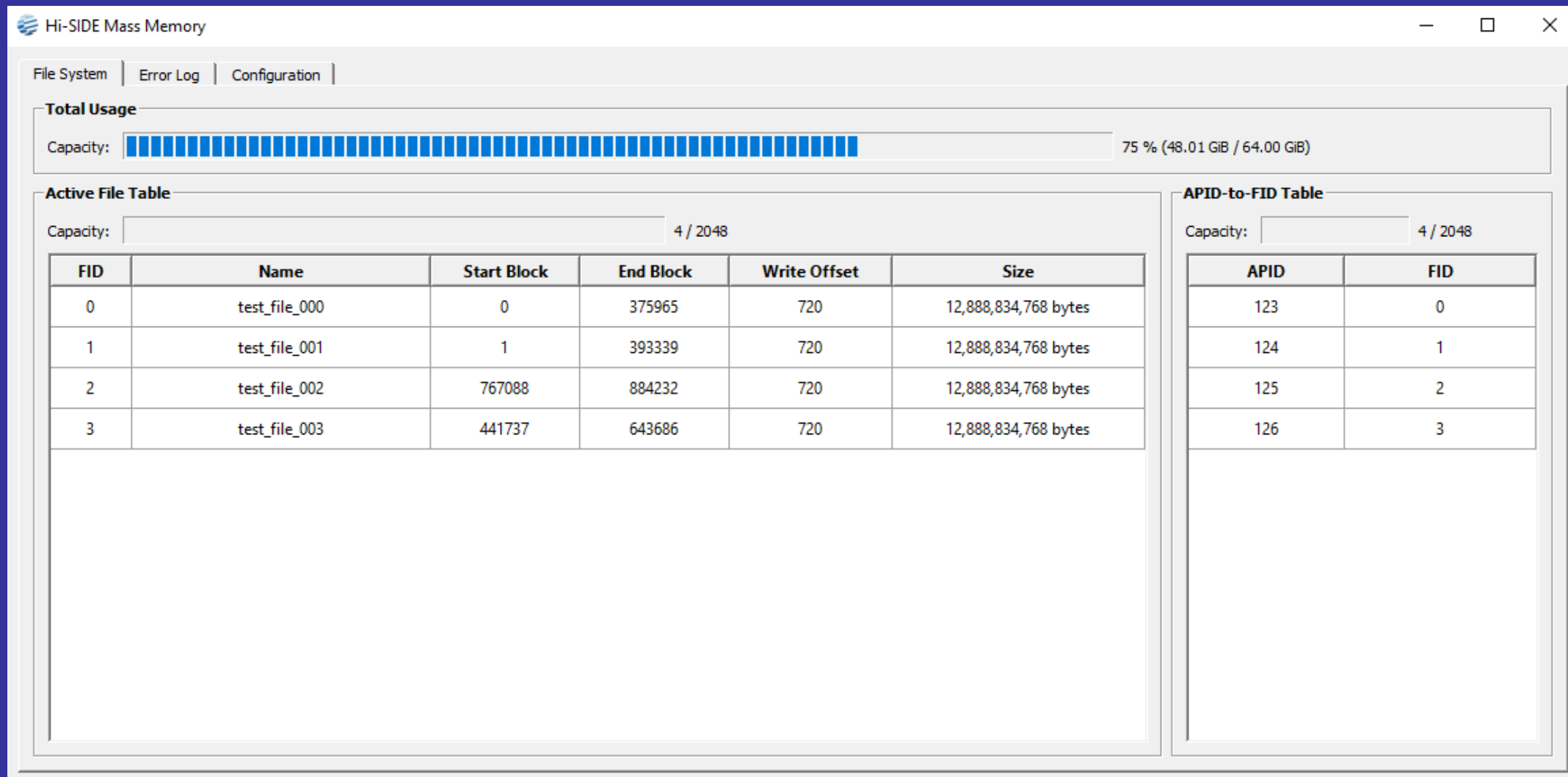


Mass-Memory Software

- 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

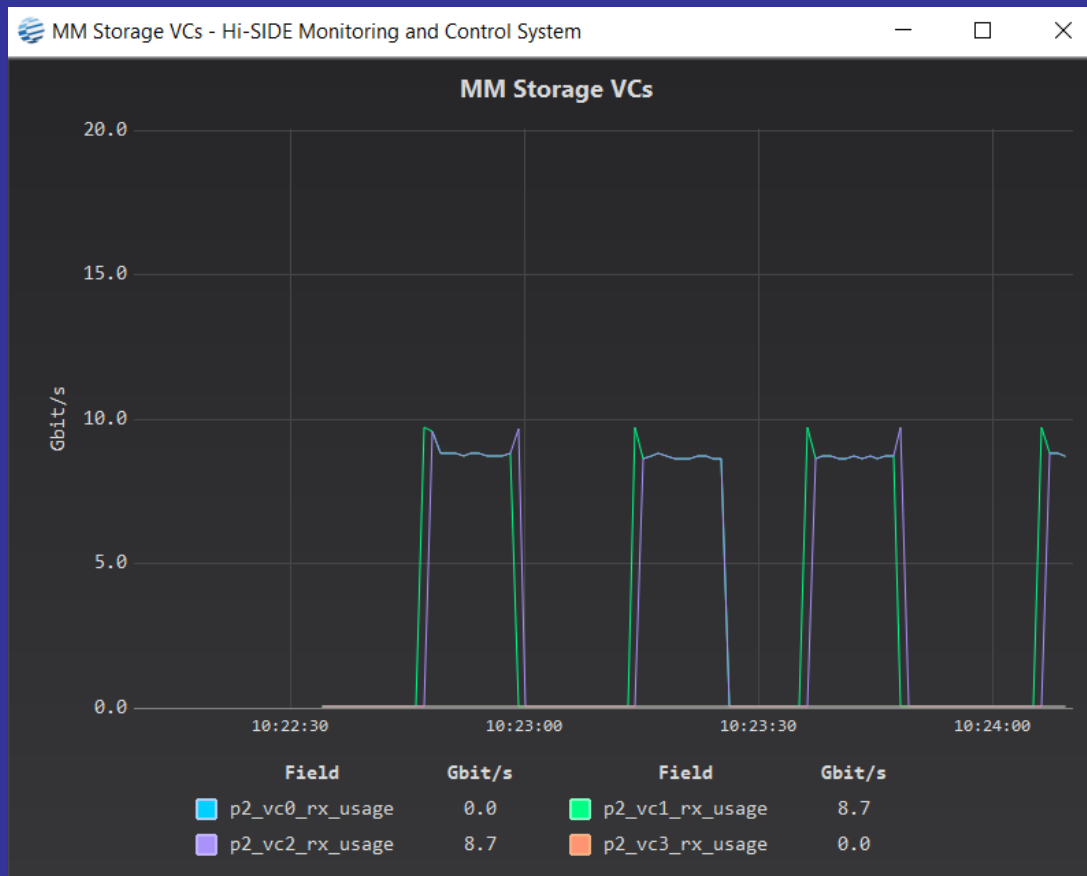


Mass-Memory Software



Mass-Memory Software: Performance

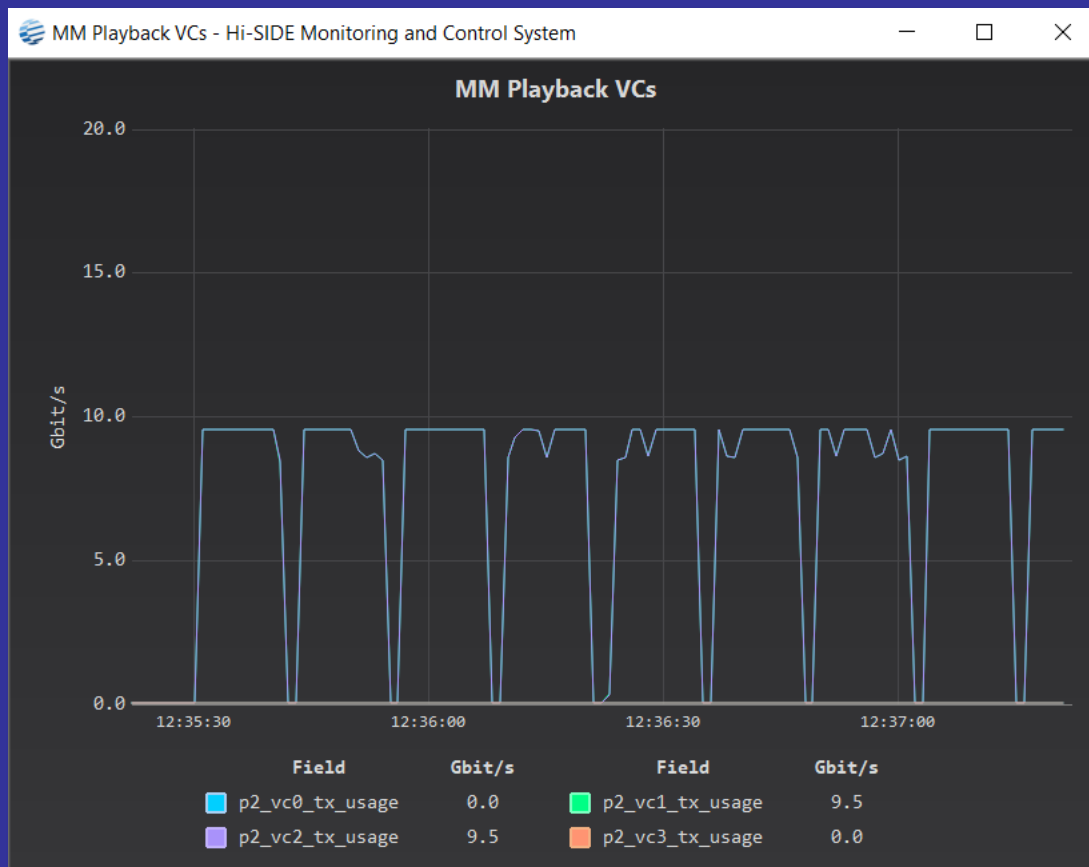
- Storing two files from two PDEP sources at approximately 8.5 Gbit/s on two VCs (17 Gbit/s total)



Statistics - Hi-SIDE File Transmit			Statistics - Hi-SIDE File Transmit		
	Last Second	Total		Last Second	Total
Data Characters	1,082,459,452	7,627,555,492	Data Characters	1,069,874,620	6,738,063,464
Data Rate	8.660 Gbit/s		Data Rate	8.559 Gbit/s	
EOP Characters	16,515	116,373	EOP Characters	16,323	102,802
Clear			Clear		

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)

