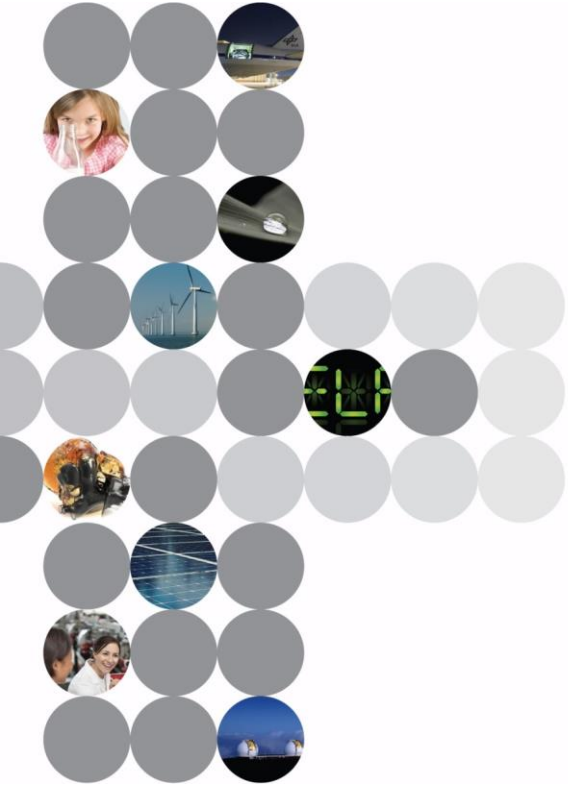


Sensors for LiDAR and TOF

Chur, 21.06.2018

Alexandre Pollini
Senior project manager, lead on CSEM LiDAR program

Holy grail quest for autonomous navigation (automotive) LiDAR

Image from movie “Monty Python and the Holy Grail”

1. Reliability
2. Low-cost
3. All-weather
4. Timestamped 3D images within range precision
5. Calibrated measurements (e.g. B&W shift)
6. Field-of-view: 360° in AZ and EL
7. Nonmechanical scanning
8. Measurement rate to avoid motion artefact

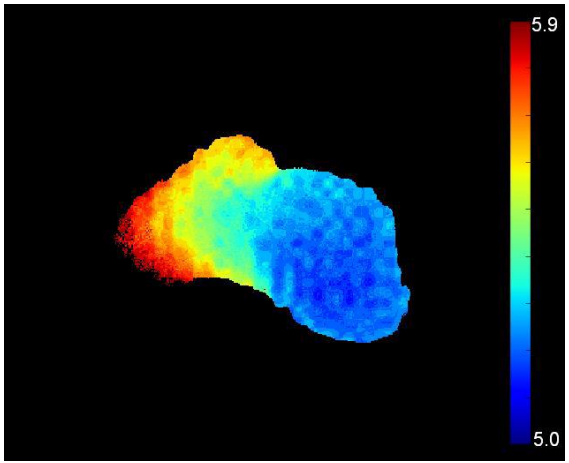
(from SPIE-Optical Engineering)

CSEM at a glance

Our mission

Development and transfer of microtechnologies and electronics to the industrial sector to reinforce its competitive advantage via:

- Cooperation agreements
- Creation of start-ups
- Licensing (technology, IP, algorithms)

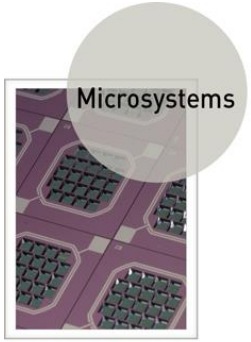


Status

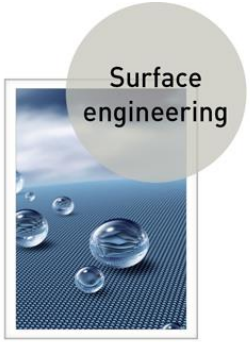
Incorporated, not-for-profit **RTO**, supported by the Swiss Government

- Public-private partnership
- Swiss watchmaker heritage

CSEM technology platforms to foster innovation

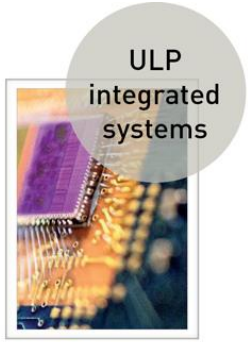


- Design & process
- Integration & packaging



- Bio-surface engineering
- Nano-surface engineering
- Printable electronics

- Automation
- Scientific instrumentation
- Medical technologies



- System-on-chip
- Vision systems
- Wireless

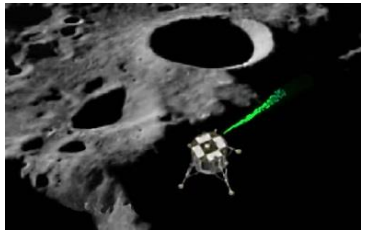
- Emerging & thin film PV
- PV-cells & modules
- Energy systems

