STAR-Dundee

SpaceWire Technologies deliver multi-gigabit data rates for on-board Spacecraft

SpaceTech Expo 2013

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STAR-Dundee

Introducing SpaceFibre

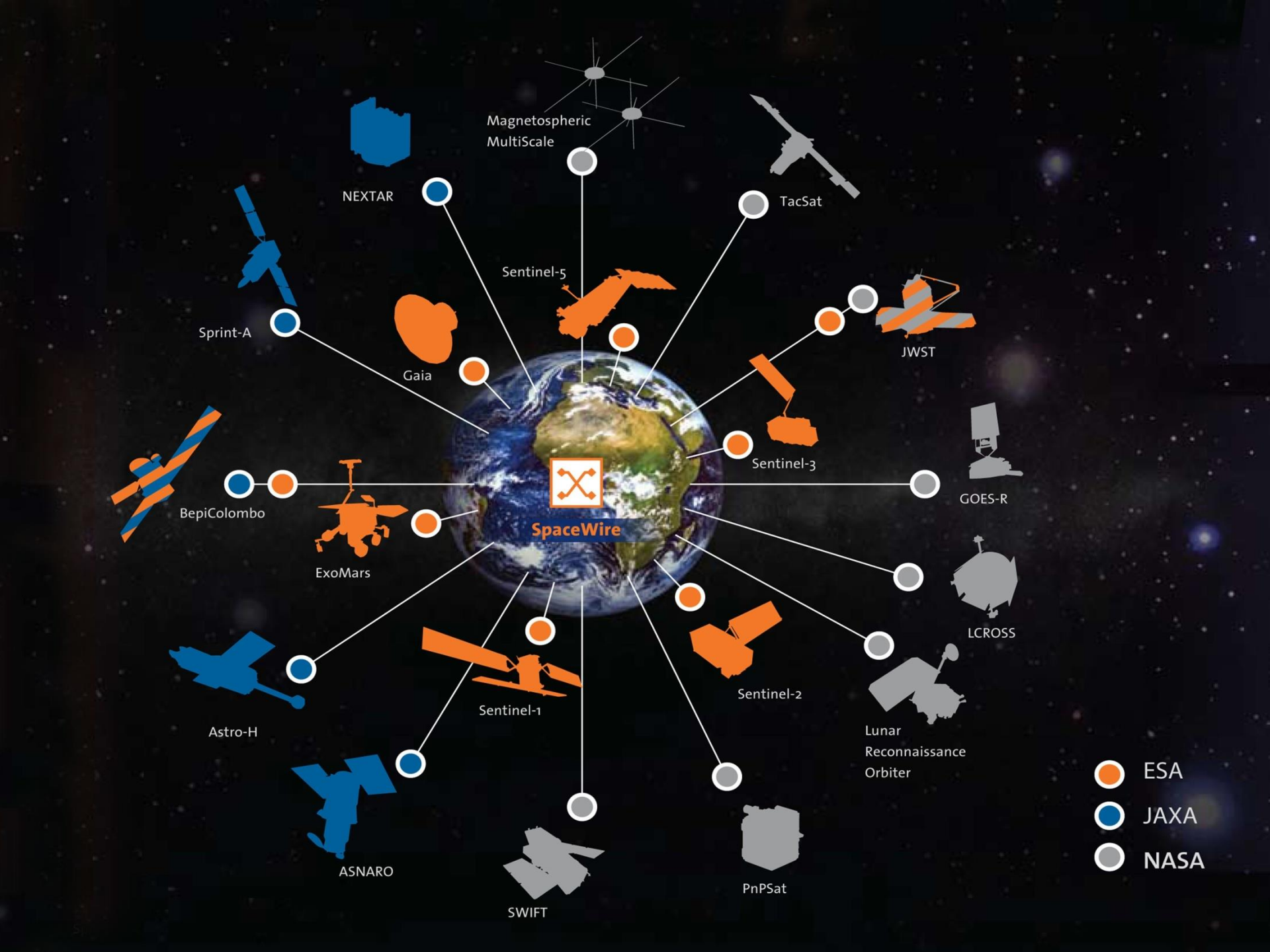
A very high-speed serial data-link for use in data-handling networks for high data-rate payloads