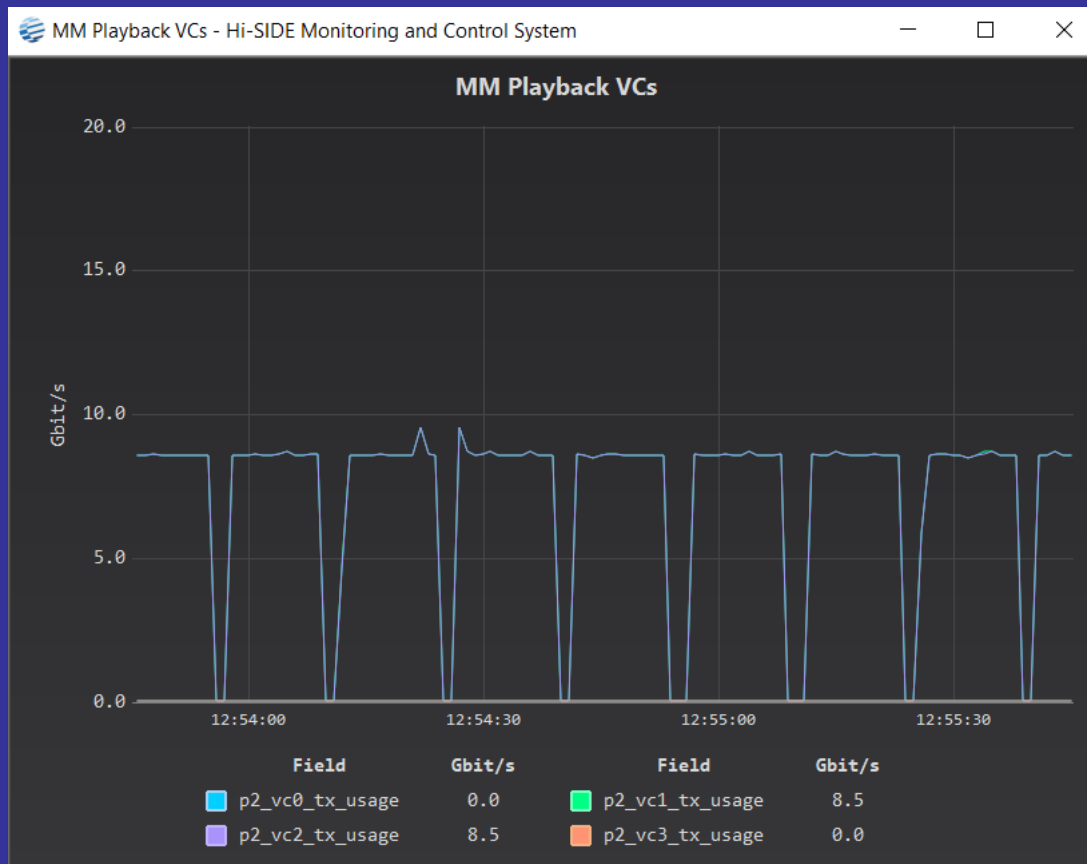


Statistics - Hi-SIDE File Receive		
	Last Second	Total
Data Characters	1,210,003,952	112,372,619,752
Data Rate	9.680 Gbit/s	
EOP Characters	18,461	1,714,460
EEP Characters	0	0
Transfer Frames	0	0
Space Packets	18,461	1,714,460
Complete Files	1	104
Invalid Packets	0	0
Clear		

Statistics - Hi-SIDE File Receive		
	Last Second	Total
Data Characters	1,209,537,274	112,370,755,120
Data Rate	9.676 Gbit/s	
EOP Characters	18,454	1,714,432
EEP Characters	0	0
Transfer Frames	0	0
Space Packets	18,454	1,714,432
Complete Files	1	104
Invalid Packets	0	0
Clear		

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)

