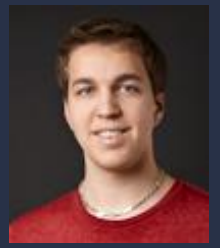

A. Ambühl


F. Droz


J. Holzer


C. Meier


D. Nguyen


C. Pache


J.-C. Roulet


A. Ummel

S. Humbert

New Space Flash LiDAR: Development Trade-Offs and Applications

Christophe Pache, Group Leader, CSEM
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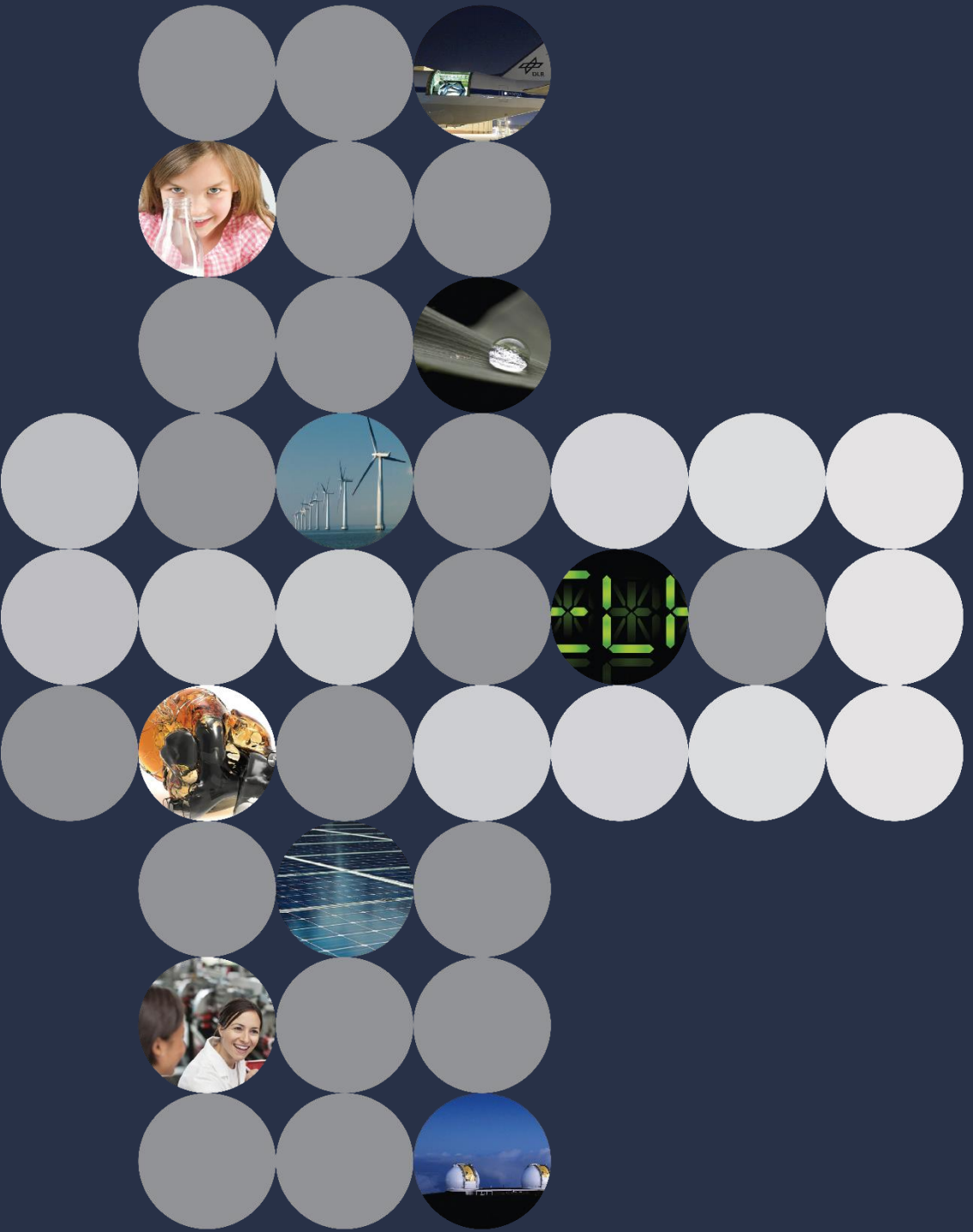


CSEM

*Facing **the** challenges of **our** time*

Our **mission**

Development and transfer of world-class (micro-)technologies to the industrial sector in order to reinforce its competitive advantage.

- Cooperation agreements with established companies
- Encouraging the creation of start-ups

CSEM at a glance

96.9

Turnover
(Mill. CHF)

44

Nationalities

552

Persons

44

New ventures

233

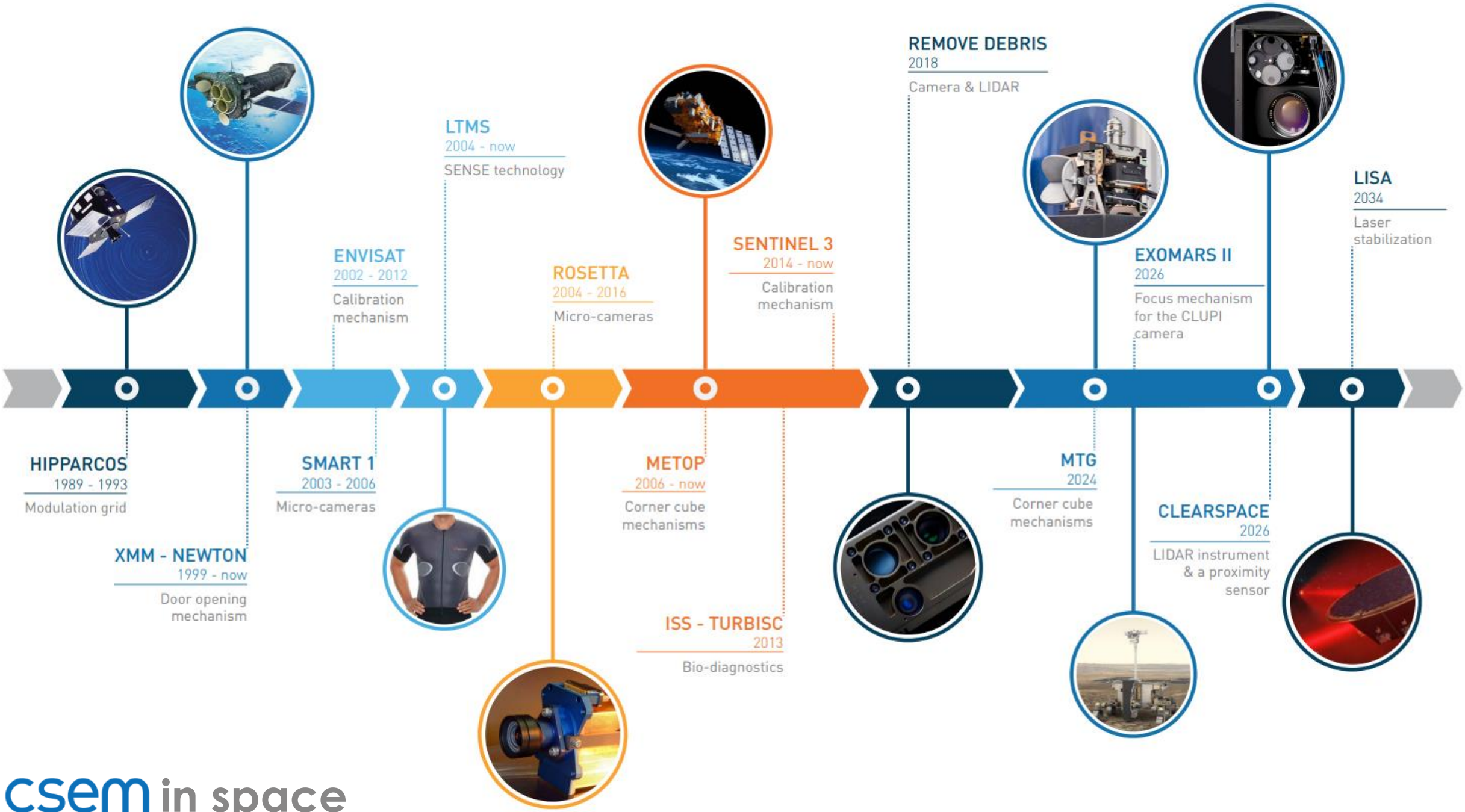
Industrial clients

205

Overall patent family

75

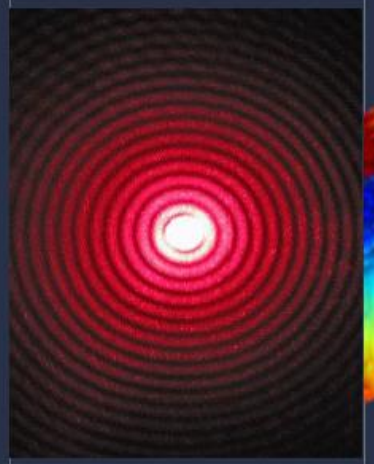
European
projects



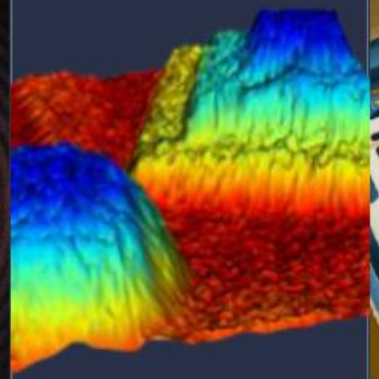
csem in space

SCIENTIFIC INSTRUMENTATION

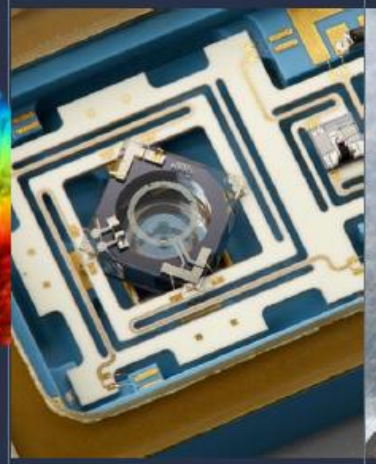
LASERS



LIDARS



QUANTUM SENSORS



SPACE MECHANISMS

ADDITIVE MANUF

WATCH MECHANISMS

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Expertise

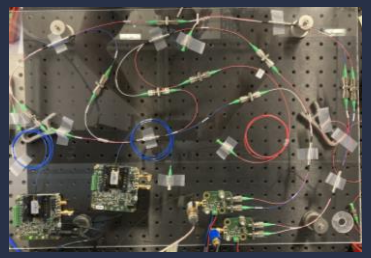
- System design & integration
- Miniaturisation