SpaceFibre: Gigabit data-rates for Spacecraft

- What is SpaceFibre?
  - Legacy & Flight heritage: SpaceWire
  - Requirements leading to SpaceFibre
- What is SpaceFibre?
  - Features and Architecture
- What is SpaceFibre?
  - SpaceFibre implementations
  - Products and Availability

SpaceWire – flight heritage & legacy

- ESA standard published 2003, authored by Steve Parkes UoD.
  - SpaceWire CODEC IP core & Router
- Purpose of SpaceWire standard:
  - facilitate construction of high performance on-board data-handling systems
  - help reduce system integration costs
  - promote compatibility between data-handling equipment and subsystems
  - support the re-use of data-handling equipment across different missions
- Key features:
  - Simple, small and low power interfaces readily implemented in ASICs and FPGAs
  - Bi-directional, full duplex point-to-point links supporting data rates up to 200 Mbits/s
  - Extensive network capabilities provided by routers
  - Comprehensively documented international standard
  - Many radiation-tolerant components available
- Established standard for data networking on-board spacecraft


Magnetospheric
MultiScale
NEXTAR
TacSat
Sentinel-5
Sprint-A
Gaia
JWST
Sentinel-3
BepiColombo
GOES-R
SpaceWire
ExoMars
LCROSS
Sentinel-2
Sentinel-1
Astro-H
Lunar
Reconnaissance
Orbiter
ASNARO
PnPSat
SWIFT
ESA
JAXA
NASA

SpaceFibre Requirements

- SpaceFibre Objectives
  - Compatible with SpaceWire
    - At the packet and network levels
  - High speed
    - 2 Gbits/s now (2.5 Gbit/s signalling)
    - 5 Gbits/s planned (6.5 Gbits/s signalling)
  - Very high speed
    - Multiple lanes e.g. 4 lanes 8 Gbits/s
  - Galvanic isolation
  - Copper and fibre optic implementations
    - 5 m copper
    - 100 m optical fibre
  - Low mass cable
    - 60 g/m copper
    - 30 g/m fibre

SpaceFibre Requirements

- Target capabilities for space applications
  - Very high-speed
  - Point-to-point
  - Virtual networks
  - Virtual circuits
  - Low latency signalling
  - Integrated networks
- QoS – Quality of Service
  - Deterministic behaviour
- FDIR – Fault Detection Isolation and Recovery
  - Improve reliability

STAR-Dundee

Qualitative Requirements

	Distance	Rate	Latency	Packet size	QoS
Data-handling network	Short to long	Low to very high	Not important	Short to long	Reserved bandwidth
Control bus	Short to long	Low	Low	Short to long	Deterministic delivery
Telemetry bus	Short to long	Low	Low	Short	Reserved bandwidth
Computer bus	Short	Very high	Low	Short to long	Reserved bandwidth
Time-sync bus	Short to long	Low	Very low	Short	High priority
Side-band	Short	Low to high	Very low	Short	High priority

SpaceFibre Introduction

- Spacecraft on-board data-handling network
  - Compatible with SpaceWire at packet level
- Targeting support of:
  - high data-rate payloads, e.g synthetic aperture radar and hyper-spectral optical instruments
  - robust, long distance communications for launcher applications
  - avionics applications with deterministic delivery constraints
- SpaceFibre key features
  - High performance
  - Low latency
  - Integrated QoS
  - Integrated FDIR capabilities
- Being developed by Steve Parkes and UoD, for ESA