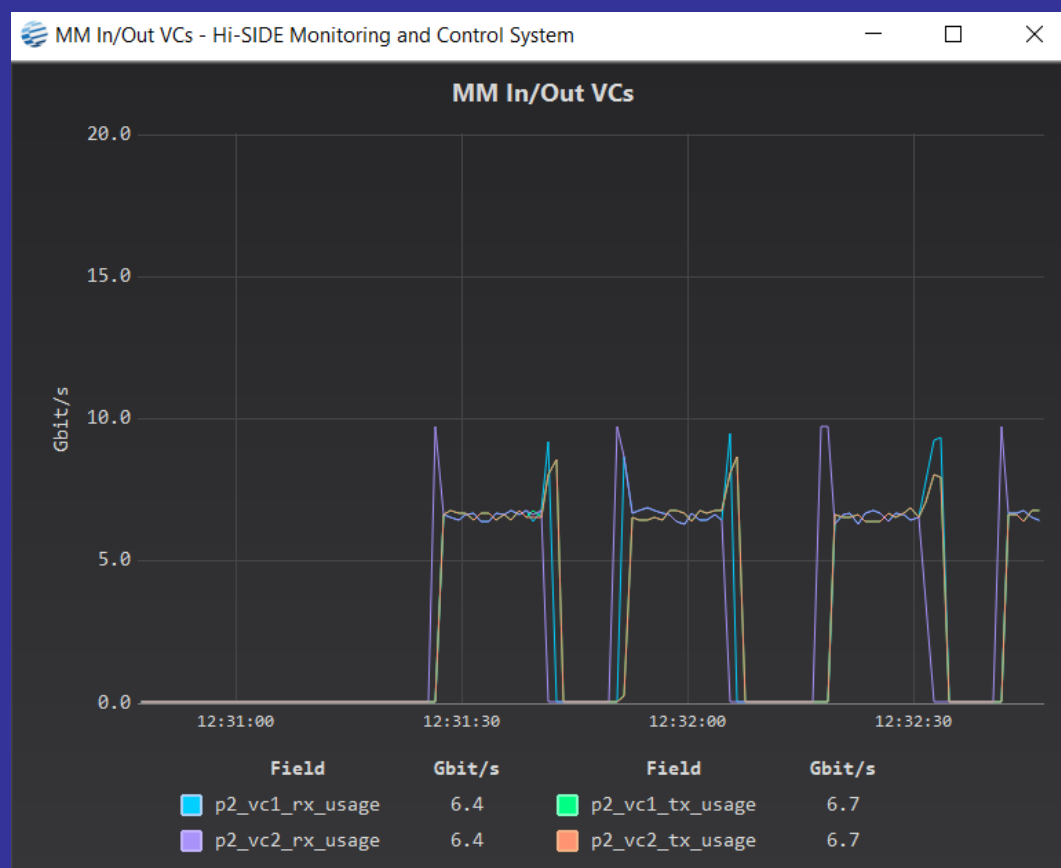


Statistics - Hi-SIDE File Receive		
	Last Second	Total
Data Characters	1,065,496,896	58,208,761,836
Data Rate	8.524 Gbit/s	
EOP Characters	519,248	28,366,843
EEP Characters	0	0
Transfer Frames	519,248	28,366,843
Space Packets	15,735	859,626
Complete Files	1	52
Invalid Packets	0	0
	Clear	

Statistics - Hi-SIDE File Receive		
	Last Second	Total
Data Characters	1,065,351,204	58,207,358,268
Data Rate	8.523 Gbit/s	
EOP Characters	519,177	28,366,159
EEP Characters	0	0
Transfer Frames	519,176	28,366,158
Space Packets	15,733	859,605
Complete Files	1	52
Invalid Packets	0	0
	Clear	

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



Statistics - Hi-SIDE File Transmit

