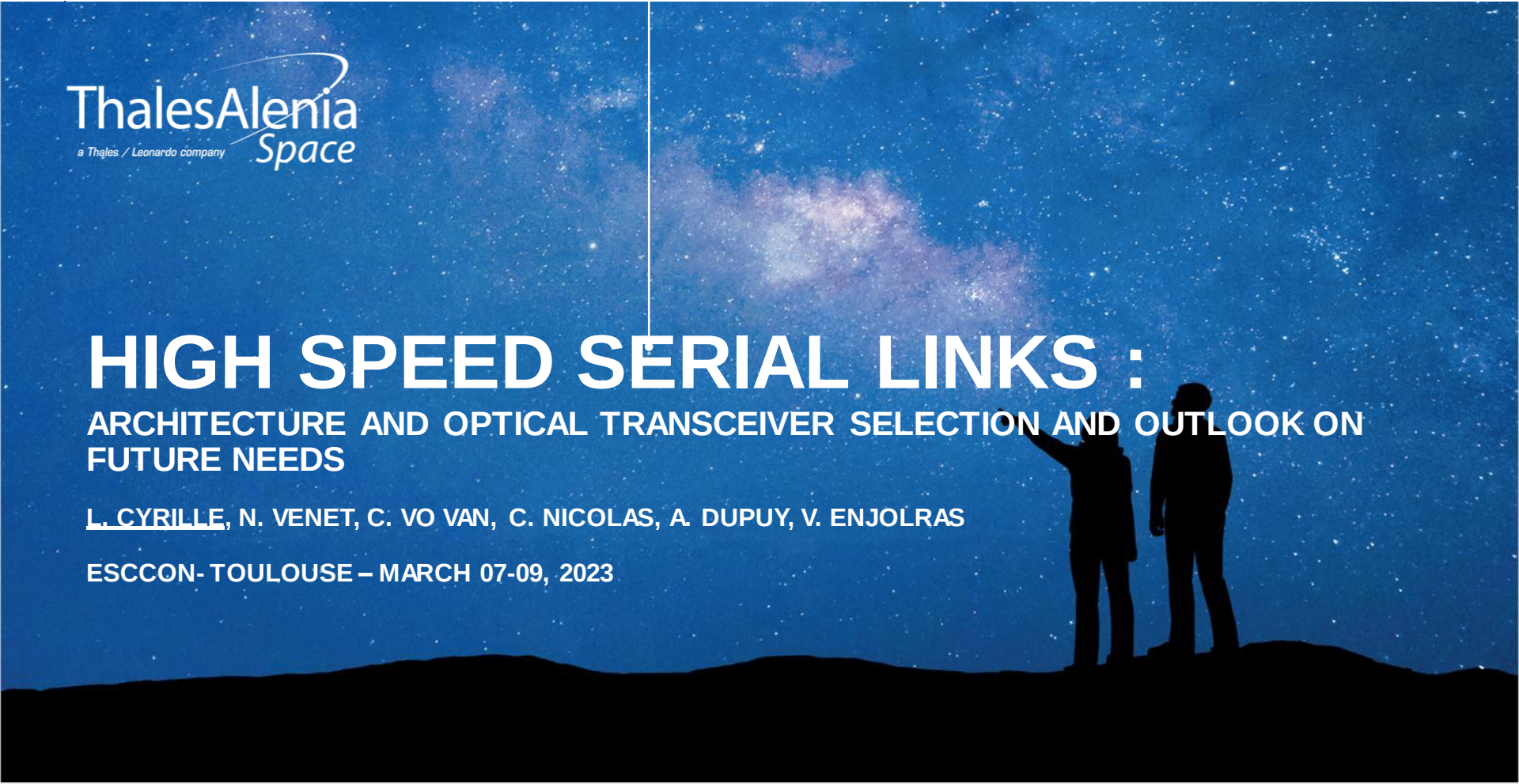

HIGH SPEED SERIAL LINKS :

ARCHITECTURE AND OPTICAL TRANSCEIVER SELECTION AND OUTLOOK ON FUTURE NEEDS

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ESCCON- TOULOUSE – MARCH 07-09, 2023

