OBDP
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Teledyne e2v

"New Space" use cases permitted by Radiation Tolerant Space qualified Compute intensive solutions from Teledyne e2v

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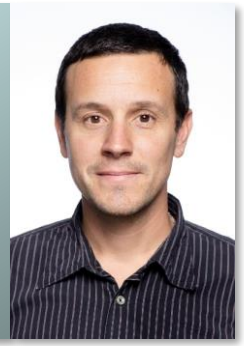

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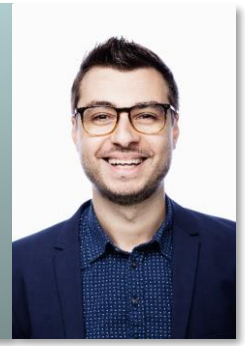

TELEDYNE e2v
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Agenda

- Introduction on Teledyne e2v vision and strategy on space needs
- Teledyne e2v approach for bringing state-of-the-art components to Space
- Radiation results on the LS1046-Space
- New applications permitted

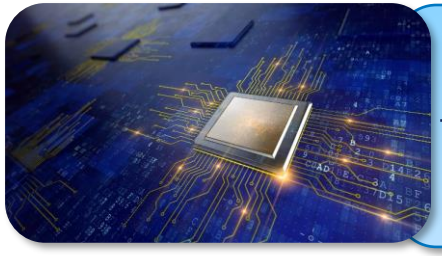
General Trends & Innovation areas

New Launchers

Simulation & Augmented Reality

In Orbit Services & In Orbit Re-Use

Heterogeneous Data Analytics



(Autonomous) On Board Processing

New Platforms & Boosters

Ground-Space & Sat-2-Sat Data / Comms

Trends & Innovation served by Teledyne e2v

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Simulation & Augmented Reality

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Heterogeneous Data Analytics

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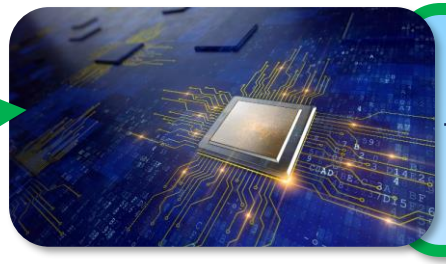

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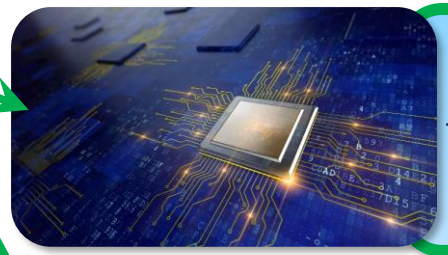
With Traditional Computing or AI Algorithms



(Autonomous) On Board Processing

New Platforms & Boosters

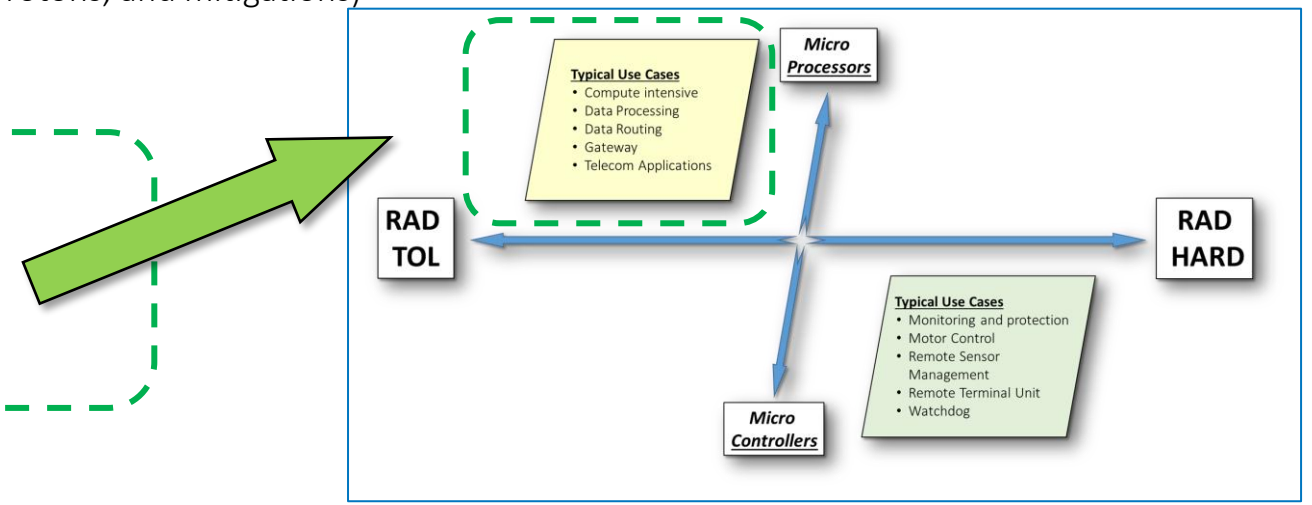
Ground-Space & Sat-2-Sat Data / Comms

Compute Intensive Radiation Tolerant solutions

- Supplier of Advanced & High Performances Radiation Tolerant Space Compute Intensive solutions
  - Bringing **existing COTS solutions** to **Space environments** through
    - ***Space Screening,*** *Qualification*
    - ***Radiation characterizations***

- Enabling Fully tested & qualified Space Compute Intensive solutions into Space
  - Highest grade Testing & Qualifications thanks to long term partnership with leading vendors (NXP)
    - *Access to all **test vectors, burn in platforms**, same **testers** leading to highest quality testings and test coverage*
  - **Fully Tested and characterized in Radiation** (TID, SEE HI & Protons, and mitigations)