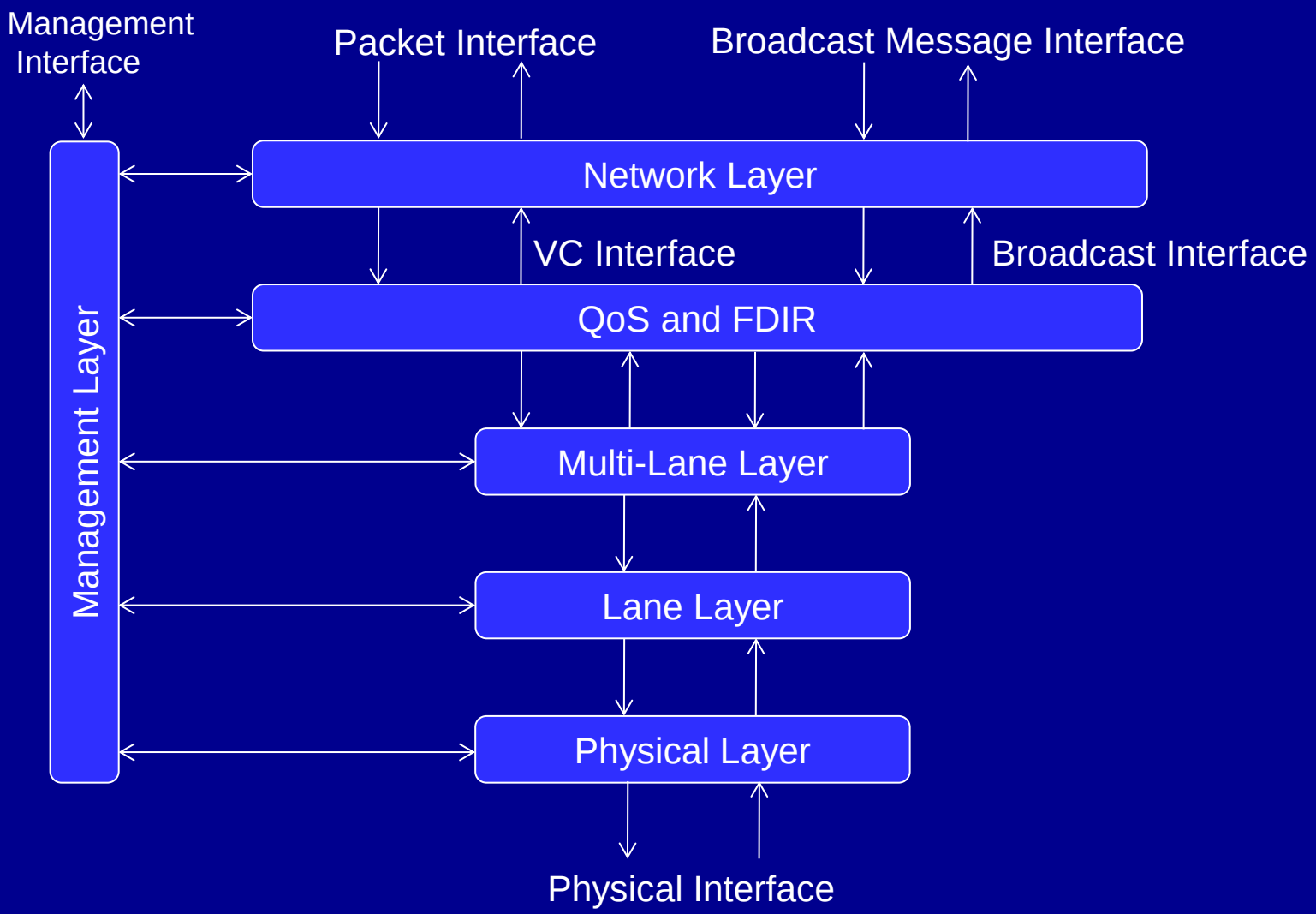
SpaceFibre Key Features

- High performance
  - 2.5 Gbits/s with current space qualified technology
  - 20 Gbits/s and higher with future technology and multi-laning
- Low latency
  - QoS precedence
  - Broadcast channels
- QoS
  - Integrated
    - Bandwidth reservation
    - Priority
    - Scheduling for deterministic data delivery

SpaceFibre Key Features

- FDIR
  - Fault detection
    - Parity/disparity
    - Invalid 8B/10B codes
    - Enhanced Hamming distance
    - CRC
    - Over and under utilisation of expected bandwidth
  - Fault isolation
    - Galvanic isolation (AC coupling)
    - Data framing – time containment
    - Virtual channels – bandwidth containment
  - Fault recovery
    - Rapid link-level retry
    - Graceful degradation on lane failure
    - Babbling idiot protection
    - Error reporting

SpaceFibre Protocol Stack



SpaceFibre Layers

- Network
  - Packets
    - Packages information to be sent over link
    - <Destination Address><Cargo><EOP>
    - Transfer of packets over network
    - Same routing concepts as SpaceWire
    - Path and logical addressing
  - Broadcast Messages
    - Broadcasts short messages across network
    - Can carry time-codes, time messages, events
- Management
  - Configures, controls and monitors status