Date: 27/02/2023
Ref: 0005-00163171 82
Template: 83230347-DOC-TAS-EN-011

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DTP : BRIEF PRESENTATION

- Digital Transparent Processors are used in advanced flexible telecom payloads to provide

  Flexible, transparent and reconfigurable channel routing

- Usecase examples :
  - Changes in traffic allocation reflecting customer's needs
  - Progressive growth of operator ground infrastructure
- Thales Alenia Space Successive DTP generations provide steady improvements in capacity
- Latest generation, DTP6G, is under development (CDR end 2021 – qualification 2023)
- 2nd generation using optical-link-based High Speed Serial Link (HSSL)

DTP : ROADMAP

CAPACITY

1THz

100GHz

10GHz

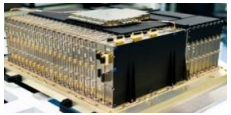
1GHz

0.1GHz

DTP6G

DTP 5G

In Development (CDR)
5 FMs in prod



DTP3G

1 FM in orbit (Q4 21)
4 FM in AIT

DTP2.5G

2 FM in orbit (Q4 19, Q4 21)
3 FM delivered to AIT

DTP2G

1 FM in orbit since 2017
1 FM delivered

DTP1G

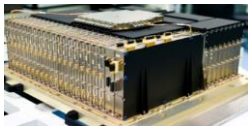
2 FMs in orbit since 2005&2006
2 FMs in orbit since 2014

MTSAT

2 FMs in orbit 2005-2015

2003 2006 2010 2014 2017 2019 2021 2023

DTP : HSSL ROADMAP



DTP 6G

Topology	Fiber
Lane number	Up to 1800
Link speed	> 20Gbps
E2E link energy cost	10-15 pJ/bit

DTP 5G

Topology	Fiber
Lane number	Up to 1300
Link speed	>10 Gbps
E2E link energy cost	15-20 pJ/bit

DTP 3G

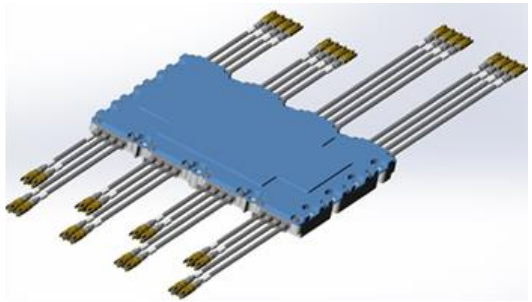
Topology	Cable
Lane number	Up to 120
Link speed	> 6 Gbps
E2E link energy cost	15 pJ/bit