Most needed expertises for LiDAR

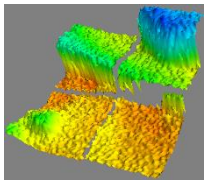
LiDAR development fields

- **Atmosphere probing (90's to now)**
  (e.g. aerosols, clouds or ash detection, optical comm. terminals)
  → airborne LiDAR for Geophysica stratospheric aeroplane

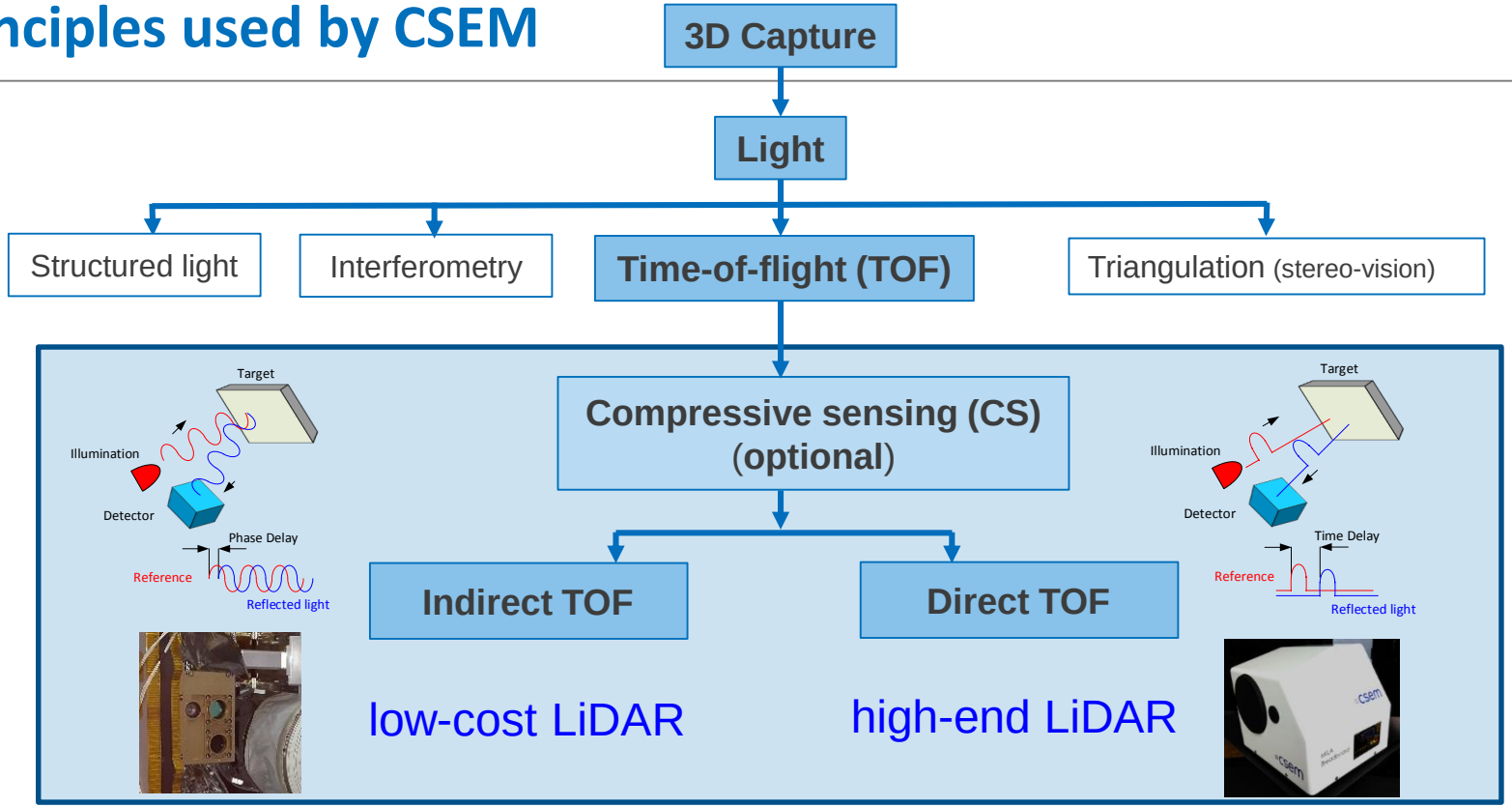
- **Space (2008-now)**
  - **Landing** on celestial object (e.g. Mars sample return mission):
    high velocities (30-40 m/s), limited on-board processing resources,
    low and uniform target albedo (Moon 0.07)
    = **Requires state-of-the-art Imaging LiDAR**
  - **Rendezvous** (e.g. automatic space debris removal):
    low velocities, processing resources for datafusion, often high target albedo
    = **Relaxed operation constraints → lower cost solution**