- Complementing the Space European Offer and allowing additional Use-cases in Space
  - Space Radiation Tolerant Compute Intensive solutions Positioning



Radiation Tolerant Space Portfolio

Teledyne e2v Offering

RAD TOL — Radiation Testing Results Available

RAD TOL — Radiation Testing On Going

Shipment / Flight Heritage

Under Development

Proposed RAD TOL

ORGANIC package solutions

Ruggedized radiation tolerant technology
Standard plastic package
Device selection and lot validation

ECSS-Q-ST-60-13C & NASA EEE-INST-002 - Section M4 – PEMs

- P2020 RAD TOL
- P5020 RAD TOL
- *LS1046* RAD TOL
- *Qormino QLS1046-4GB* RAD TOL
- *4GB DDR4* RAD TOL
- *LX2160* RAD TOL

CERAMIC Non-Hermetic FlipChip

Ruggedized radiation tolerant technology
Advanced packaging on ceramic
Standardized quality grade

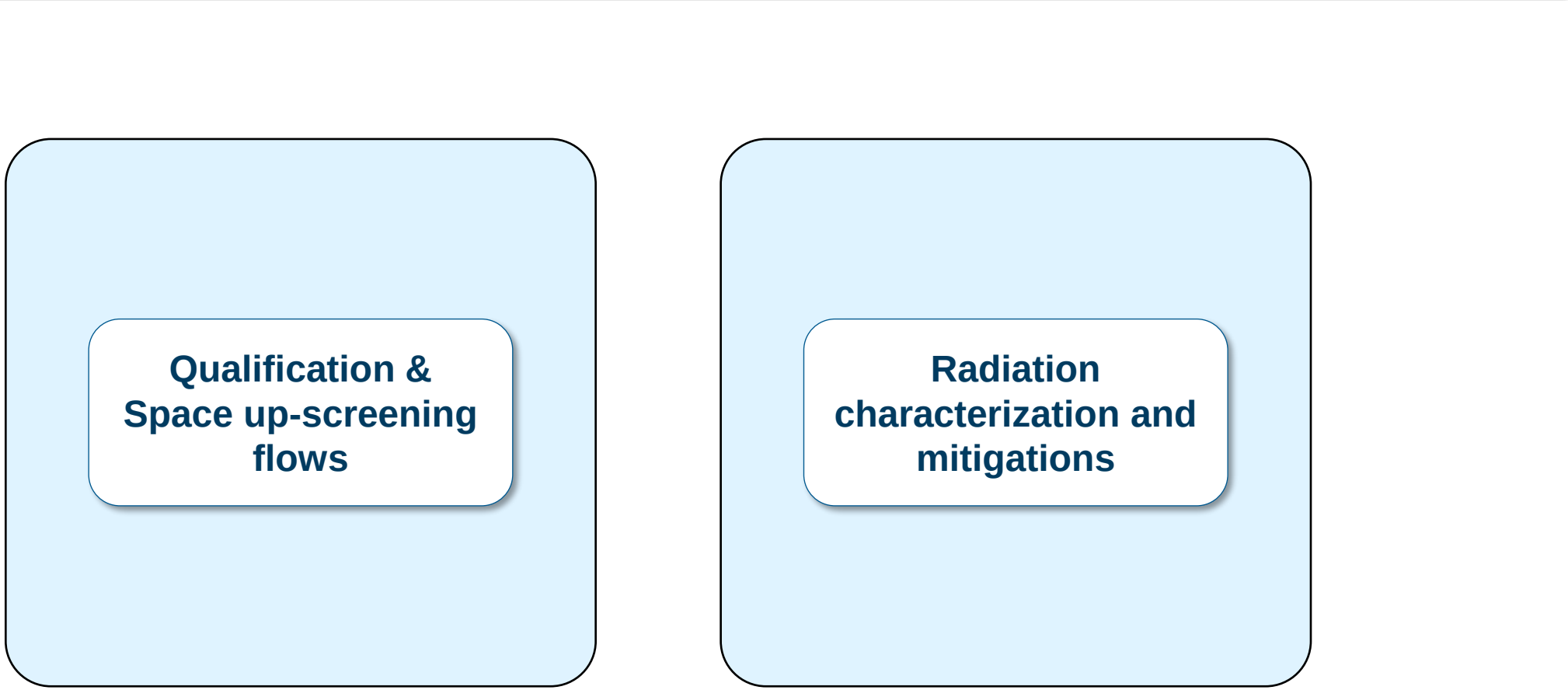
QML-Y Flow

- PC7448 RAD TOL
- PC8548 RAD TOL

How Teledyne e2v brings COTS solutions to Space environments

Bringing existing COTS solutions to Space environments

How it is done - Relies on 2 main competences



Space manufacturing flows at Teledyne e2v

Executive Summary

Default Features

Space Level Screening

- Serialization
  - ✓ *Clearly identify every device manufactured*
- Ruggedized to Hi-Reliability
  - ✓ *-55C to +125C*
  - ✓ *Non-RoHS*
- 100% inspection
  - ✓ *X-rays, CSAM, visual, dimensional ensuring defect-free flight units*
- Advanced dynamic & static burn-in
  - ✓ *To eliminate infant failures*

Lot by lot Qualification

- Life test, Temp. cycling, HAST testing
  - ✓ *On every lot manufactured*
  - ✓ *Guarantee compliance with Space Grade*
- **DPA performed on every lot**

ECSS / EEE-INST-002 Levels

Level 1

- *Commercial communication satellites*
- *Weather monitoring and Earth observation satellites*
- *Launch Vehicles*
- *Manned Space Flight*