1. Flash imaging LiDAR

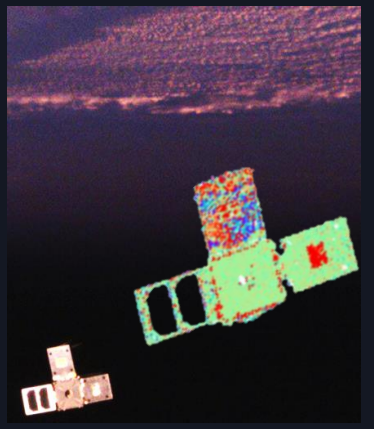
- Snapshot acquisition (< 20 ms)
- High spatial resolution
- Adaptive field-of-view

2. FMCW LiDAR

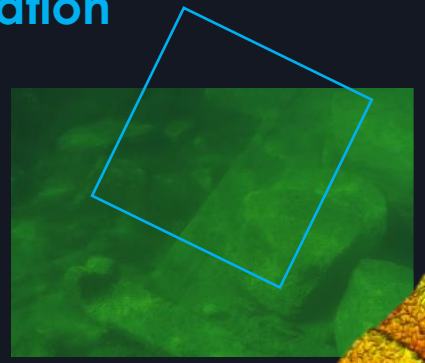
- Invisible
- Coherent
- High axial precision (< 50 µm)

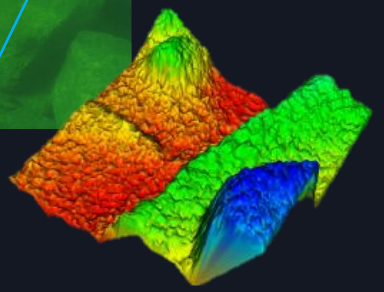


Applications



- **Space: 3D pose estimation**
- **Bathymetry**
- All-weather navigation
- Geodesy
- Environment perception





- Surface metrology – additive manufacturing
- Gas sensing

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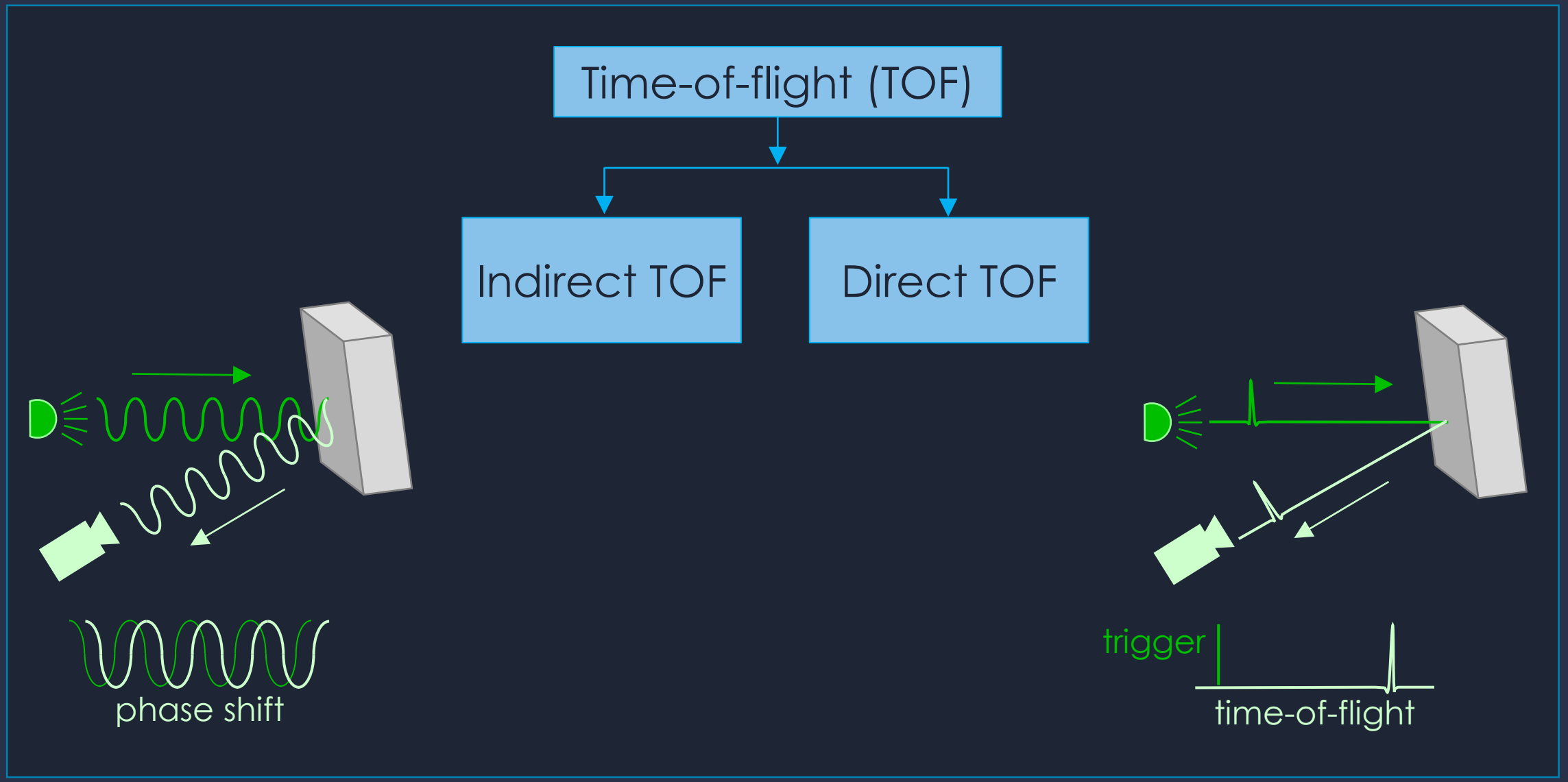
Flash imaging LiDAR