	Last Second	Total
Data Characters	801,234,304	11,650,998,488
Data Rate	6.410 Gbit/s	
EOP Characters	12,224	177,758
<button>Clear</button>		

Statistics - Hi-SIDE File Transmit

	Last Second	Total
Data Characters	818,014,080	12,670,533,780
Data Rate	6.544 Gbit/s	
EOP Characters	12,480	193,313
<button>Clear</button>		

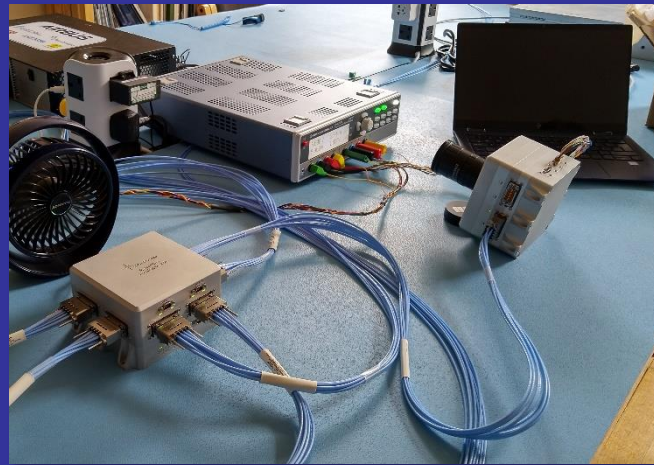
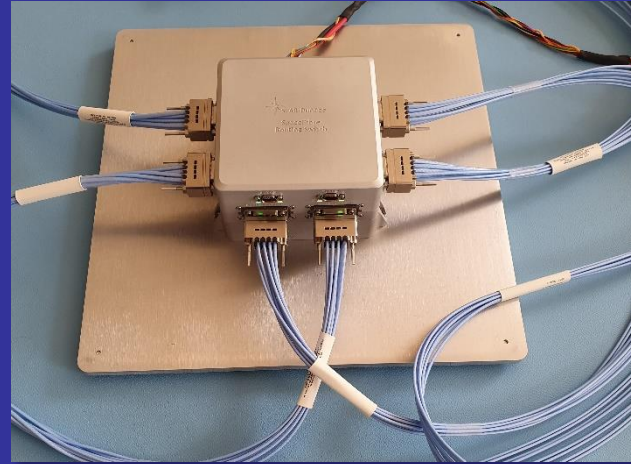
Statistics - Hi-SIDE File Receive

	Last Second	Total
Data Characters	815,216,130	9,543,932,532
Data Rate	6.522 Gbit/s	
EOP Characters	12,437	145,610
EEP Characters	0	0
Transfer Frames	0	0
Space Packets	12,437	145,610
Complete Files	0	8
Invalid Packets	0	0
<button>Clear</button>		