SpaceFibre Layers

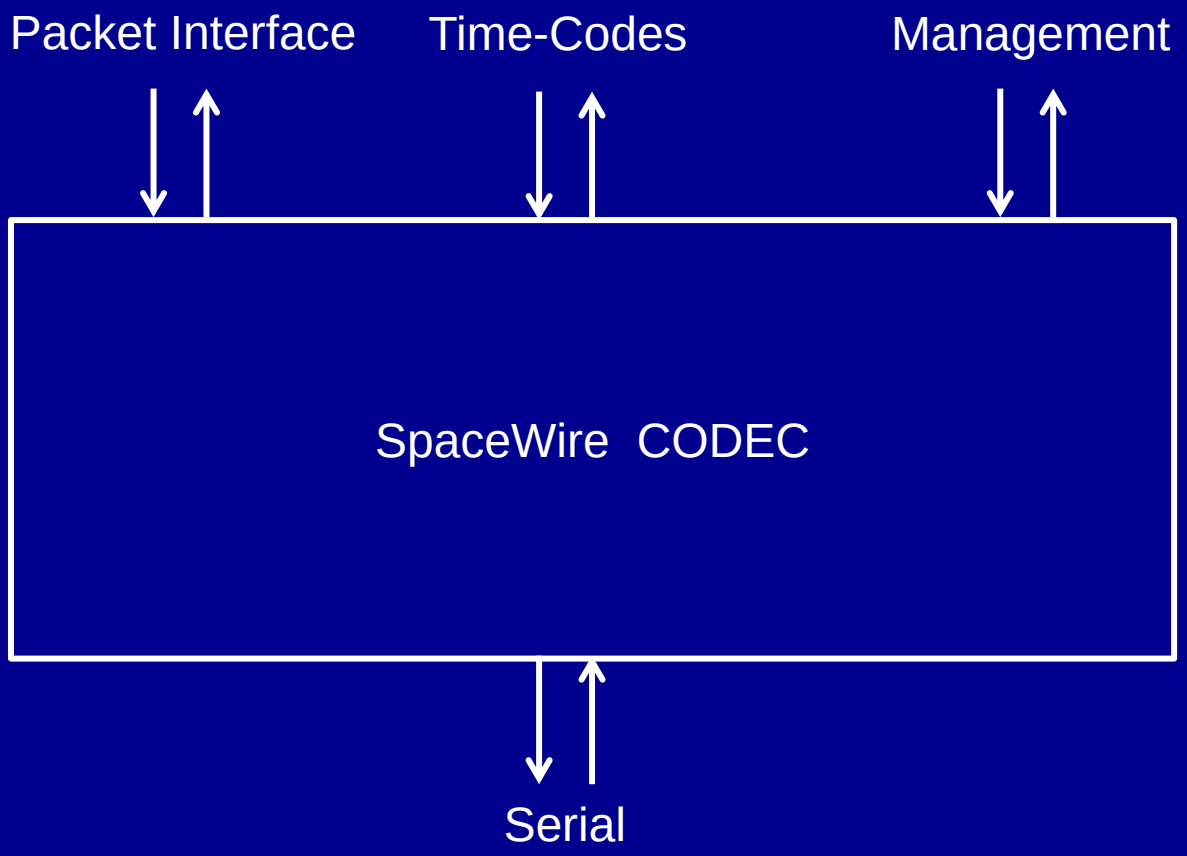
- QoS and FDIR
  - Virtual Channel:
    - Quality of service and flow control
  - Framing:
    - Frames information to be sent over link
    - Scrambles SpaceWire packet data
  - Retry:
    - Recovers from transient errors
      - Single bit error cannot corrupt data or protocol operation
      - Can cope with bit error rate of 10^{-5}
      - Automatic reconnection when BER lower than expected
- Multi-Lane
  - Runs several SpaceFibre lanes in parallel
  - Provides higher data throughput and redundancy with graceful degradation