CSEM's developments & positioning

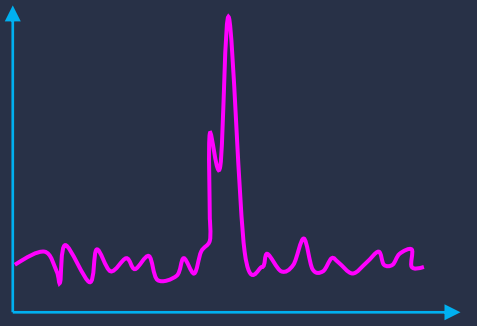
Imaging TOF technologies



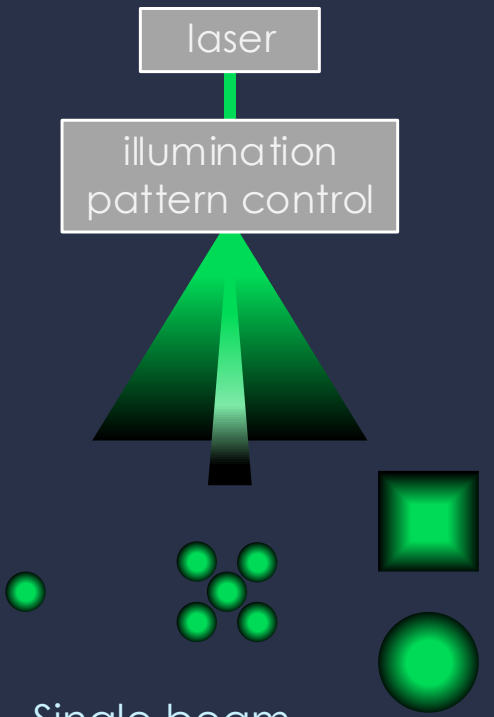
Hybrid flash imaging LiDAR

System design

Time-gating & multiple echoes

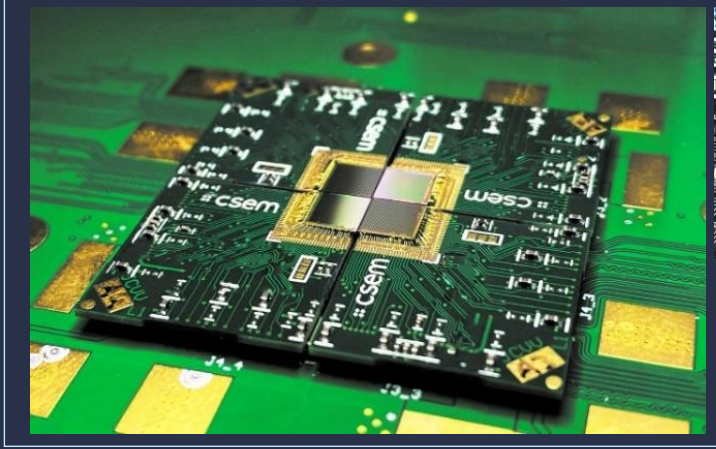


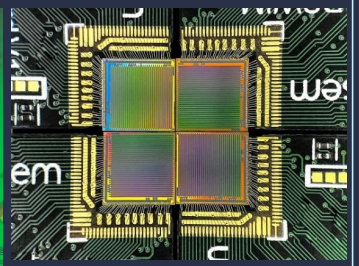
Illumination pattern control



- Single beam
- Multiple beams
- Large field-of-view

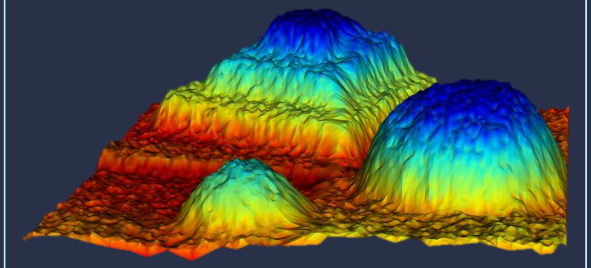
Focal plane: time-of-flight detectors





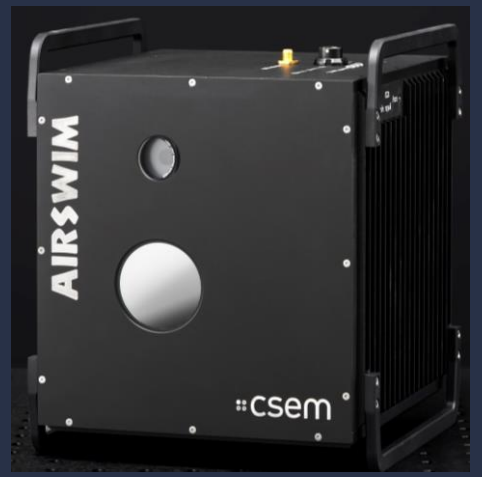
FONDAZIONE BRUNO KESSLER

Processing



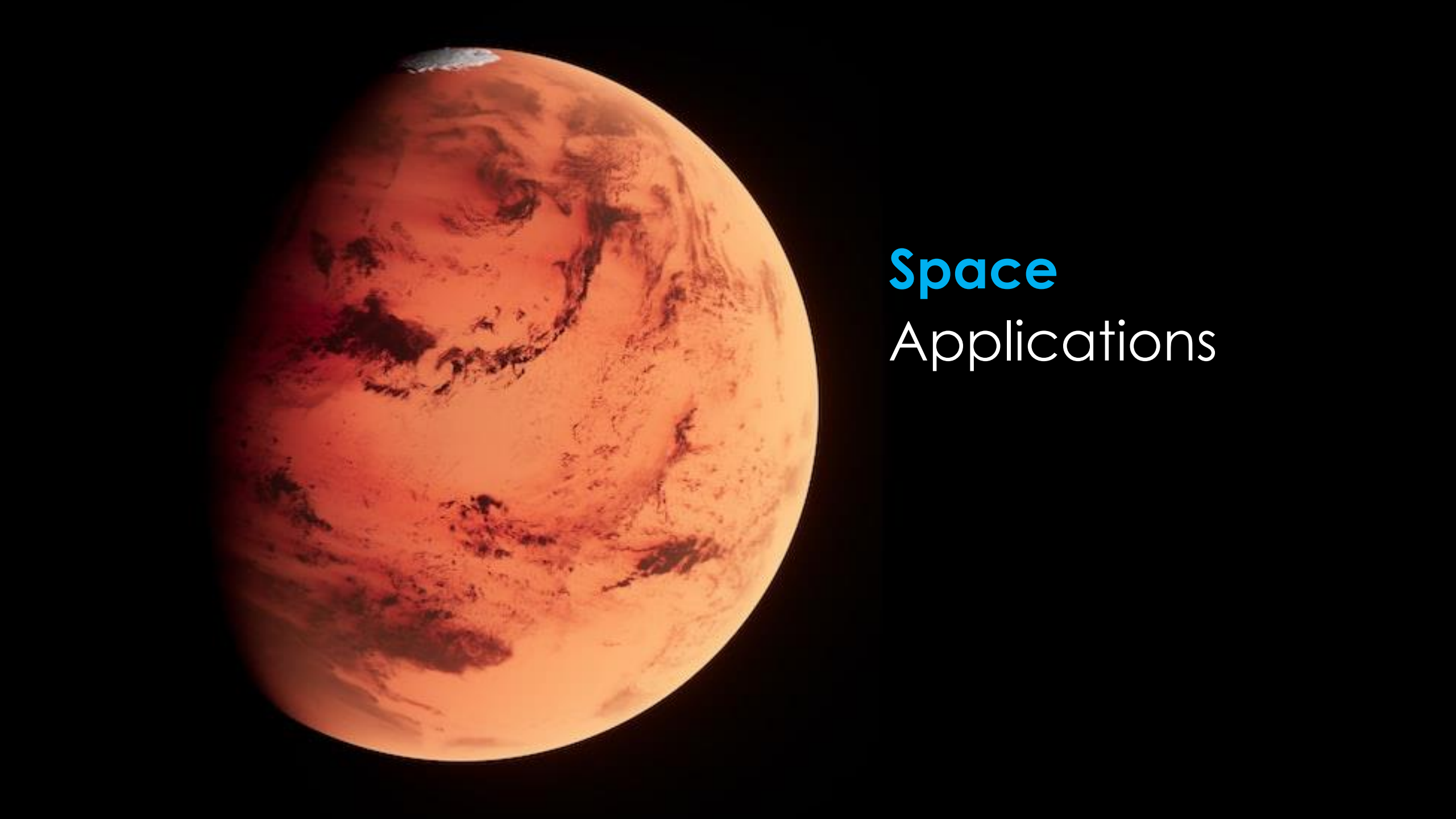
Current LIDAR specifications

Specifications	AIRSWIM	RemoveDebris
Application	Bathymetry	Space (rendezvous)
Architecture	d-TOF	i-TOF
Laser	Pulsed, Class 4, λ = 532 nm	Laser diode, Class 4, λ = 808 nm, cw mod.
Sensor resolution	128 x 128 2023: 256 x 256 or 512 x 512	120 x 160
Precision	< 5 cm at 100 m in air	< 10 cm at 60 m
FOV [°]	5 - 20	20
Size [cm^3]	20 x 17 x 19	10 x 10 x 15
Weight [kg]	6.5	< 2
Power consumption [W]	< 55	15
Frame rate [Hz]	> 4 (target: 10)	20



AIRSWIM

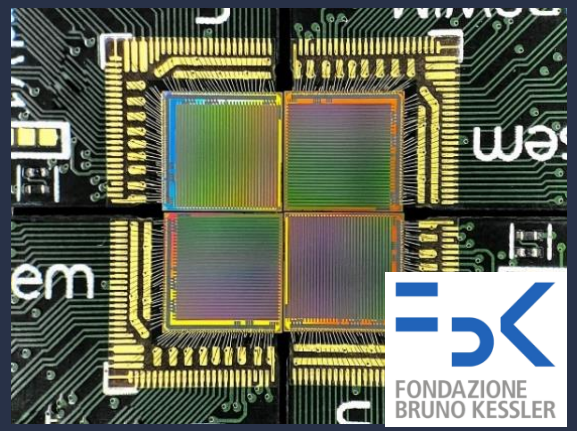
Remove Debris



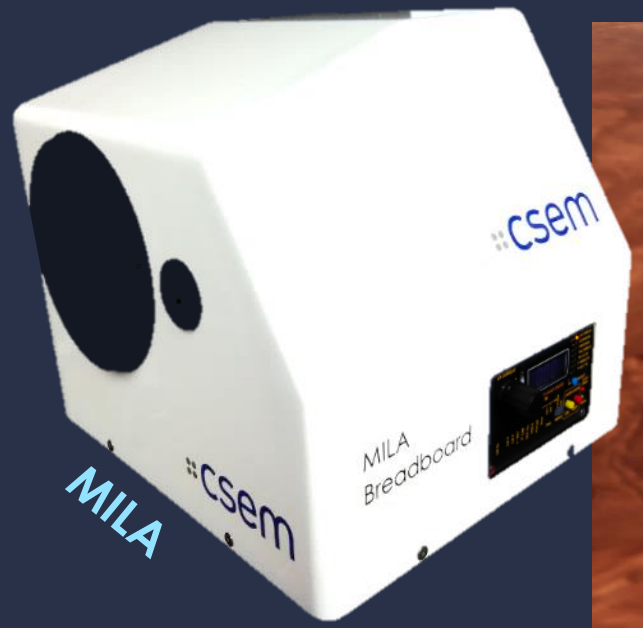
Space
Applications

High-end development path

- **Landing** application
- Direct-TOF SPC architecture, 2018: TRL4 delivered to ESA