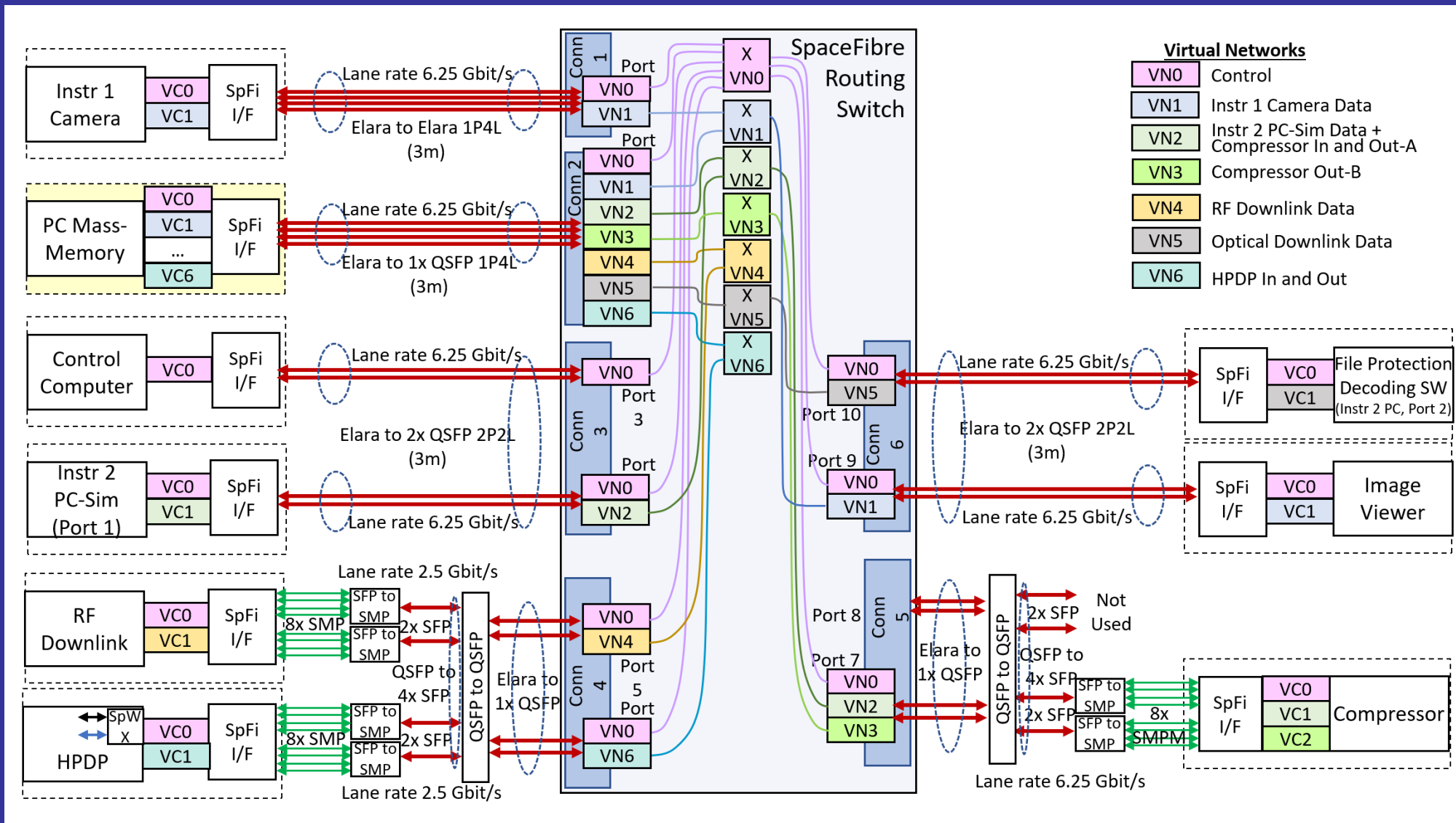
Statistics - Hi-SIDE File Receive

	Last Second	Total
Data Characters	815,203,778	9,543,468,414
Data Rate	6.522 Gbit/s	
EOP Characters	12,437	145,603
EEP Characters	0	0
Transfer Frames	0	0
Space Packets	12,437	145,603
Complete Files	0	8
Invalid Packets	0	0
<button>Clear</button>		