SpaceFibre Layers

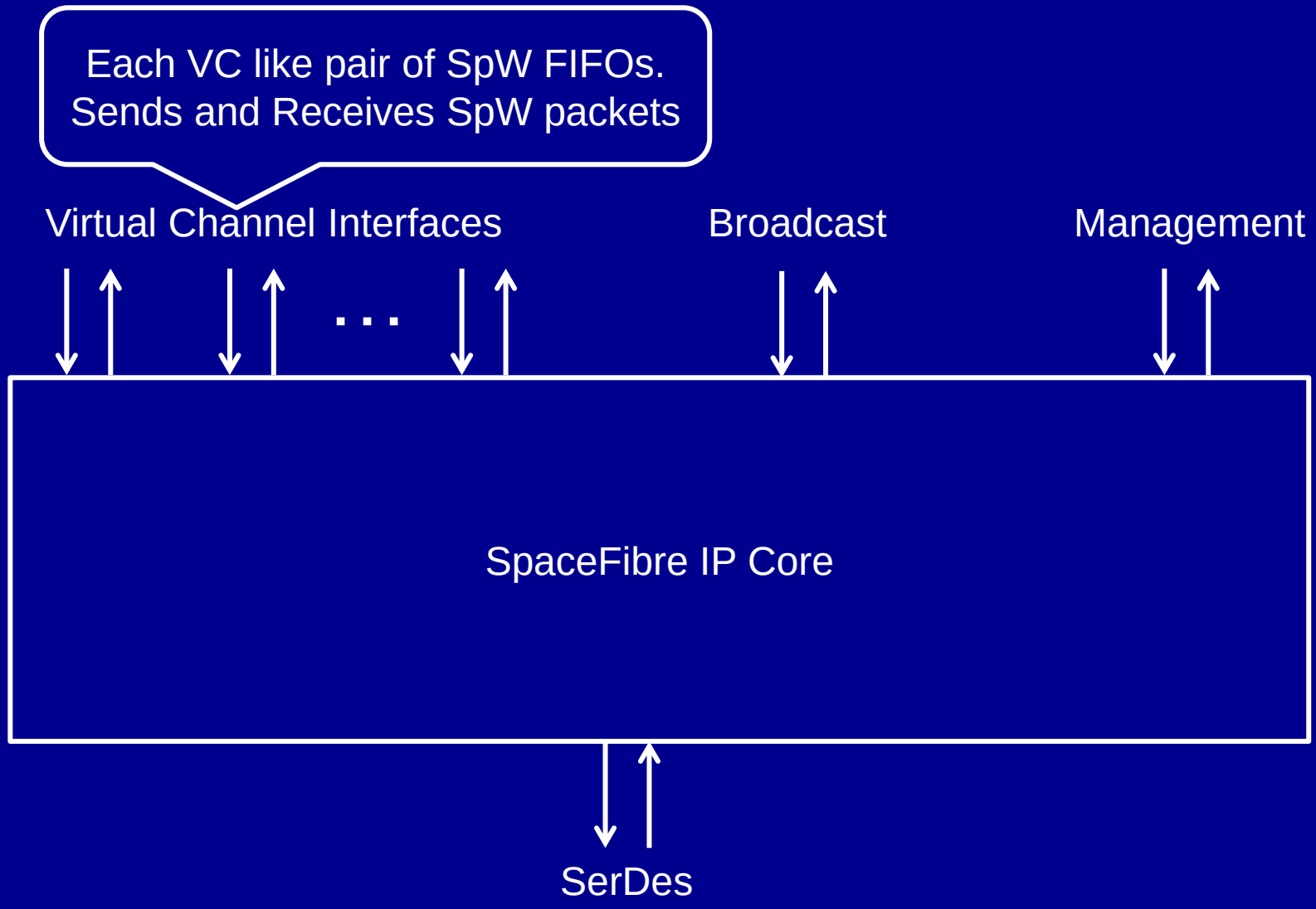
- Lane
  - Lane control
    - Lane initialisation and error detection
  - Encoding/Decoding:
    - Encodes data into symbols for transmission
    - 8B/10B encoding
    - DC balanced

- Physical:
  - Serialisation:
    - Serialises SpaceFibre symbols
    - Includes oversampling clock-data recovery
  - Fibre optic or electrical medium