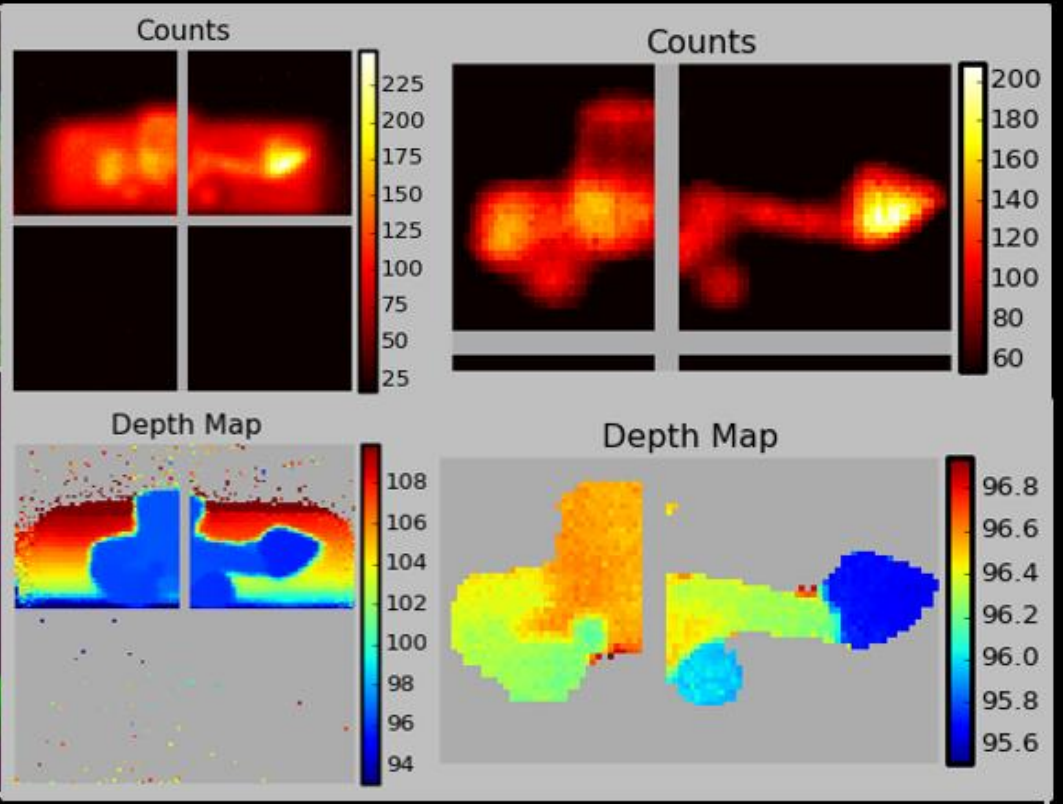


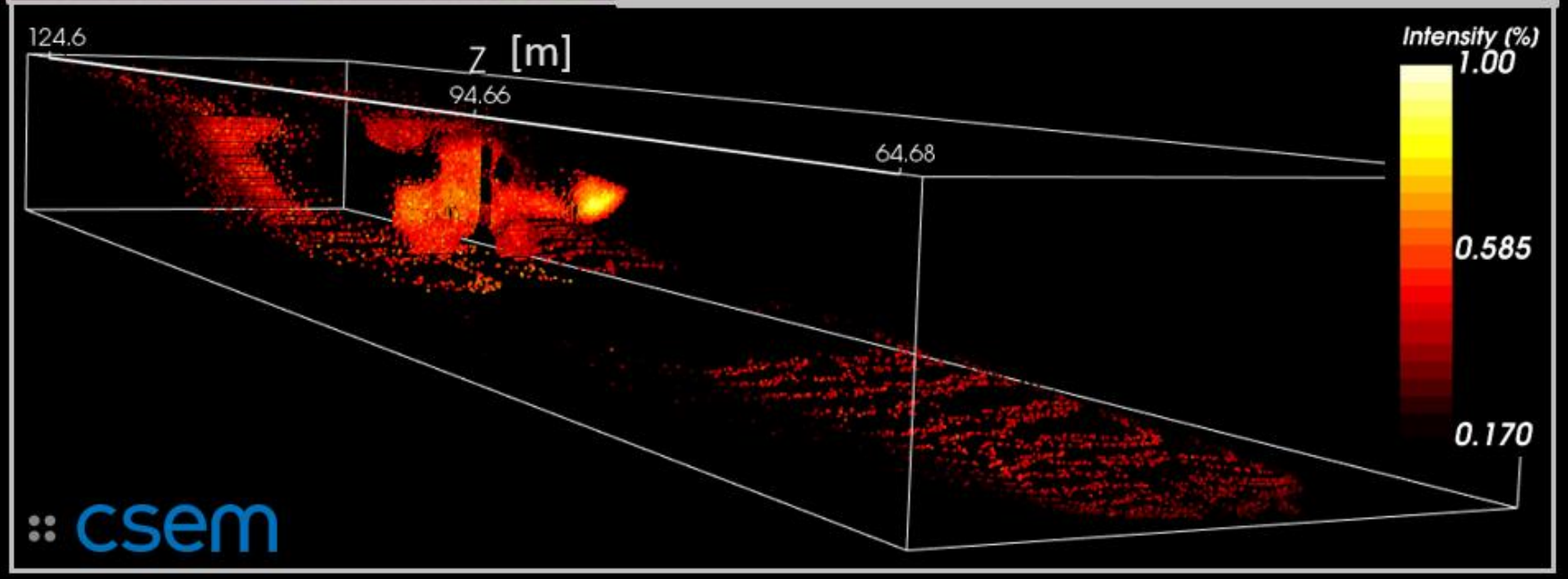
MILA64 detector



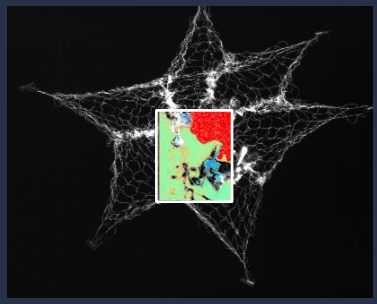
MILA

Demonstration at 100 m

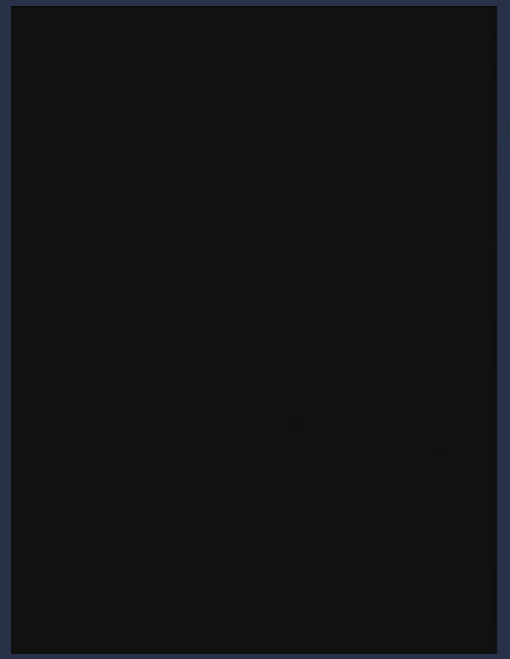




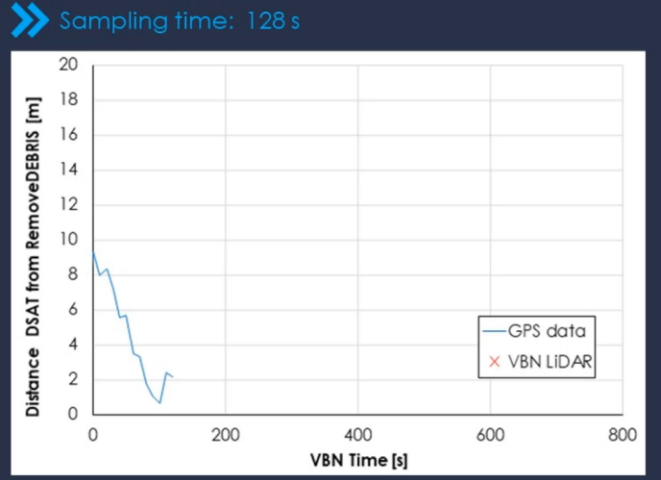
Debris removal missions – New Space

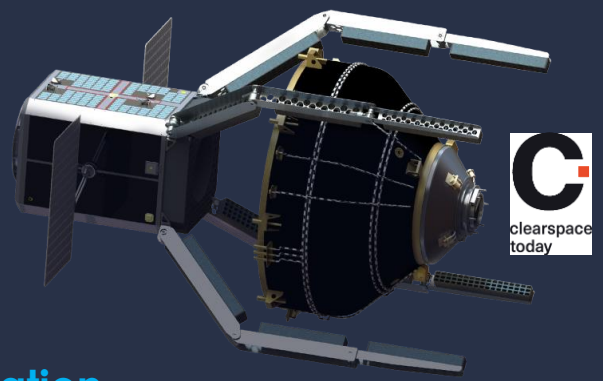


- **RemoveDEBRIS**
  - Launch with SpaceX in April 2018
  - NET and VBN in-orbit experiments
  - Mission end April 2019



VBN experiment data





- **ADRIOS**
  - Launch: 2025
  - **Further miniaturisation**
  - **Embedded processing**, i.e. system-on-chip

Confirmed potential for **future commercialisation** (in-orbit maneuvers)

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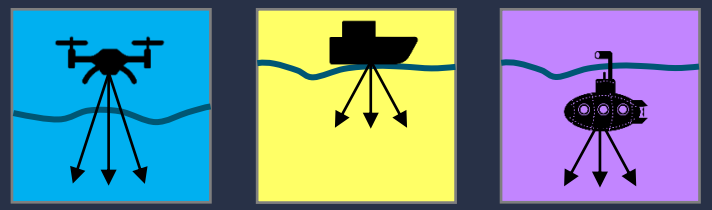
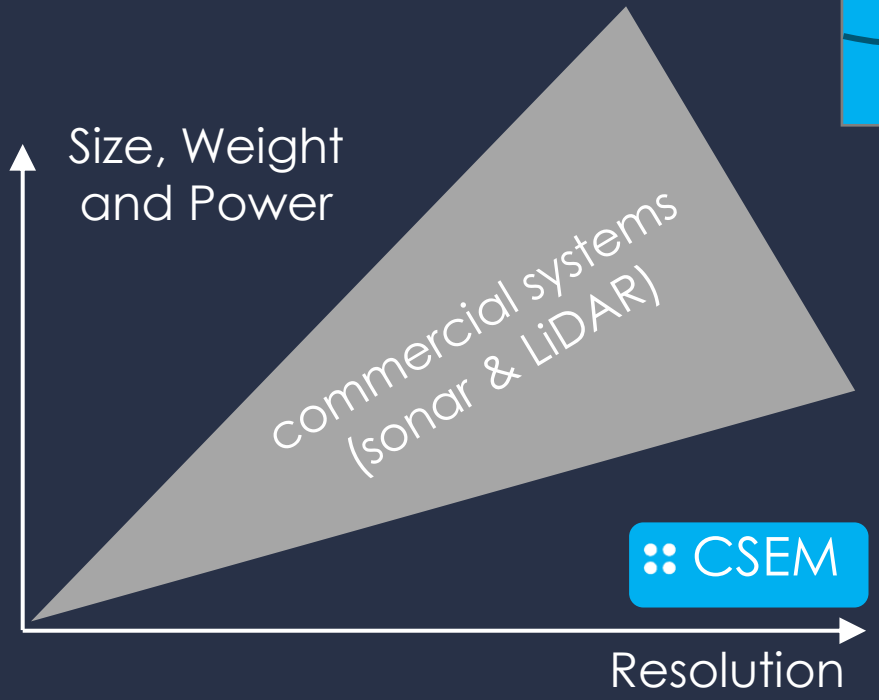
Bathymetric Applications