Level 2

- *Cubsesats and Satellite Constellations*
- *Science missions*

Level 3

- *Cubsesats*
- *Short space missions*

T e2v's view

Reliability

High end Space Qualification

Higher Samples lot
Increased Life Cycle Tests
Increased Test Hours

Entry level

Lower Samples Lot
Reduced Life Cycle Tests

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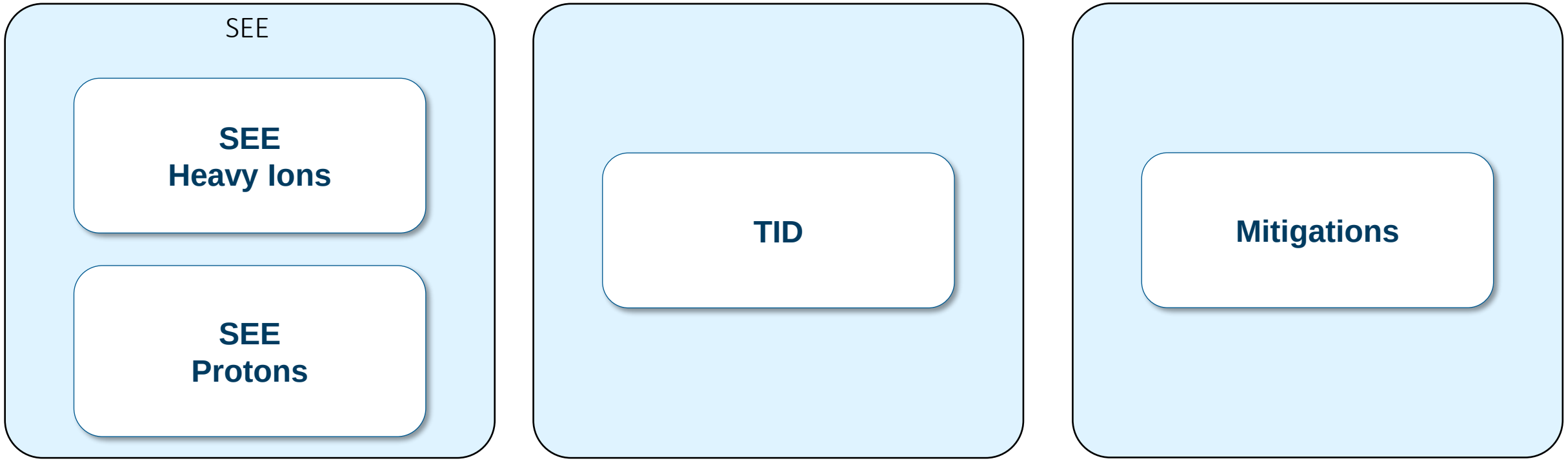
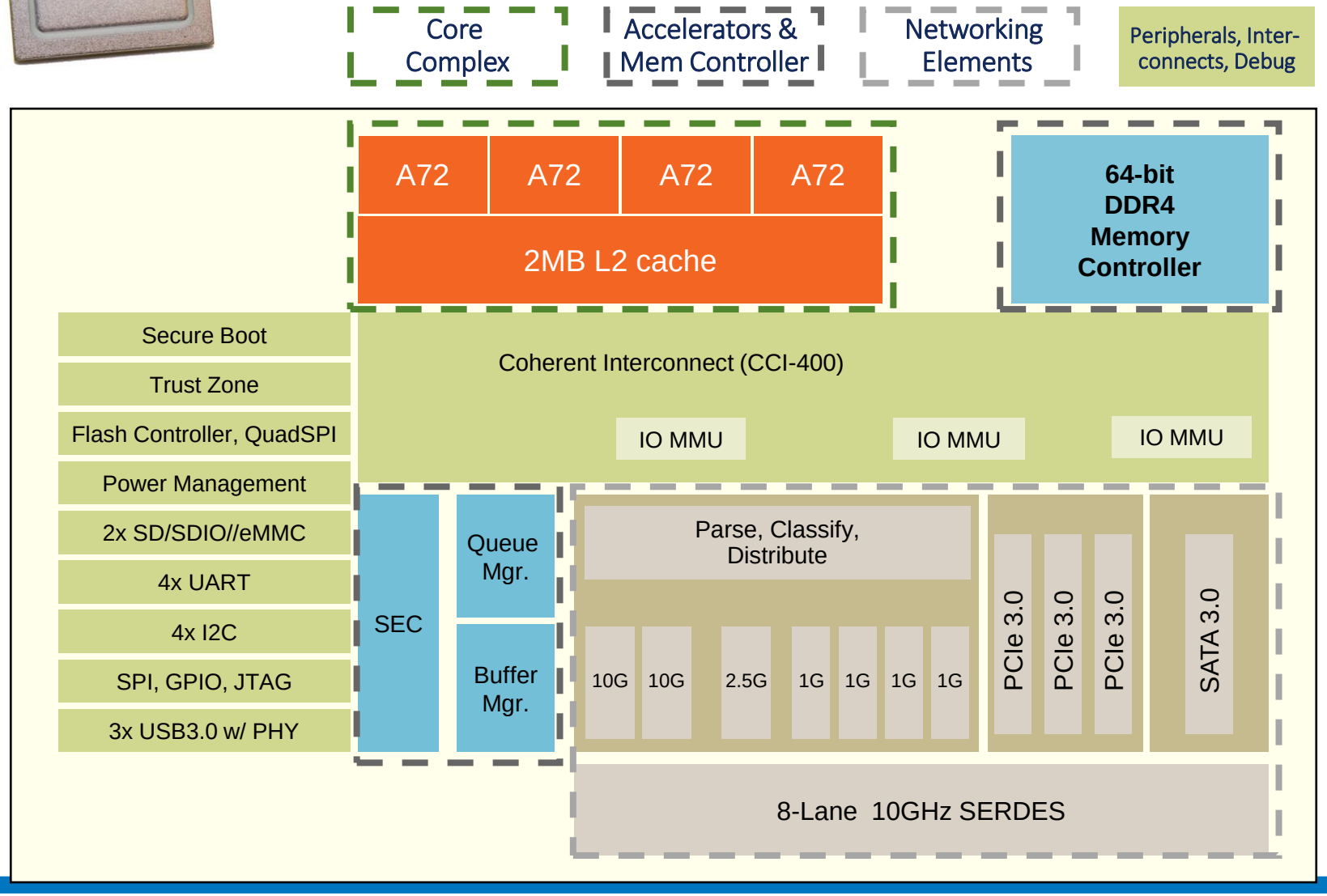
Radiation strategy