SpaceWire CODEC



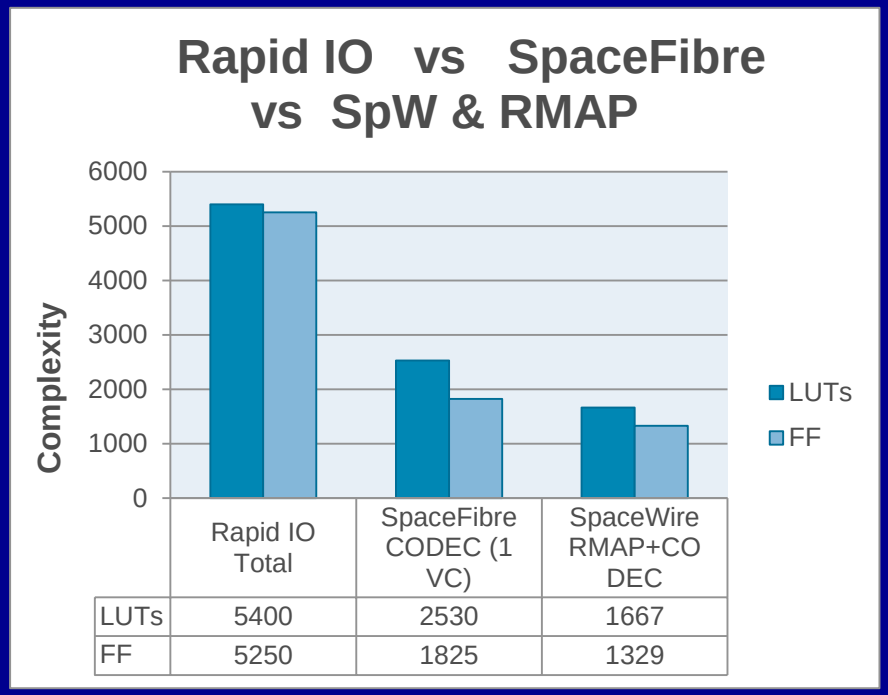
SpaceFibre IP Core



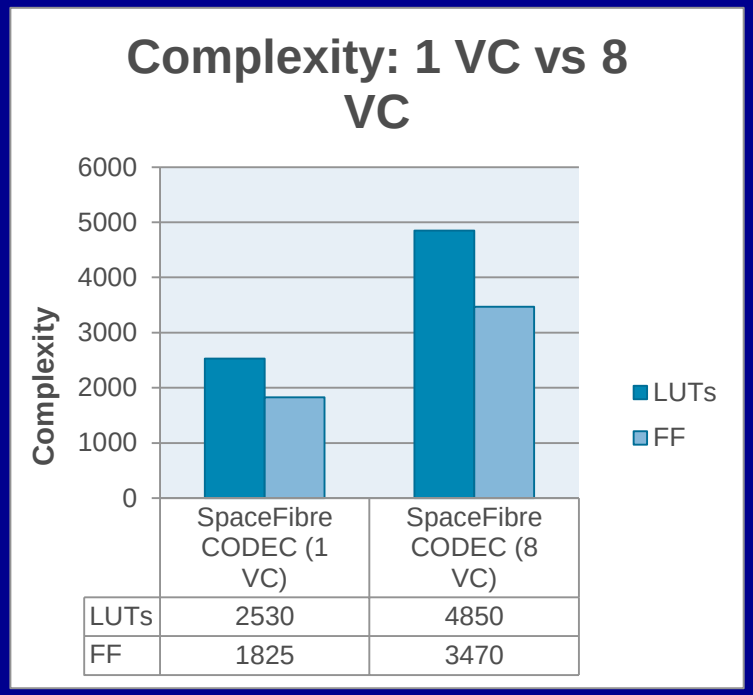
SpaceFibre IP Core

- VHDL IP Core
  - Compliant to current version of standard
    - Draft E published October 2012
  - Interfaces
    - Virtual channel interface
    - Broadcast channel interface
    - Management interface
  - QoS
    - Integrated priority and bandwidth reservation
    - Scheduling with 64 time-slots
  - Retry
    - Rapid retry
  - Single lane
    - Multi-lane support will be provided 2Q2013
- Beta released March 2013

SpaceFibre IP core Implementation



	Rapid IO Total	SpaceFibre CODEC (1 VC)	SpaceWire RMAP+CODEC
LUTs	5400	2530	1667
FF	5250	1825	1329