UNDERWATER 3D IMAGING
Multi-platform flash LiDAR

CSEM key differentiators and positioning





- ✓ High precision
- ✓ Low cost

Synergies with **Space**:

- ➢ **Remote operation → autonomy**
- ➢ **Low power**
- ➢ **Miniaturisation constraints**

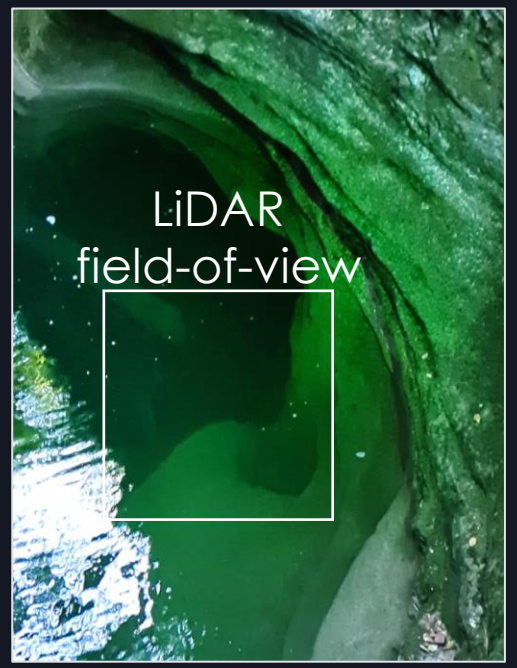
Shallow water 3D mapping

Infrastructure monitoring

Objects detection

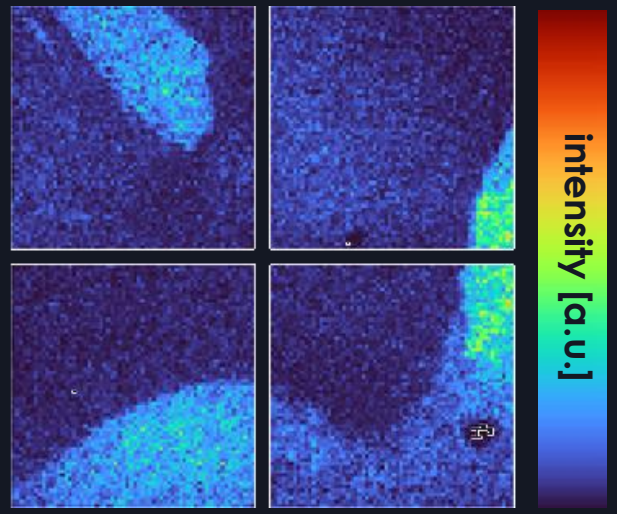
Airbone underwater imaging

MARITIME ROBOTICS

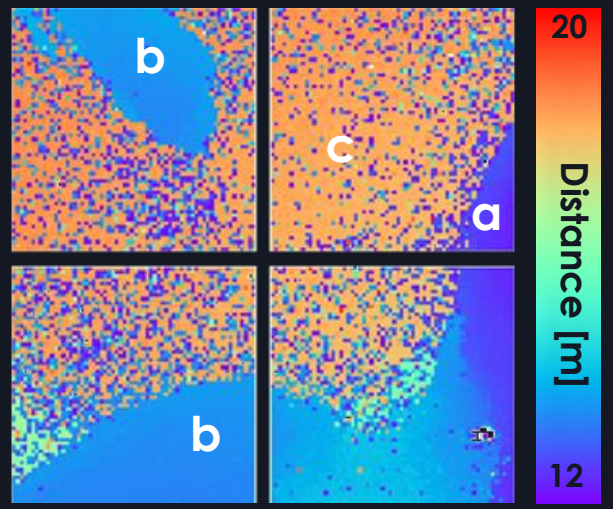


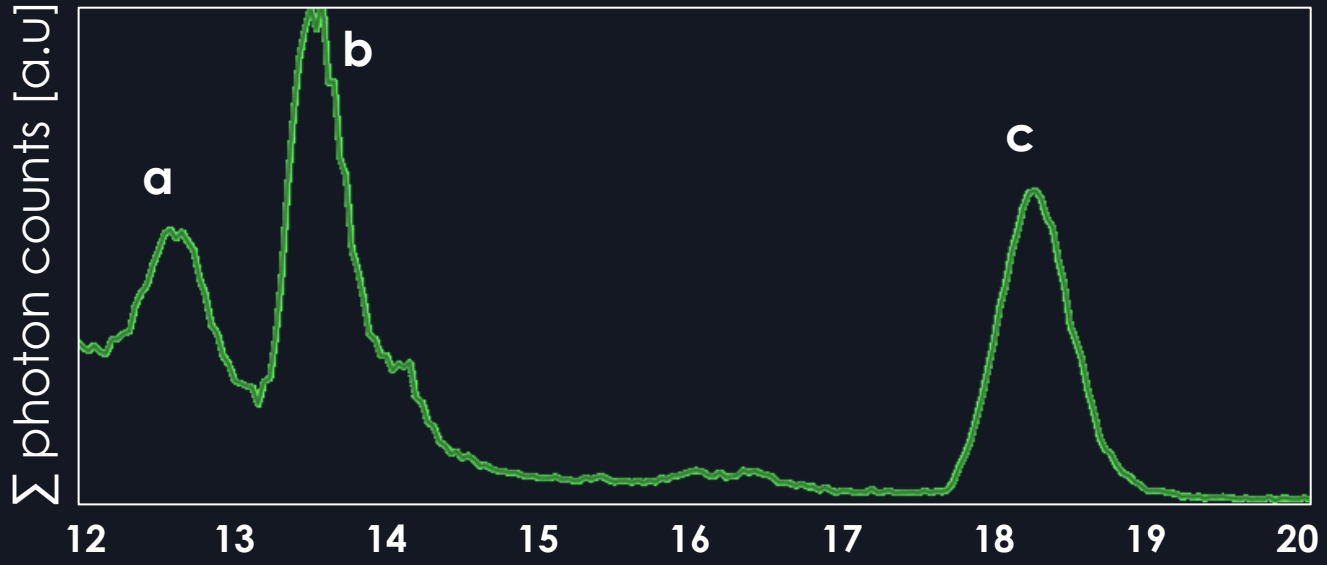