3 Key pillars



How Teledyne e2v address complex products

Case of LS1046-Space - Quad ARM® Cortex®A72



Core & Memory Subsystem

- 4x ARM Cortex A72 up to 1.8GHz
- 2MB total L2 cache
- 64-bit DDR4 up to 2.1GT/s

Interfaces

- Three PCIe Gen3 controllers (x4, x2 and x1)
- 1x SATA 3.0
- 3x USB 3.0 with PHY
- 2x SD3.0/SDIO/eMMC 4.5

Network IO

- 2x 10GbE
- 1x 2.5GbE
- 4x 1GbE

Datapath Acceleration

- SEC- crypto acceleration
- Datapath Acceleration Architecture

How Teledyne e2v address complex products

Challenges for characterization

+ SoC with many peripherals	→	Hard to locate each error and to test everything at once
+ Flip-chip product	→	Requires to thin with a proper planarity
+ Power consumption can be high	→	Needs to mount a cooling system
+ Not rad-hard by design	→	Tons of data to analyze and process

SEE – Test methodology

Hardware :

- Design and manufacture specific hardware in order to :
  - Use a board adapted for each step
  - Be able to thin properly the part
  - Manage power supplies
  - Monitor as much currents as needed
  - Install thermal regulation system properly
  - Simplify the interface with our existing general monitoring system

Software :

- Develop specific software in order to :
  - Use a program adapted for each step
  - Use an incremental approach
  - Customize as much as we want
  - Be able to modify and debug on the fly during testing

SEE - Incremental testing

Typical strategy

Radiation Tests

SEE

SEE Step 1
Core & ON RAM

Target : ~60 MeV*mg2/mg
- Define LU threshold
- Monitor SEFIs

Initial SEE report
- ✓ *Cross-sections*
- ✓ *Orbital error rates*

SEE Step 2
Peripherals

Targets : ~60 MeV*mg2/mg
- Define LU threshold
- Characterize **all relevant peripherals**
- **SEFI classification**

Final SEE report
- ✓ *Cross-sections*
- ✓ *Orbital error rates*
- ✓ *SEFIs classification*

SEE Step 3
All

SEFIs Mitigation
- Test mitigation techniques
- Recommendations to reduce error rates

Application note
- ✓ *SEFIs mitigation techniques & proposals*

TID – Test methodology

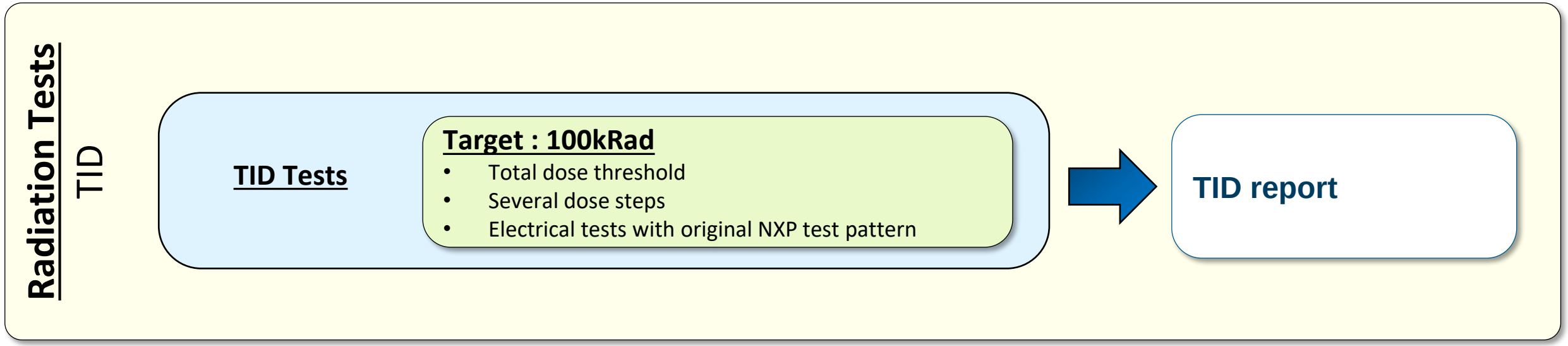
Hardware :

- Leverage availability of THB boards for TID testing
- Leverage same test platform as NXP for electrical test

Software :

- Leverage Teledyne e2v – NXP partnership which allows to :
  - Use original NXP test program for each electrical step
  - Provide same test coverage as NXP

TID – Full test coverage



LS1046-Space example - Radiation characterization results

LS1046-Space example

SEL results

DUT (Part ID)	Ion Specie	Effective LET [MeV.cm²/mg]	Run Duration [s]	Temperature (Diode) [°C]	Entered Fluence [ions/cm²]	SEL count
4	126Xe44+	62.5	619	125	1.00E+07	0
4	126Xe44+	62.5	551	125	1.00E+07	0
4	126Xe44+	62.5	515	125	1.00E+07	0
3	126Xe44+	62.5	561	125	1.00E+07	0
2	126Xe44+	62.5	603	125	1.00E+07	0
4	89Kr29+	32	931	125	1.00E+07	0