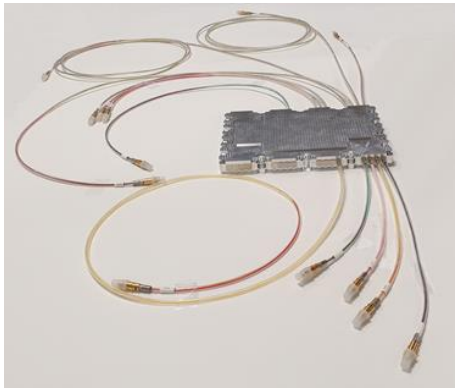
DTP 2.5G

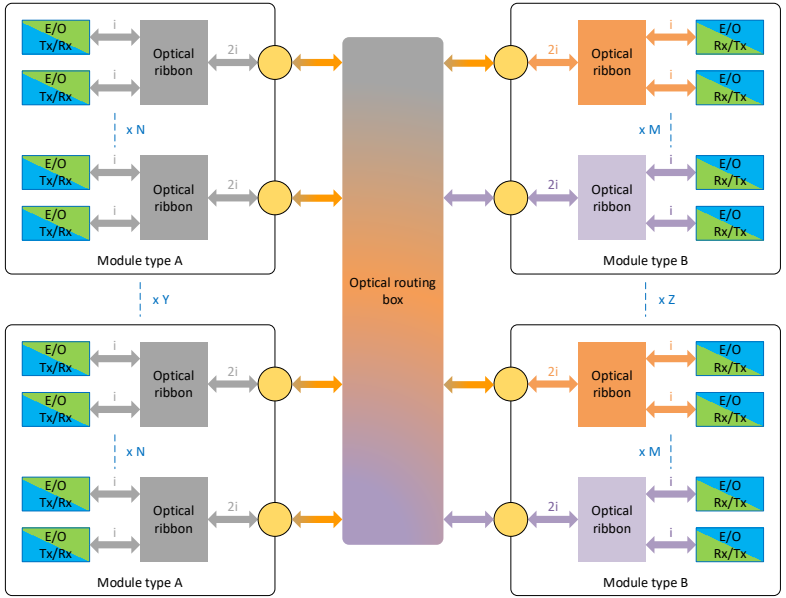
Topology	Backplane
Lane number	Up to 160
Link speed	>2 Gbps
E2E link energy cost	100 pJ/bit

OPTICAL HSSL : PASSIVE OPTICAL INTERCONNECTS

- DTP architecture based on modules interconnected with fibers
  - Inside modules, optical transceivers perform the Electro/Optical (E/O) conversion
  - Optical links with data rates above 20Gbps
  - Fiber ribbons are used to travel between modules
  - Optical routing boxes shuffle the fibers between the modules

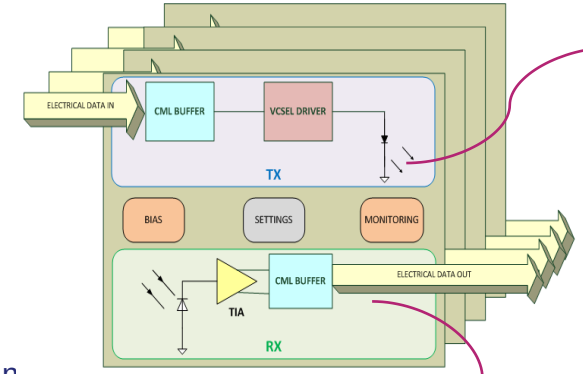


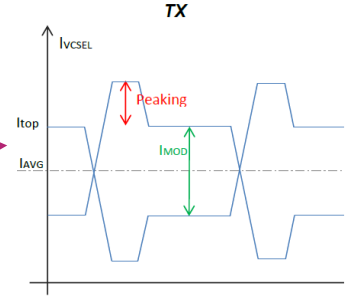


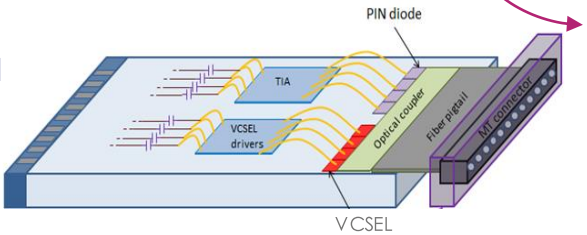


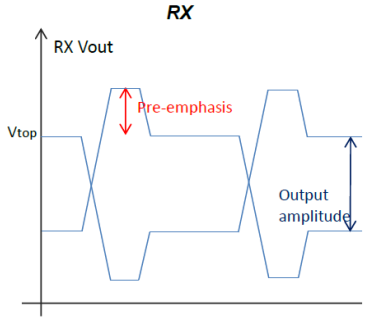
OPTICAL HSSL : OPTICAL TRANSCEIVERS (1/6)

- At the heart of optical HSSL is the optical transceiver in charge of the electro-optical (E/O) conversion
- The DTP6G transceiver is composed mostly of :
  - 4 Transmit (Tx) channels including
    - A Driver converting voltage to current
    - Vertical Cavity Self Emitting LASER (**VCSEL**) converting current to light
  - 4 Receive (Rx) channels including
    - A Photodiode converting received light to curren
    - Trans Impedance Amplifier converting current back to voltage
- The waveforms associated to the optical and electrical interfaces of the transceivers can be tuned on :
  - Optical average, modulated and peak current
  - Electrical voltage amplitude and pre-emphasis