- **Diversification with ground applications (now)**
  (e.g. bathymetry, drone/helicopter flying in all-weather, geodesy, etc.)

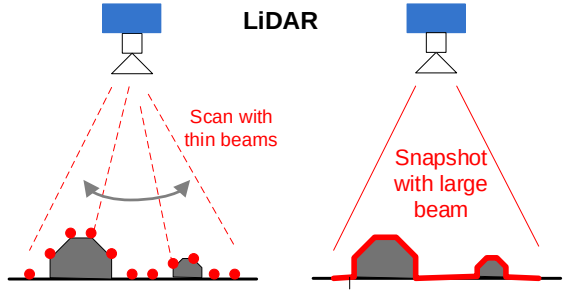


TOF principles used by CSEM



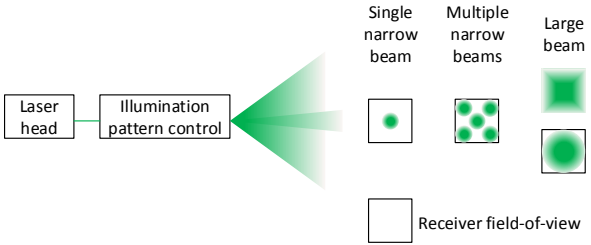
Advocate of Hybrid Flash Imaging LiDAR concept

- **Flash LiDAR**



- **Design advantages**
  1. Solid-state architecture
  2. Simplicity (less mechanical parts)
  3. Robustness (ease micro-vibrations isolation)
  4. Small form factor (no scanning mechanism)
  5. Independant from other sensors

- **Hybrid → System = 2D TOF detector + illumination pattern control**



- **One instrument for:**
  1. Single distance/altitude
  2. Attitude, multiple distances
  3. 3D imaging

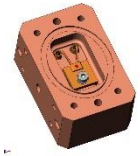
- **Adaptation to:**
  1. Range, propagation medium or relative velocity change (e.g. clear sky / fog)
  2. Instantaneous available data transfer rate and processing bandwidth

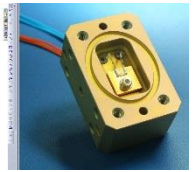
LiDAR Value Chain, positioning

csem

Component

- Illumination head (laser, vcsel)
- TOF detector
- Lens, diffuser, DOE
- Optics
- Spatial light modulator
- FPGA
- Processor





Sub-systems

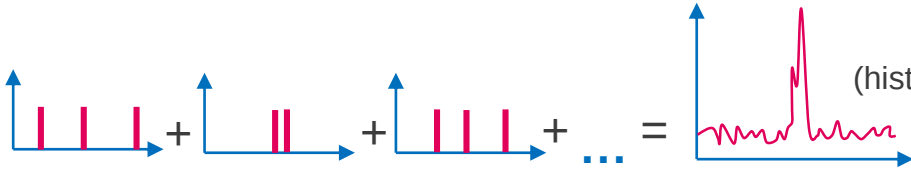
- Illumination source
- Focal plane
- Optics
- Drivers
- Read-out circuits
- Electronic boards

System

- Assembly
- Integration
- Synchronisation
- Illumination pattern
- Testing
- Calibration

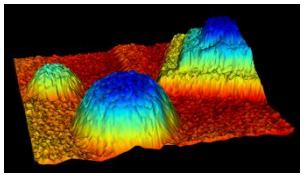
Embedded processing

- Real-time
- Histogramming
- Multi-exposure fusion
- Peak detection
- LOS (Az, El) / Distance
- Compressive sensing