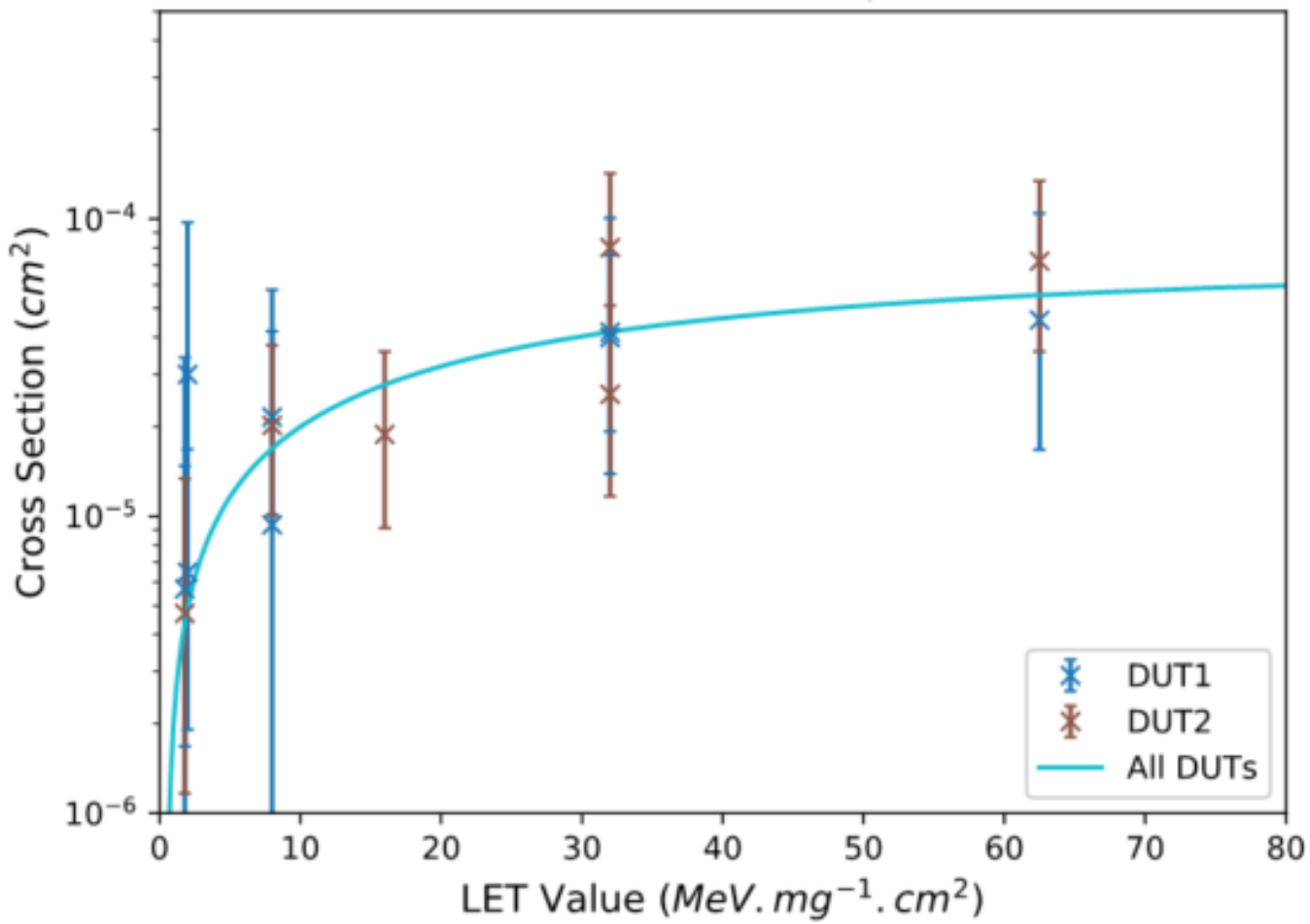
LS1046-Space example

SEFI classification

DUT (Part ID)	Ion (Symbol)	Test mode	Effective LET [MeV.cm²/mg]	Run Duration [s]	Fluence (Effective) [ions/cm²]	Flux [ions/cm².s]	H Reset (single)	H Reset (multiple)	PO Reset	Power Cycle	SEFI (Total)	Cross Section/device [cm²]
2	Xe	I2 + oc	62.5	1084	1.53E+05	185	4	3			7	4.57E-05
3	Xe	I2 + oc	62.5	1208	1.94E+05	414	11	3			14	7.23E-05
2	Kr	I2 + oc	32	1044	1.44E+05	193	4	2			6	4.16E-05
2	Kr	I2 + oc	32	1172	3.26E+05	1024	5	8			13	3.99E-05
3	Kr	I2 + oc	32	919	2.12E+05	1306	8	9			17	8.02E-05
3	Kr	compress	32	757	4.28E+05	1585	6	3	2		11	2.57E-05
3	Fe	I2 + oc	16	972	6.90E+05	1235	10	2	1		13	1.88E-05
2	Ar	I2 + oc	8	633	5.57E+05	1896	12				12	2.15E-05
2	Ar	I2 + oc	8	534	1.07E+05	225	1				1	9.36E-06
3	Ar	I2 + oc	8	1012	6.93E+05	1186	11	3			14	2.02E-05
2	Ne	I2 + oc	2.6	526	7.73E+05	2281	5				5	6.47E-06
2	Ne	I2 + oc	2.6	564	1.00E+05	213	3				3	2.99E-05
2	O	I2 + oc	1.8	581	8.79E+05	2065	4	1			5	5.69E-06
2	O	I2 + oc	1.8	491	1.20E+05	244	0				0	
3	O	I2 + oc	1.8	480	8.50E+05	2500	3	1			4	4.70E-06