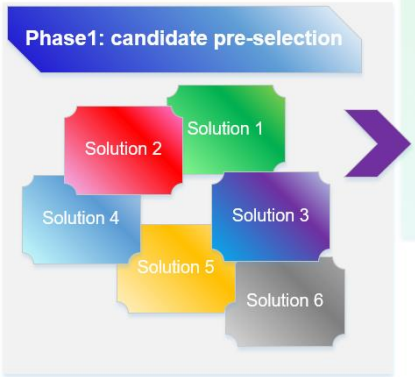


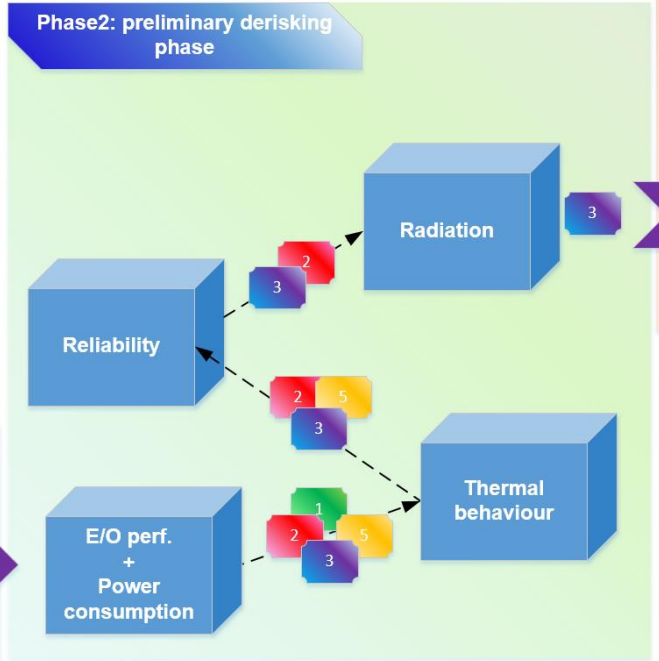




OPTICAL HSSL: OPTICAL TRANSCEIVERS (2/6)

- Selection phases
  - Phase 1 : preselection of best candidates from market
  - Selection based on:
    - Sample availability
    - Price
    - Form factor
    - preliminary performance data



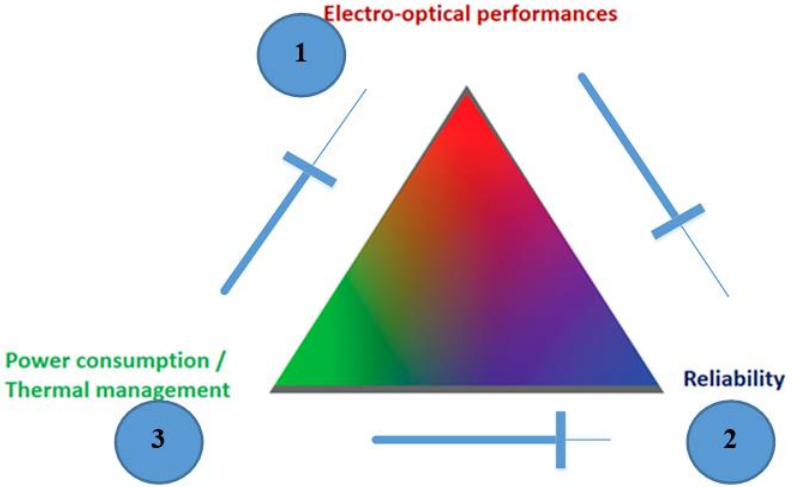


- Phase 2 : selection based on tests and analyses
- Phase 3 : final step on selected candidate

OPTICAL HSSL: OPTICAL TRANSCEIVERS (3/6)

↑ VCSEL currents
↑ boosting features & corrections

- Three major aspects to evaluate in phase 2
  - E/O performances
    - to achieve link performance goals
    - Depends on tunable features
    - In the end, not the most differentiating element between candidates
  - Reliability
    - Critical for space missions
  - Power Consumption/Thermal management
    - Key aspects for DTP budgets
    - It is mandatory to define each component junction temperature inside the package and draw a thermal map of the transceiver
    - Suitable measurement techniques are needed
- These aspects are interdependent and a compromise must be found