Areuse river,
Neuchâtel, Switzerland

Intensity

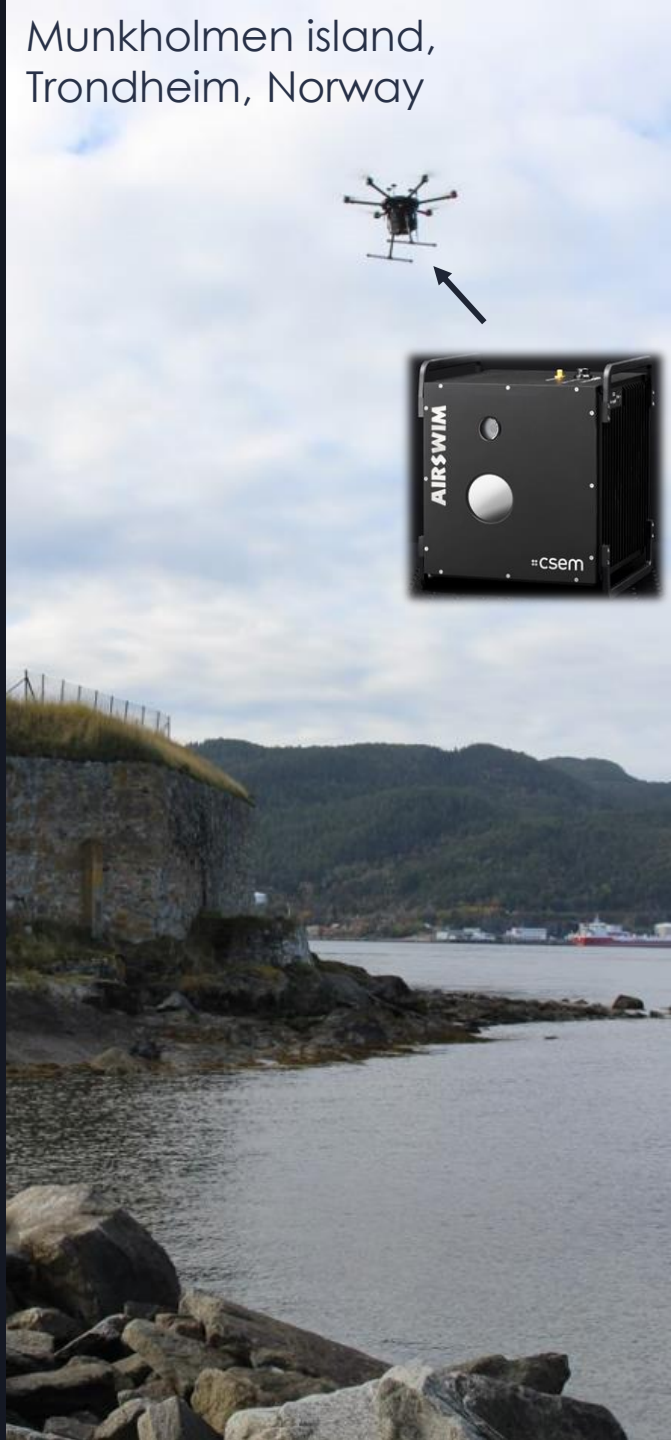


Depth map





Munkholmen island,
Trondheim, Norway



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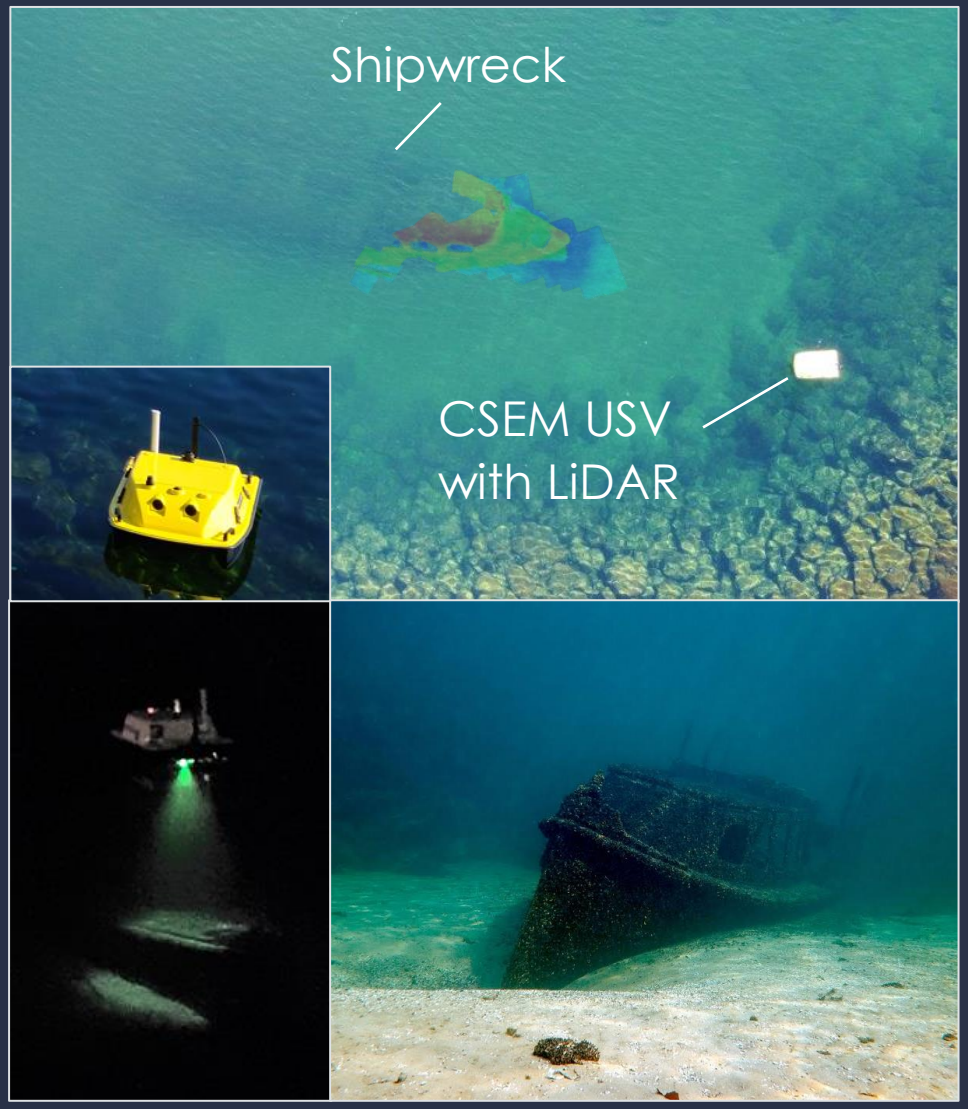
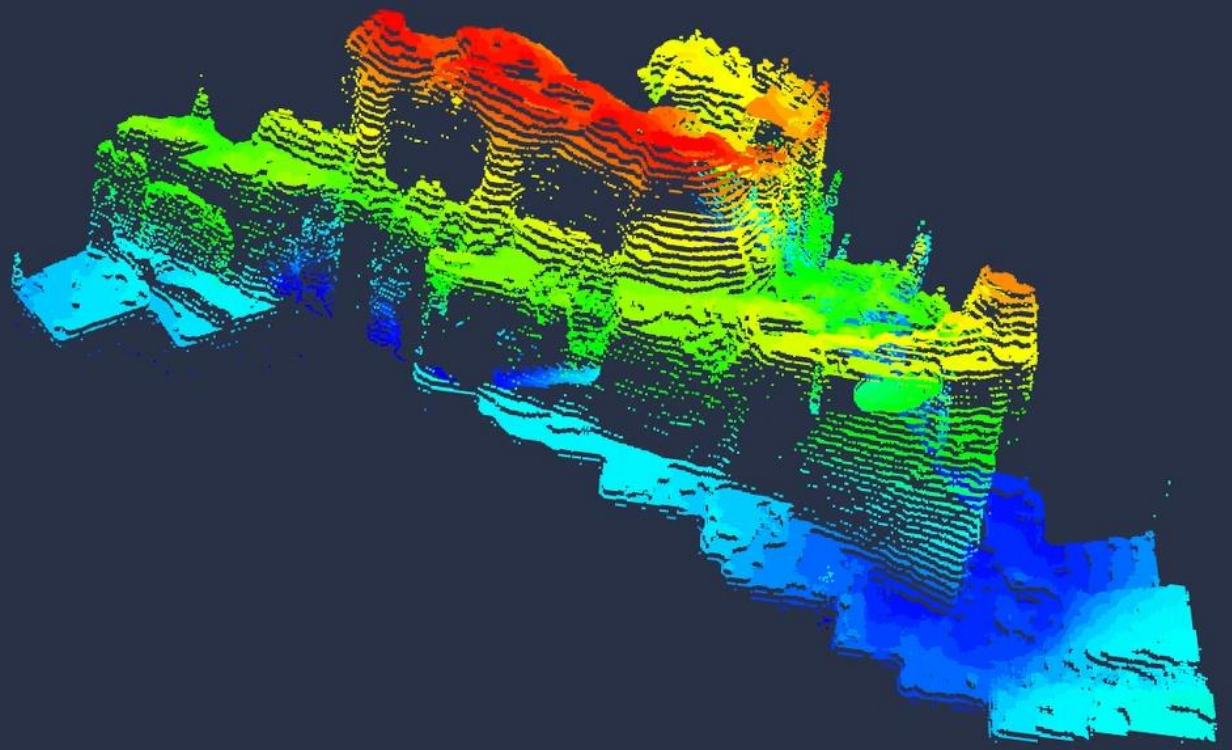
Demonstration from unmanned surface vehicle (USV)





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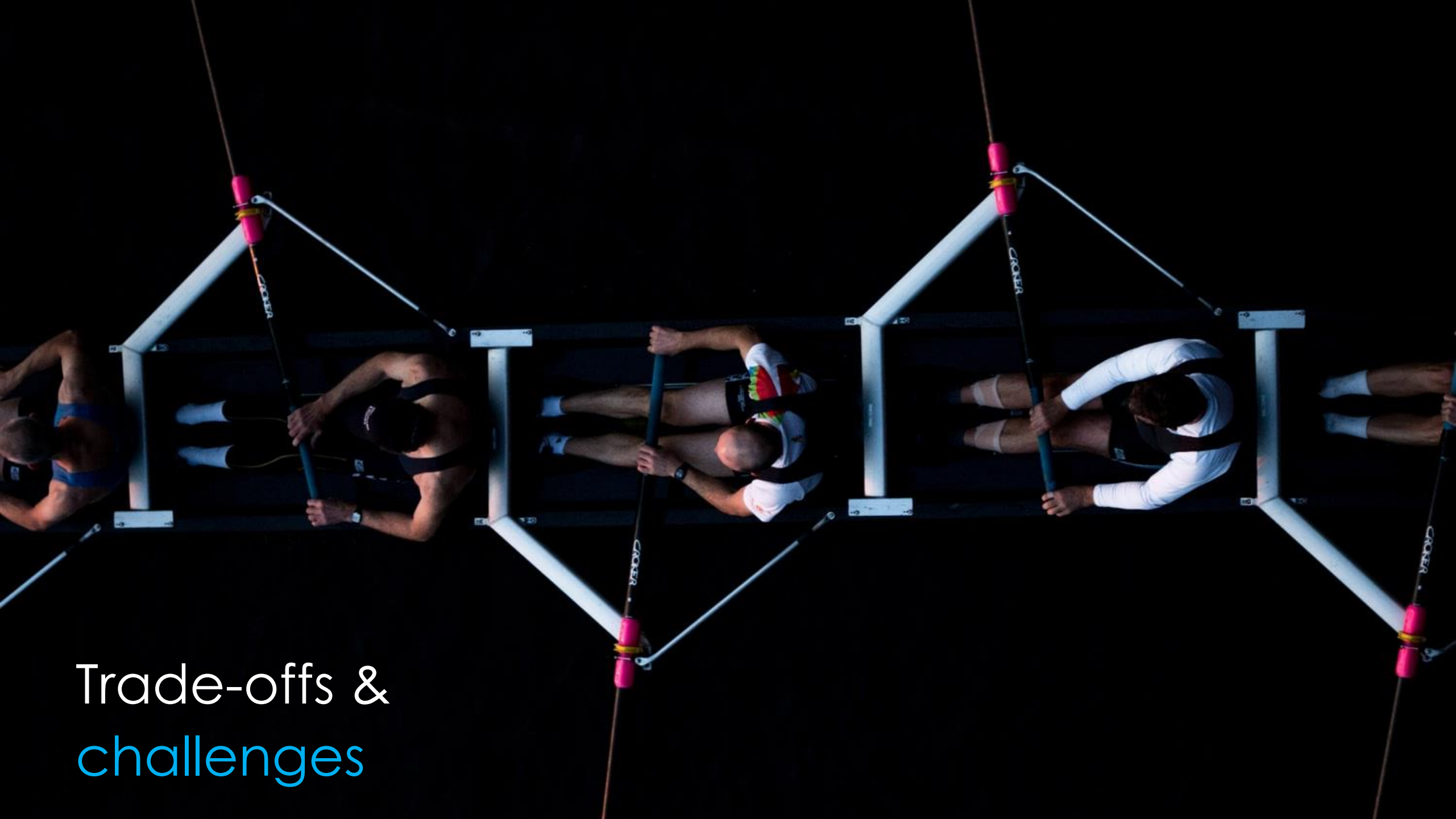
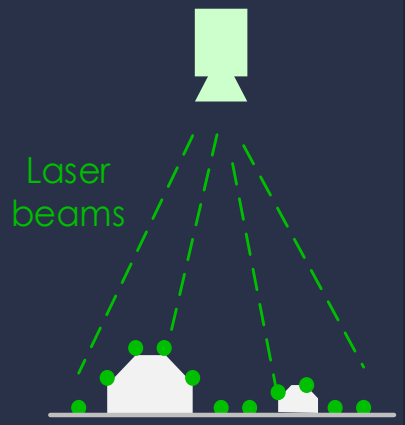
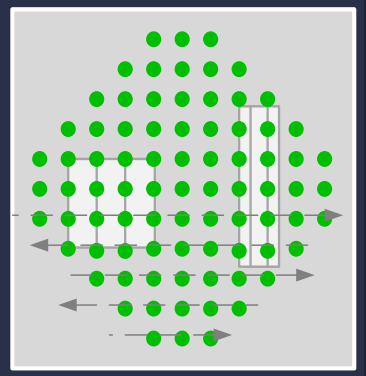