LS1046-Space example

SEFI cross-section

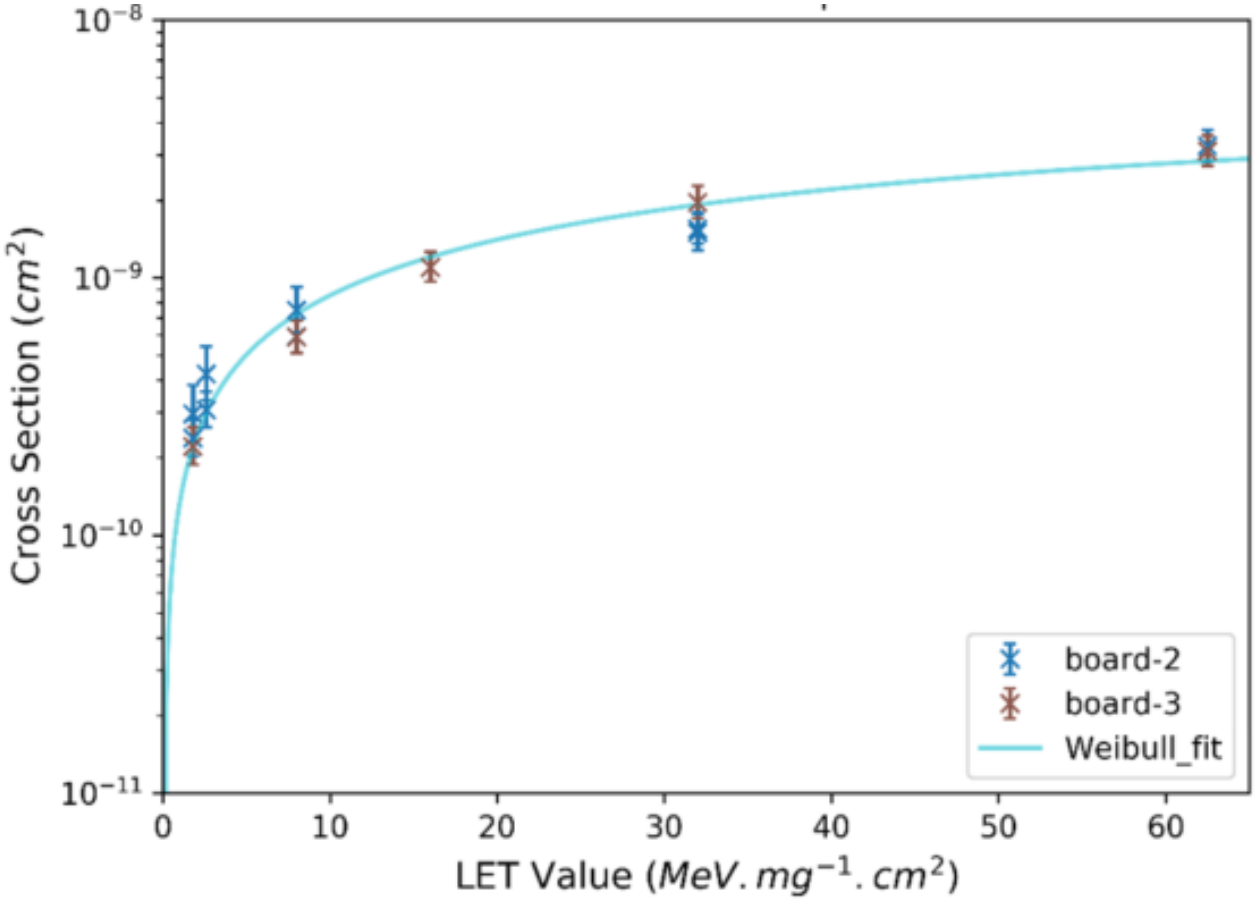


Weilbull parameters

A	6.92E-05
x0	0.5
s	0.83
W	34.75

LS1046-Space example

SEU (core) cross-section



Weibull parameters

A	5.09E-09
x0	0.1
s	0.81
W	80.16

LS1046-Space example

Peripherals (PCIe)

Run	Ion	Fluence [cm^{-2}]	duration	board	sd card	Tests running	PCIe errors	PCIe SEFI	PCIe effective fluence [cm^{2}]
RUN012	Ni	1.00E+06	1388	5	bin 19h41	nor, spi, eth, pci, ddr_ecc	0	3	9.17E+05
RUN013	Ni	1.00E+06	1951	5	bin 19h41	nor, spi, eth, pci, ddr_no_ecc	2	7	8.24E+05
RUN014	Ne	1.00E+06	876	5	bin 19h41	nor, spi, eth, pci, ddr_no_ecc	0	0	1.00E+06
RUN015	Ne	1.00E+06	829	5	bin 19h41	nor, spi, eth, pci, ddr_ecc	1	0	9.69E+05
RUN016	Kr	1.00E+06	2880	5	bin 19h41	nor, spi, eth, pci, ddr_ecc	1	5	9.32E+05
RUN017	Kr	1.00E+06	3018	5	bin 19h41	nor, spi, eth, pci, ddr_no_ecc	1	6	9.20E+05