↓ VCSEL currents
↓ boosting features & corrections

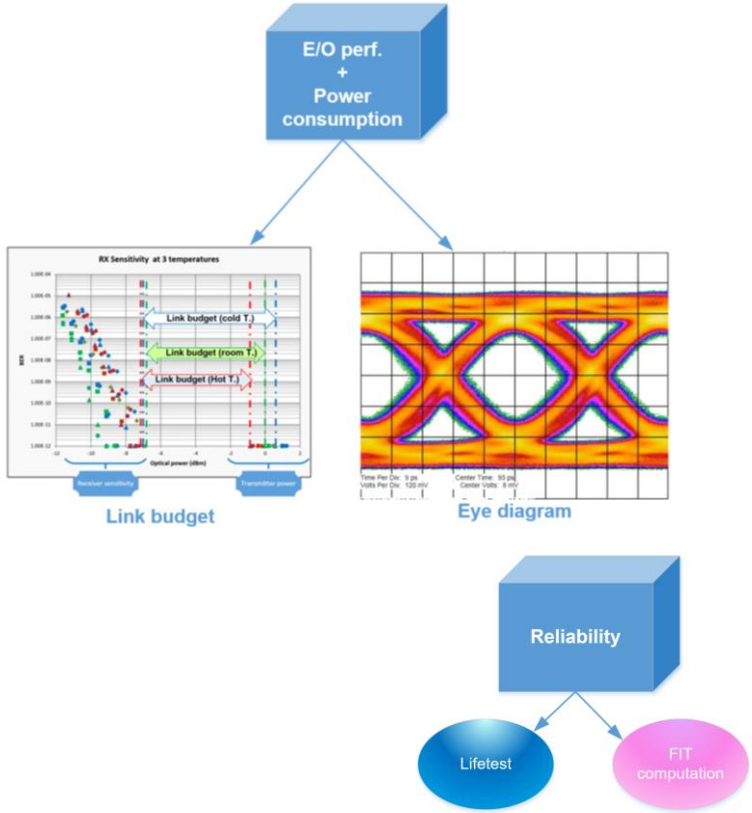
↓VCSEL current
↓ temperature

OPTICAL HSSL: OPTICAL TRANSCEIVERS (4/6)

- The measured parameters to evaluate Electro-Optical performan
  - Bit Error Rate (BER)
  - Optical eye diagram (at Tx)
  - Electrical eye diagram (at Rx)
  - Link budget (Rx sensitivity – Tx power)

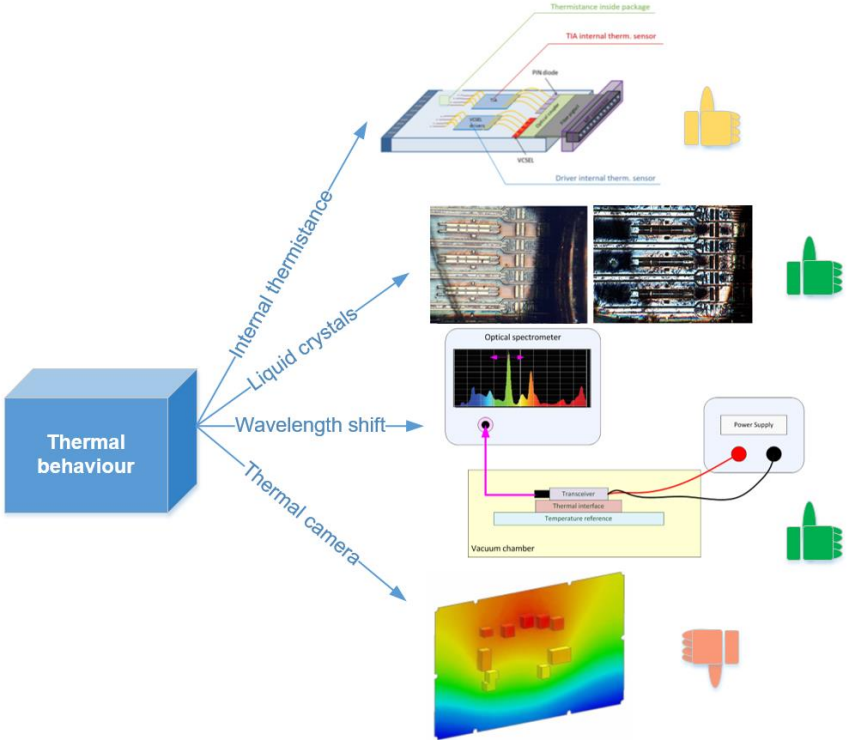
➔ **Assessed over temperature (-20°C to 85°C)**