Trade-offs & challenges

Architecture comparison

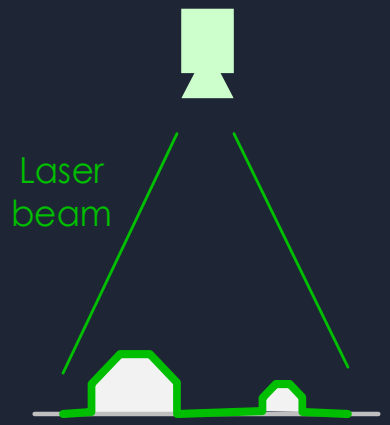
Scanning

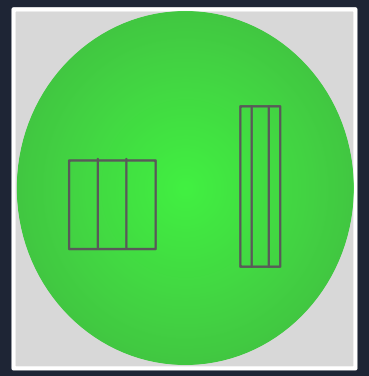




raster scan

Flash





single snapshot

- 👍 **Simplicity & reliabiliy**: better integration & product lifetime
- 👍 **High resolution**: diffraction-limited, no influence of possible scanning mechanism precision
- 👍 **Snapshot acquisition & high frame rate**: robust against motion blur and vibrations

- 👎 Limited field-of-view and/or range
- 👎 Sensitivity to sunlight → optics & electronics mitigations

➢ Well-suited for certain applications

➢ Need for adaptation of **mission requirements**

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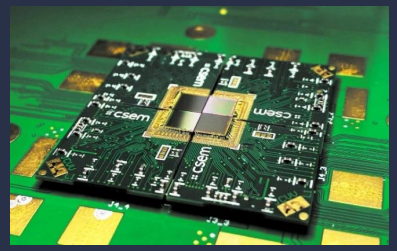
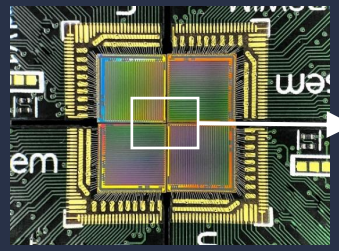
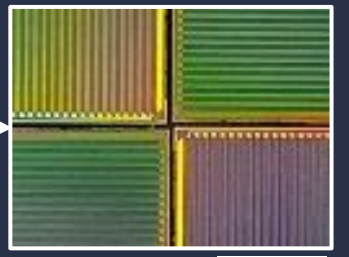
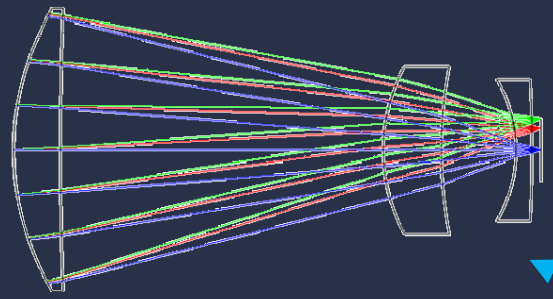
Multidisciplinary system design



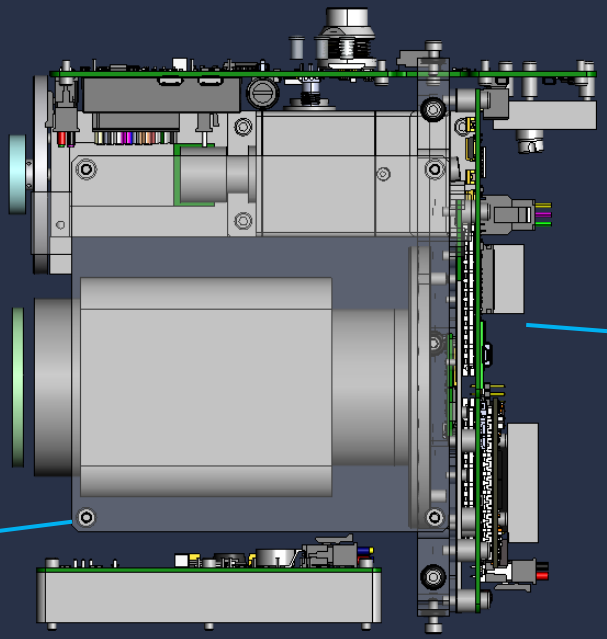




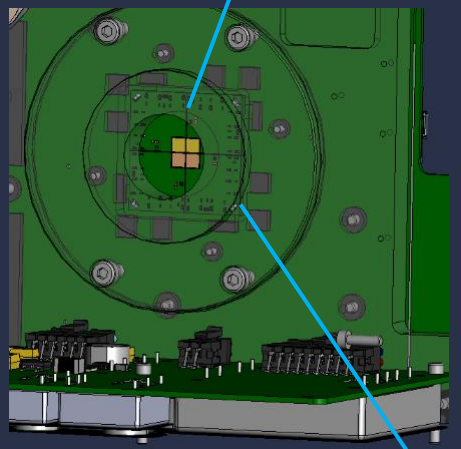
- **Optical** design



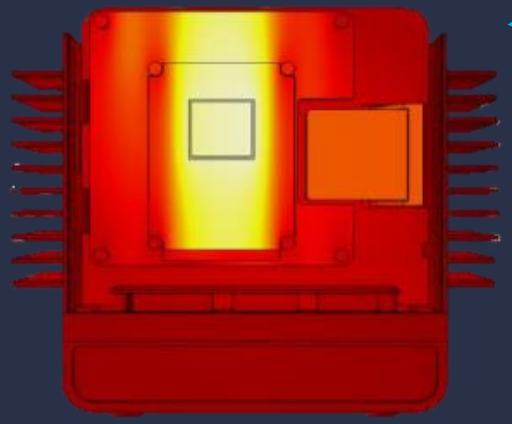
- **system** integration



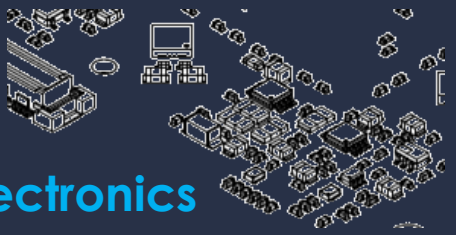
- **time-of-flight detectors**



- **heat** & vibration management



- massive **data flow** and **embedded processing**



- **fast electronics** (active gating)

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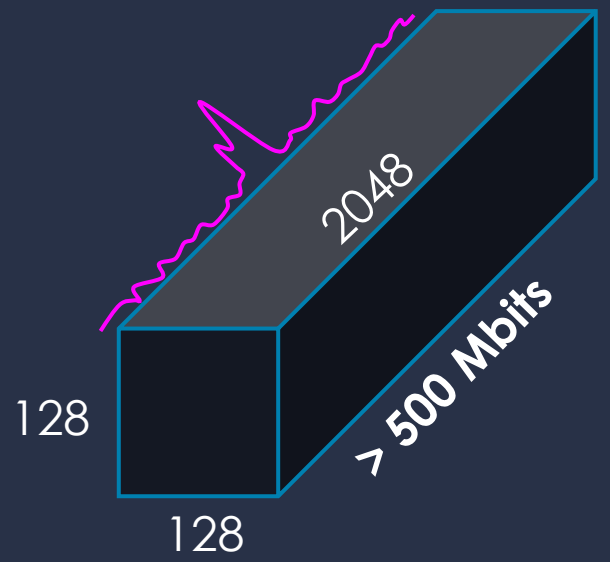
Data flow & processing

- Targeted performances
  - Frame rate: 10 Hz
  - Exposure time: < 20 ms

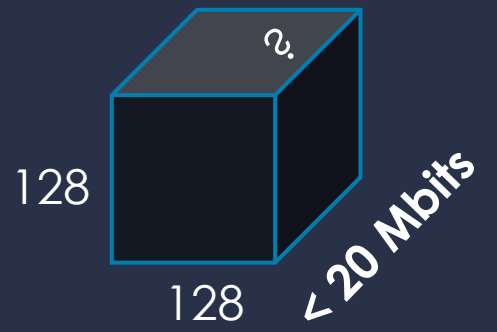
massive data rate:
> 625 GB/s

- ➢ **Parallel** read-out
- ➢ Fast memory access
- ➢ Use state-of-the-art **system-on-chip**