Integration and Final Demonstration



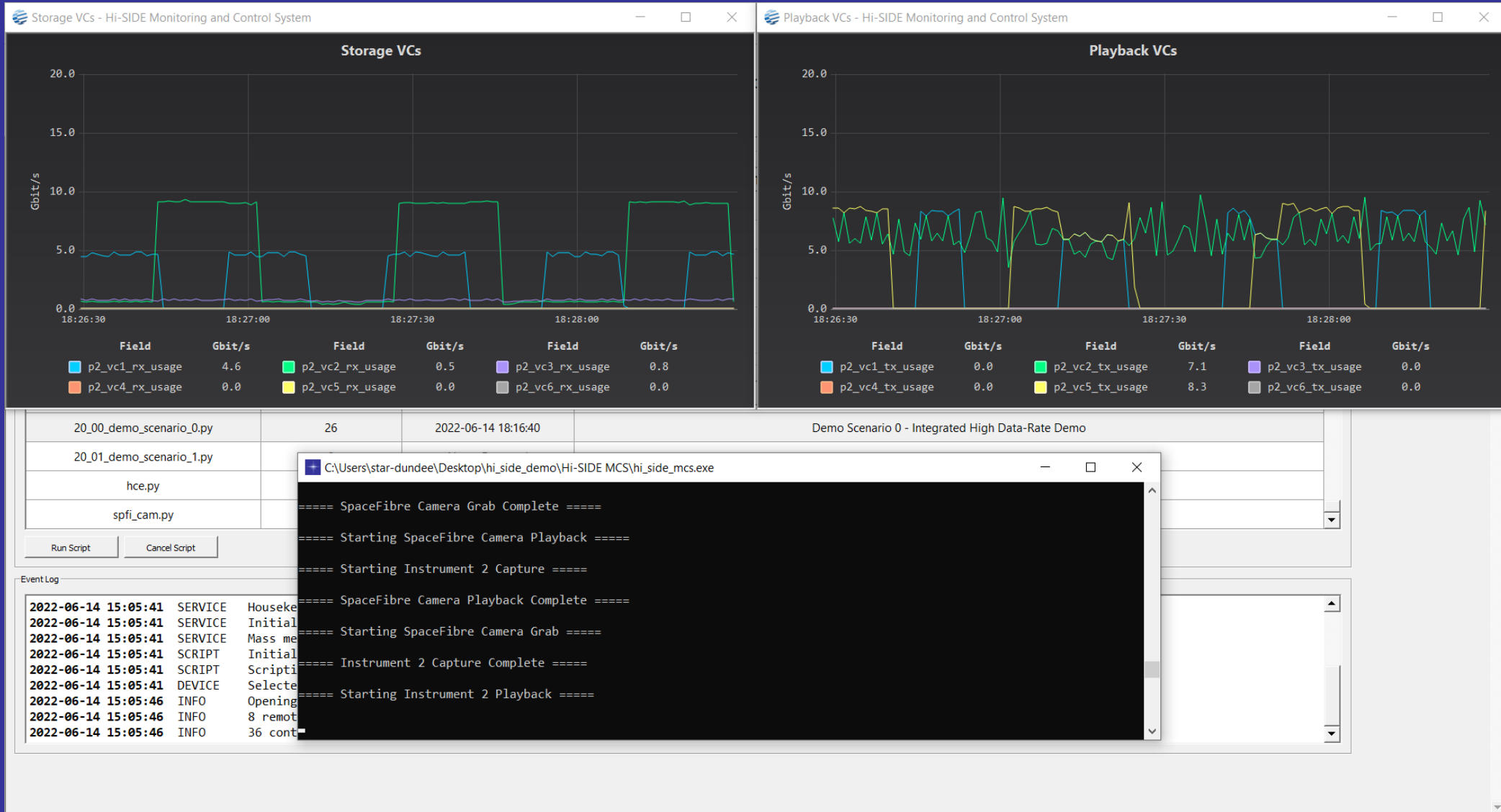
Integration and Final Demonstration



Integration and Final Demonstration



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?