LS1046-Space example

SEFI orbital error rate

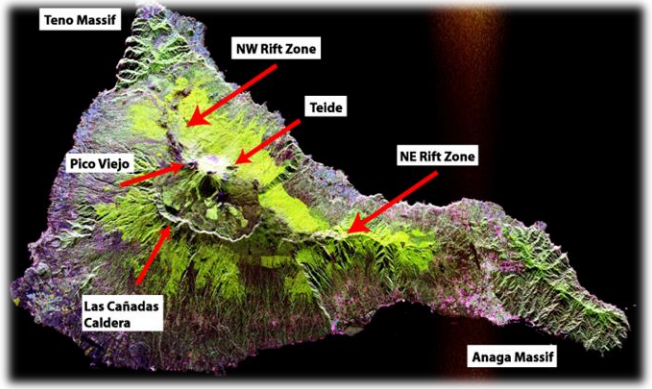
Orbit	GEO (35784 km)	GEO (35784 km)	GEO (35784 km)	ISS 51.50 400 km;400 km	ISS 51.50 400 km;400 km	ISS 51.50 400 km;400 km	Proba 2 99.28 720 km	Proba 2 99.28 720 km	Proba 2 99.28 720 km
Magnetic weather	quiet	quiet	quiet	quiet	quiet	quiet	quiet	quiet	quiet
trapped protons	AP8min	AP8min	AP8min						
solar conditions	solar min	flare (worst day)	flare (worst 5 min)	solar min	solar worst day	solar worst 5 min	quiet	solar worst day	solar worst 5 min
shielding	1 g/cm²	1 g/cm²	1 g/cm²	1 g/cm²	1 g/cm²	1 g/cm²	1 g/cm²	1 g/cm²	1 g/cm²
SEFI/day	0.01	11.70	43.50	0.00	0.01	0.03	0.01	2.61	9.71

New applications permitted

New applications – Focus on Earth observation

- Compute intensive components… but for which usage ?
  - “New Space” in the sense of doing things in Space that were not possible before
  - Processing data closer to the source - Edge computing

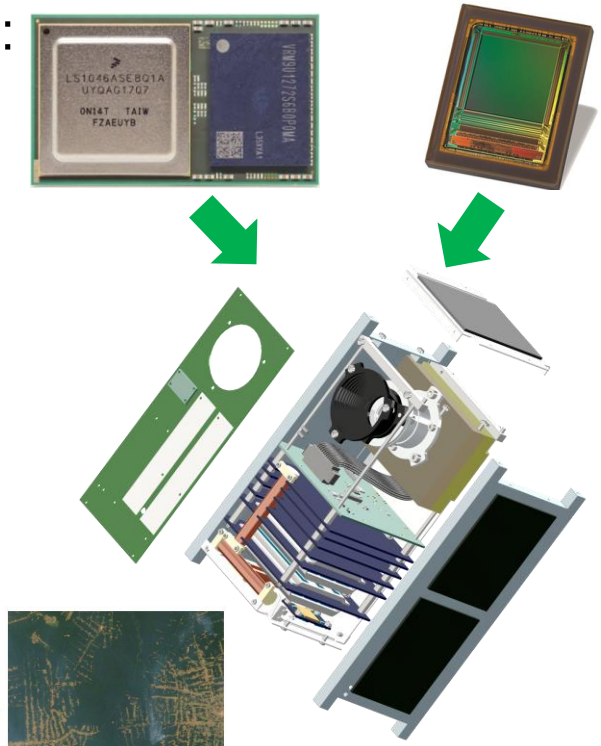
- Space based observation:
  - With visible, hyperspectral, and radar imaging
  - Observation of oceans, polar regions, volcanoes…
  - Early Warnings:
    - Monitor and warn for natural hazards
    - Look and protect from “unfriendly human activities”



- AI in Space is a new tool to extend those possibilities
  - Highly demanding in terms of computing resources

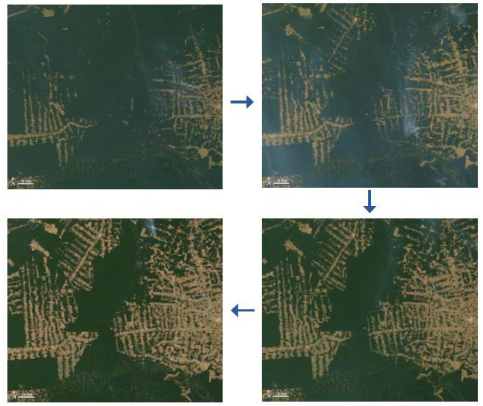
AI in Space - QlevEr Sat project

- Development & Launch of a nanosatellite for Earth observation :
  - Lead by CSUG
  - AI to process on-board the images
  - Embeds QLS1046-Space and EMERALD image sensor



- Technical advantages of the approach :
  - Pre-processed information sent to ground
  - Reduction of downlink bandwidth

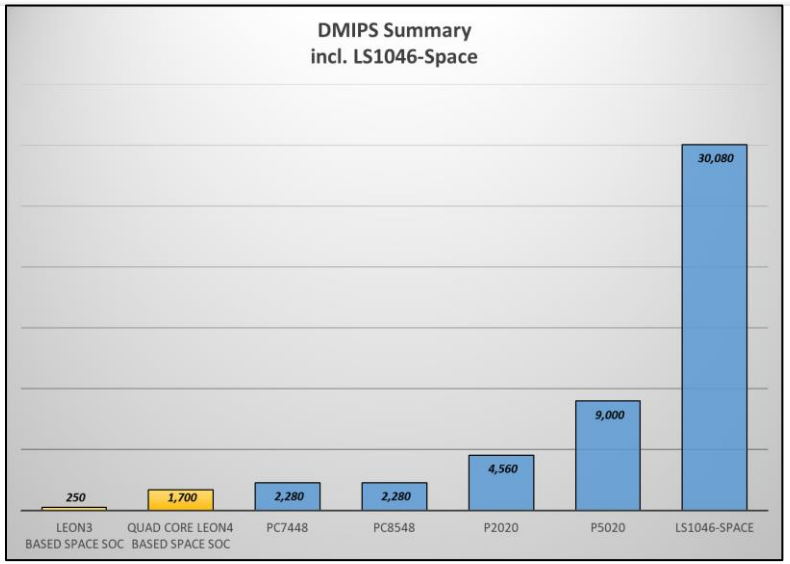
- Example use case: Observation of deforestation