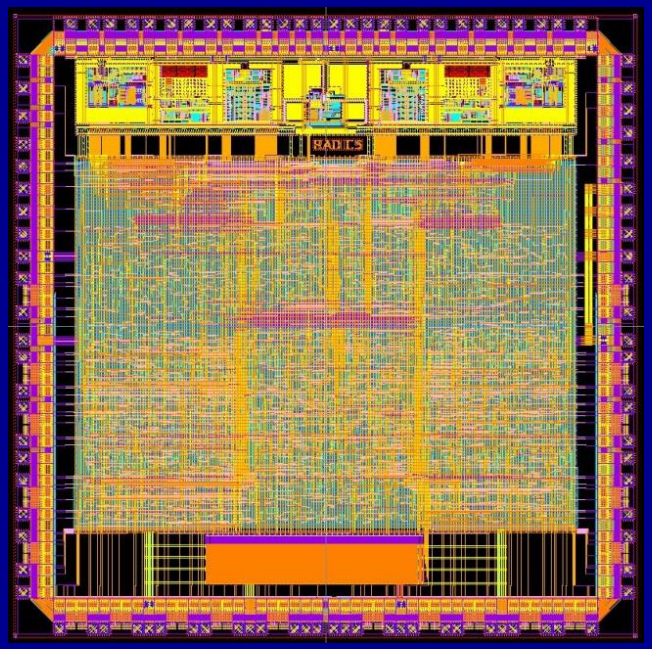
	SpaceFibre CODEC (1 VC)	SpaceFibre CODEC (8 VC)
LUTs	2530	4850
FF	1825	3470

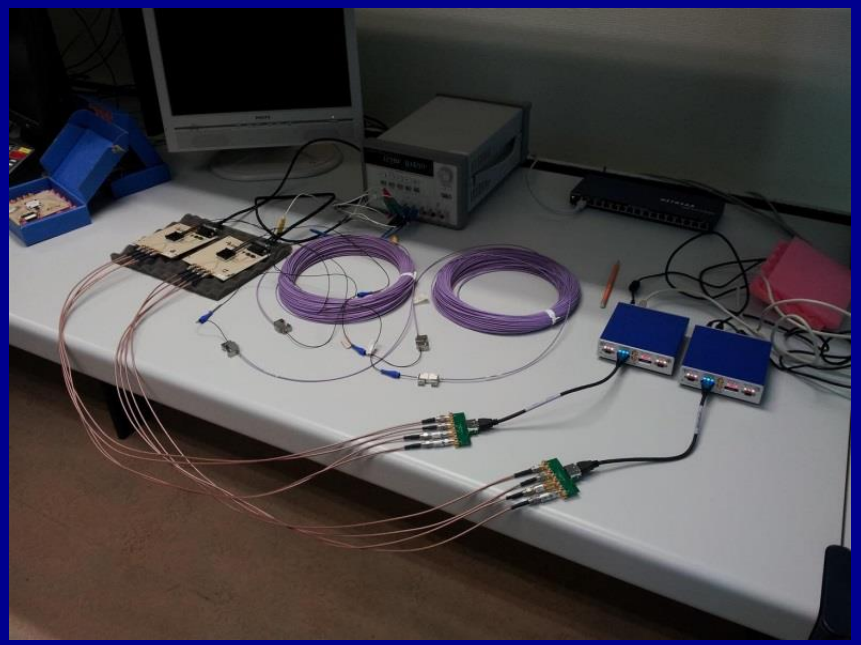
Rapid IO v2.1 x1 (Based on Xilinx srio_ds696, Spartan 6 results)

Low implementation complexity

- 12% to 20% utilisation of AX2000S (1 or 2 VCs)
- 3% to 6% utilisation of Spartan 6 75T (1 to 8 VCs)
- Similar to SpaceWire+RMAP IP core

SpaceFibre Current Availability





SpaceFibre Diagnostic Interface and Analysis

STAR Fire

- SpaceFibre interface
  - 2.5 Gbits/s signalling rate
  - 8 VCs on each SpaceFibre interface:
    - 2 VCs connected to internal SpW router
    - 6 VC connected to high speed pattern generators/checkers
- Diagnostics
  - Full analysis capabilities
    - Monitoring signals from UUT
  - Lane initialisation, Frame transfer, Broadcast operation
  - Packets over up to 8 VCs
- Analysis
  - In-line analysis between two UUTs
  - Once connection established can capture and analyse
    - Control words, Data frames,
    - Broadcast frames, Idle frames
    - Packet transfer over up to 8 VCs

ESA Projects using SpaceFibre

- 2 x High Performance COTS Based Computer
  - Astrium (Fr)
  - – Step 2 (Prototyping and Validation),
- 1 x Leon with Fast Fourier Transform Co-processor
  - SSBV (NL)
- 1 x FPGA Based Generic Module and Dynamic Reconfigurator,
  - TWT (D)
- 2 x Next Generation Mass Memory
  - Astrium (D), IDA (D)
- 1 x High Processing Power DSP, Astrium (UK)

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