Application

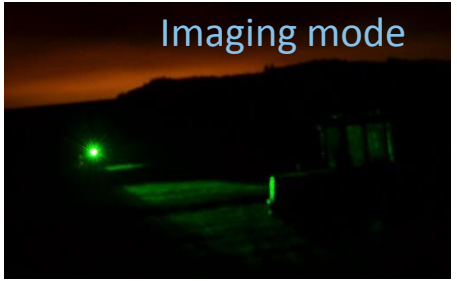
- Depth map
- User interface

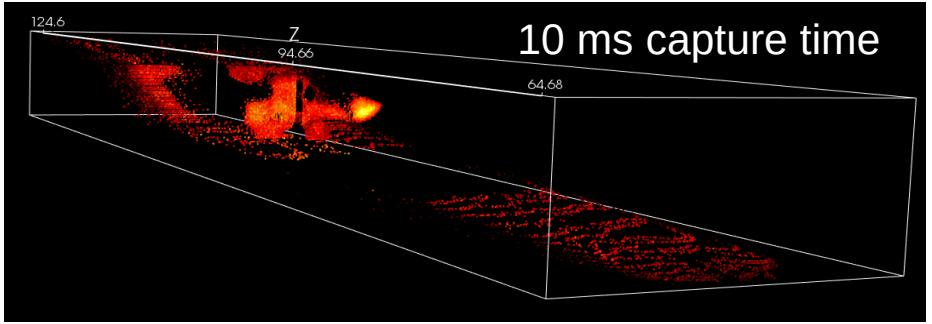


High-end flash imaging LiDAR for Mars exploration

- **TRL4 flash imaging LiDAR** delivered in 2017 to **European Space Agency** GNC Rendezvous, Approach and Landing Simulator laboratory (GRALS)

- Features:
  - Single Photon Counting
  - Direct Time-Of-Flight
  - Illumination: 1x or 3x narrow beam, 2°, 4° and 20°
  - Field-of-view: 5.8° - 128x128 pixels
  - **Altimeter mode: range > 1100 m, accuracy 3 cm**
  - **Imaging mode: range 300 m** (2°), **accuracy 3 cm**
  - Average electrical power consumption: 39 W
  - Size: 25 cm x 30 cm x 25 cm
  - Mass: 10 kg with power supply and PC
  - Not eye safe at all ranges

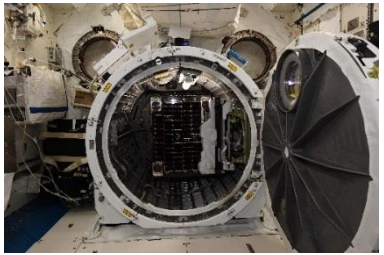


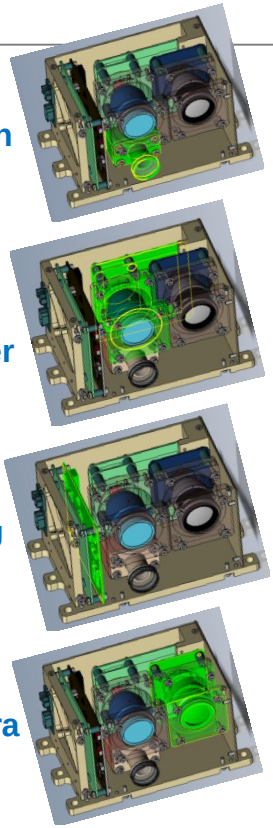


Low-cost flash imaging LiDAR for in-orbit rendezvous

- **TRL8 vision-based sensor** (flash imaging LiDAR + camera) delivered in 2017 to **Surrey Space Technology Lmt.** for **RemoveDebris** mission

- Features:
  - Indirect Time-Of-Flight
  - Illumination/Field-of-view: 15°x 17° - 160x120 pixels
  - **Imaging mode:** range / accuracy
    25 m / < 10 cm – 50 m / < 40 cm
  - Average electrical power consumption: 3.6 W
  - Size: 10 cm x 10 cm x 15 cm
  - Mass: 1.8 kg
  - Class 1M 805 nm
  - Operation: -20 to 50°C and resistant to launch vibration





Google “RemoveDebris”

Ready for 20th June deployment from ISS air-lock

Conclusion

- CSEM delivered in 2017, **TRL4 and TRL8 LiDARs** for space applications based on expertise in **solid state flash imaging LiDAR**
- **Versatility/adaptivity** due to switching/mixing between illumination patterns
- **Flash single photon counting architecture** features fit largely with the ones sought from an «holy grail» LiDAR, particularly when fast motion/movement in full-scene is present
- Leveraging on experience for space applications, provide innovative solutions for:
  - **niche markets** (e.g. bathymetry, disabled people aid, all-weather flight, industrial safety), where CSEM can use its standard business model
  - **highly competitive markets** (e.g. automotive), partnering with OEM or Tier 1 companies is mandatory

Thank you for your attention!

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