- Embedded real-time processing



real-time
compression factor: 25



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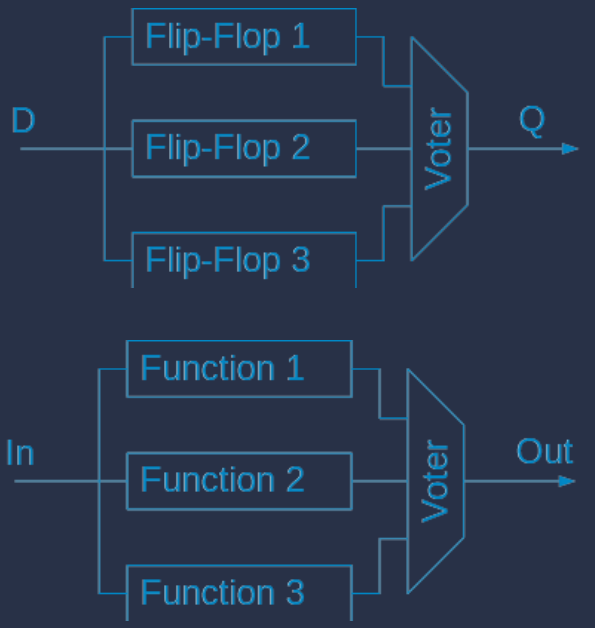
New Space electronics design – reliability risk assessment

Hardware	SW/FW mitigations	Advantages	Drawbacks
Space-grade	• Embedded redundancy • Memory protection	• Qualified technology	• Expensive • Lack of performances
COTS	• Additional redundancy • Memory & configuration protection (scrubbing) • Power control • **Supervision**	• Low cost • Recent technology: high perf. & ease of integration	• Higher risk on reliability

Redundancy



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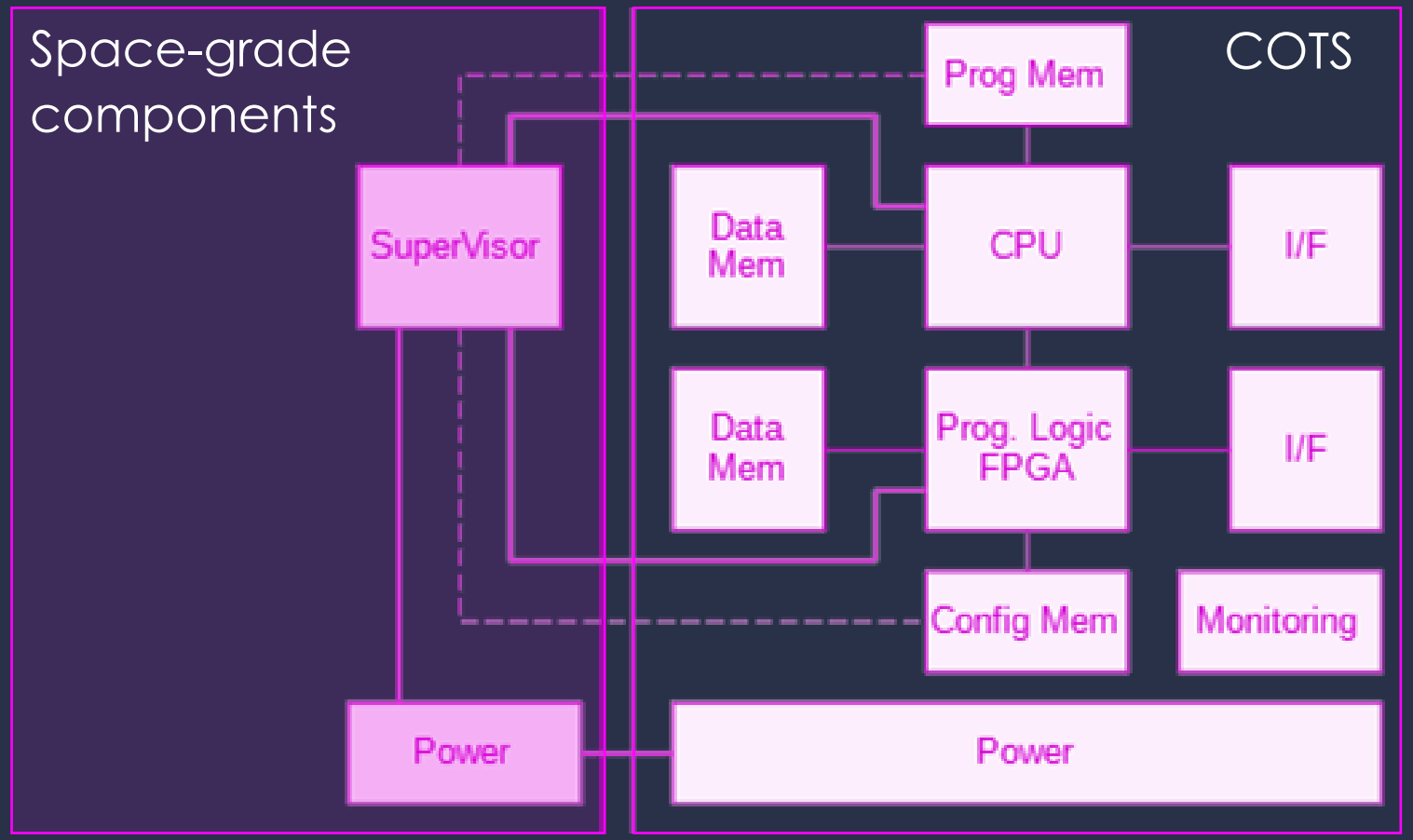
System-level mitigations at hardware level

- Enhanced reliability and performance at reasonable cost
- Mitigate risks of propagating damages to spaceraft and system itself



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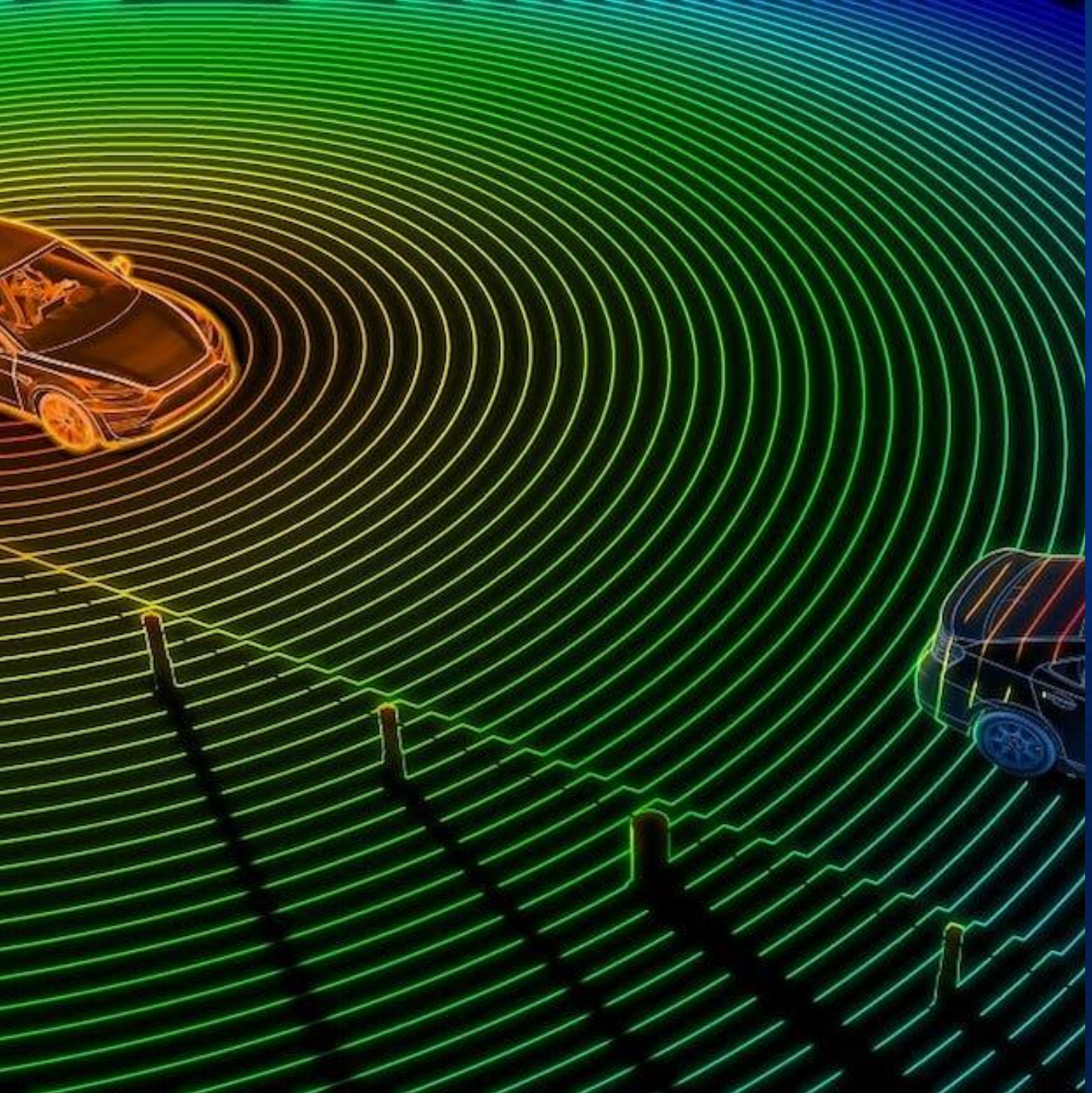
Opportunities



Thank you for your attention!

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