- Reliability is assessed according to two aspects:
  - Life duration: measured via lifetest
  - Failure In Time computation based on supplier data



OPTICAL HSSL: OPTICAL TRANSCEIVERS (5/6)

- Temperature mapping established using various methods:
  - Internal temperature sensor (Driver or TIA)
    - Easy to implement
    - Poor precision
    - Local temperature
  - Liquid crystals
    - Well defined turning point: good precision
    - Global mapping
    - Complex set-up
    - Does not provide LASER temperature (critical)
  - Wavelength shift
    - Accurate and reproducible method
    - Provides VCSEL temperature (critical)
    - Does not provide global mapping
    - Requires precisely determining VCSEL dissipation
  - Thermal camera
    - complex and potentially damaging set-up

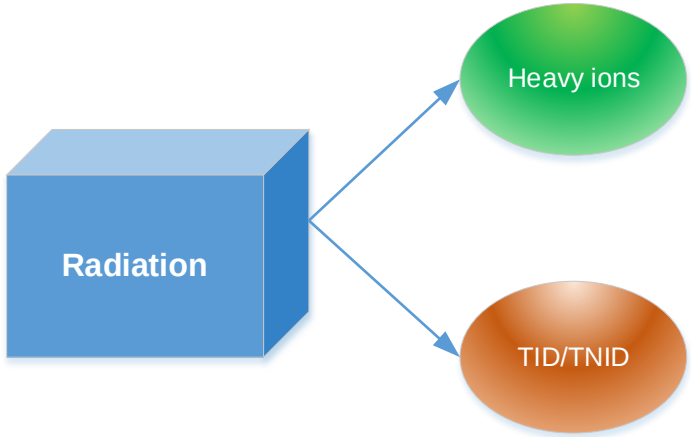


OPTICAL HSSL: OPTICAL TRANSCEIVERS (6/6)

- The remaining aspect to be tested is the compatibility to radiative environments
- This can be a major **showstopper**

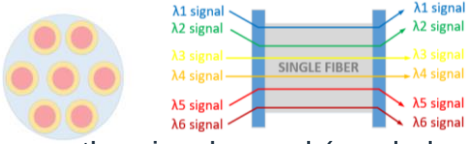
- Specification:
  - Total Ionizing Dose : 100krad with acceptable functional/performance degradations
  - Heavy Ions (Single Event Effects) :
    - No latch-up,
    - Minor and transient BER events
    - No lasting interruption of link (Single Event Functional Interrupt) limited to a few milliseconds

In some cases, mitigation techniques can be used

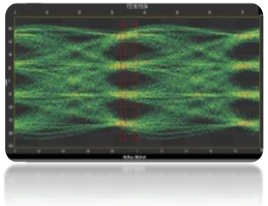


OPTICAL HSSL: PROJECTION TOWARDS FUTURE NEEDS (1/3)

- The coming DTP generations will be in constant need for more capacity
- The three main directions to consider are:
  - To increase the amount of links
    - Using multi-core fibers (left picture) or Wavelength Division Multiplexing (WDM) (right picture) for example



  - To increase the signal speed (symbol rate)
  - To increase the number of bits coded by each symbol