- **Benchmark showed that QLS1046 can perform AI for image processing on-board**
- Proof of concept realized on ground
- Electronic architecture proposed

New applications permitted - Others

- Data crunching & image compression
  - High computing performance of LS1046 confirmed in practical use



- Telecommunication satellites:
  - More efficient modulation / demodulation schemes (e.g. E-SSA),
  - Constellations of small SatCOMs offering a better coverage with capabilities to handle large data rates for the IoT

- Heterogeneous data analytics and sensor fusion
  - Can also benefit from AI: AI can see things in the data that are not visible to the “human eye”

Quick glimpse - Availability of compute intensive parts

Space Rad Tol Quad ARM® Cortex® A72

- ✓ Performances, Ecosystem & Reduced Power
- ✓ Quad 64-bit Arm® Cortex® A72, 1.8GHz, 30kDMIPS
- ✓ 2MB total L2 cache, 1-10GbE, PCIe 3.0, UARTs, SPI, I2C, …

Schedule

✓ EMs	Available
✓ EQMs	Oct 2021
✓ FMs	Feb 2022

LS1046-Space

Performances, Compact, Fault Tolerant

- ✓ 4GB; 72 bits (64 bits data + 8 bits ECC)
- ✓ 2.4GT/s target, Validated at 2.1GT/s so far
- ✓ Size 15mm x 20mm x 1.92mm

Schedule

✓ EMs	Available
✓ EQMs	Sep 2021
✓ FMs	Jan 2022

DDR4T04G72M

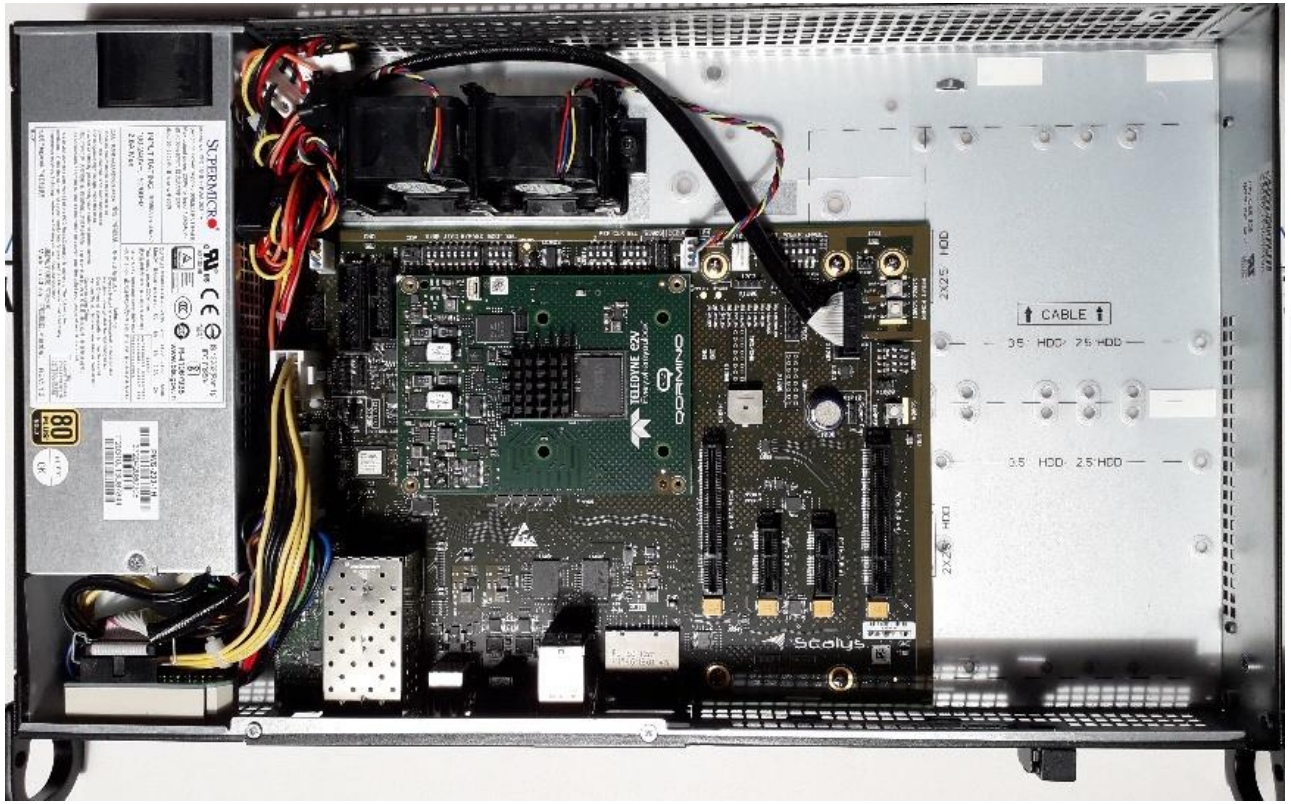
QLS1046-Space

Schedule

✓ Development Kit	Available
✓ EMs	Mar 2021
✓ EQMs / FMs	Q1 2023

Want to see how fast it can get with your application ?

Development kit is available for QLS1046-Space



Questions & Answers

Thanks for your attention

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