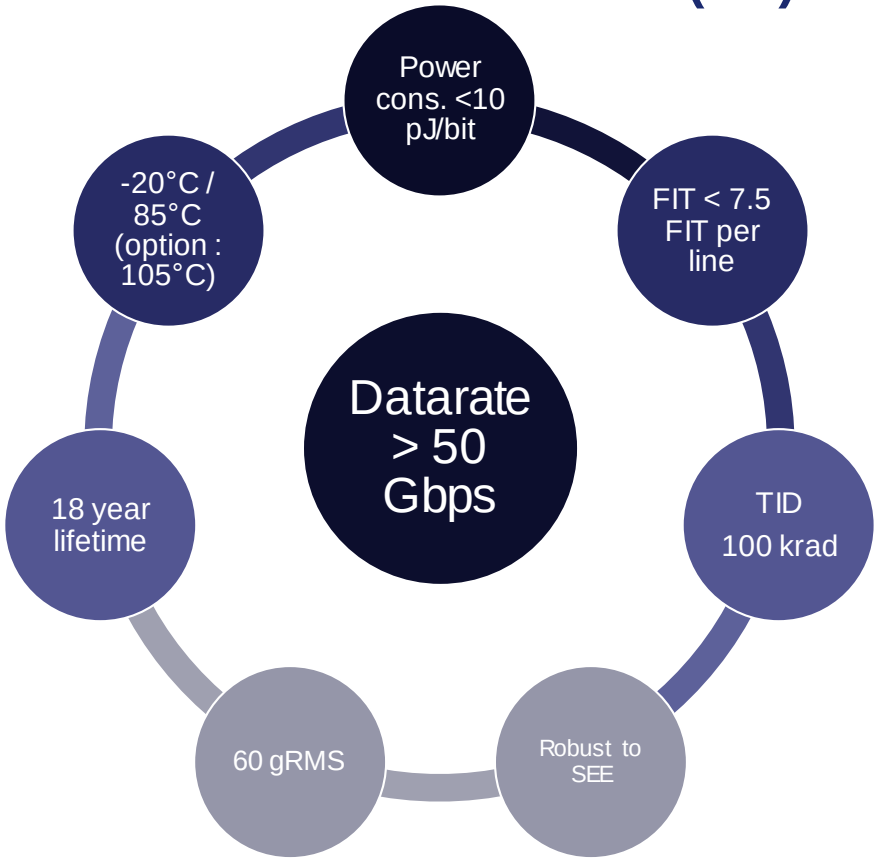
Example of PAM4 signal

Increased capacity

- Increased channel amount
- Increased symbol rate
- Bit/symbol increase

OPTICAL HSSL: PROJECTION TOWARDS FUTURE NEEDS (2/3)

- Full-Duplex (4x4 to 8x8) and Simplex (4 to 8 Rx-only and 4 to 8 Tx-only or more channels)
- Highly integrated / low mass, easy to mount/dismount, Connectivity : MT ferrule, mini-AVIM …
- In-flight re-configurability through standardized bus, Link quality TM



OPTICAL HSSL: PROJECTION TOWARDS FUTURE NEEDS (3/3)

- The path to the future transceiver generation might be:
  - Technological step on Optics :
    - Laser wavelength modification in order to overcome the bandwidth limitation of 850nm VCSELS
    - New technologies for light transmission (single mode fibers, Distributed FeedBack Laser)
  - Increase number of channels ➔ expand fiber network
  - SIP: integrating photonic functions inside a package alongside with other functions
    - To improve signal integrity
    - To save power consumption
    - To overcome space occupation and mass challenges

Continuous improvements	• Expand fiber network • Enhanced coding
Disruptive approach	• Laser technological change • SIP / Silicon Photonics

CONCLUSIONS

- Thales Alenia Space, for their new generation of Digital Transparent Processor, DTP6G, have selected new optical interconnects at >20Gbps.
- Datarate is twice that of inherited HSSL solution already in flight.
- A projection towards the future needs for telecom space applications confirms the trend for **higher datarates** while keeping optimised **mass** and **power budgets**.
- For that purpose, many solutions have been identified and must be analysed in coming years

THANK YOU

Date: 27/02/2023
Ref: 0005-00163171 82
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