SERESSA 2022
5th to 9th of December at CERN, Geneva

Radiation Hardening by Software: Advanced FDIR and Redundancy Concepts with COTS in Space

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Fraunhofer EMI

ZFT ZENTRUM FÜR TELEMATIK E.V.

Space Technology is in a Disruptive Phase Today !

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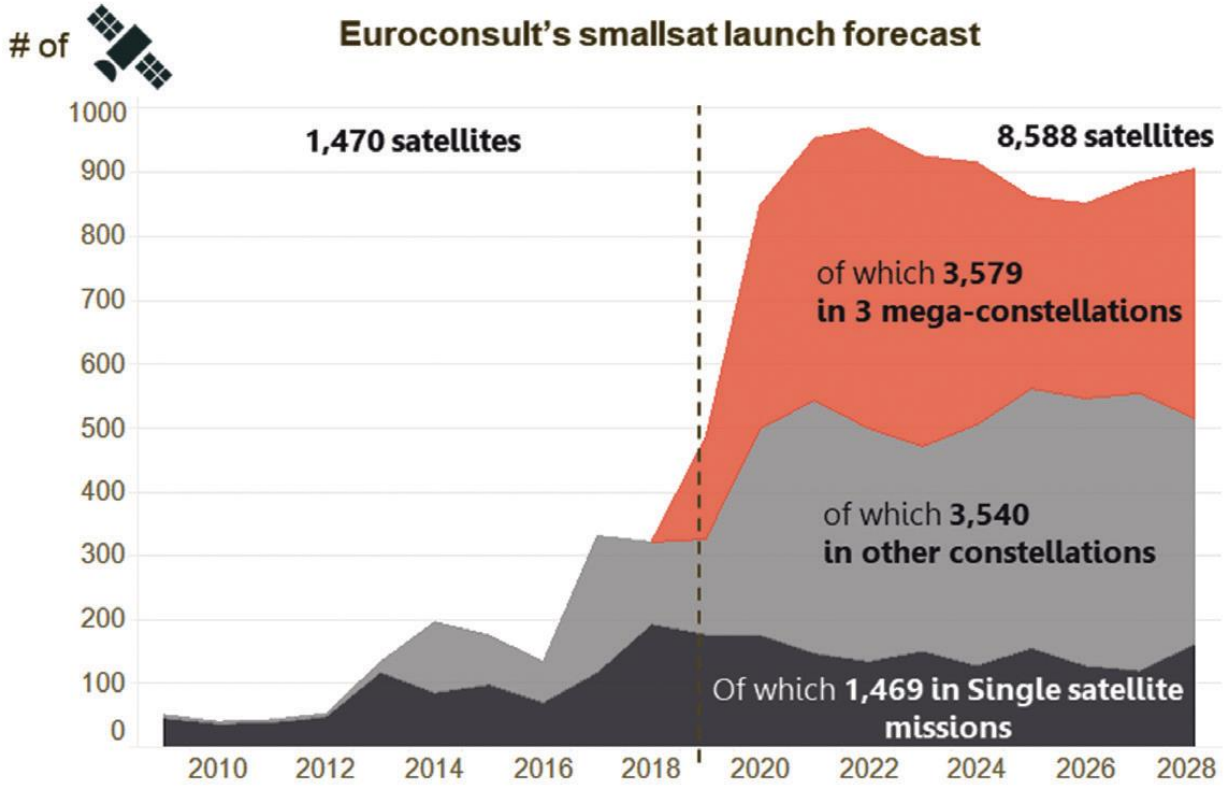
- democratisation of information: due to satellites it is more difficult to keep information secret
  in Ukraine small satellites provide telecommunication as well as Earth observation data
- satellites benefit from miniaturization to provide in a much more cost-efficient way similar functionalities like traditional satellites in orbit
  launcher costs scale with mass; production of larger quantities reduces costs, too.
- effizient use of commercial instead of special radiation hard components
  use of software (FDIR, filter technologies) for correction of radiation effects
- trends are observed to move from traditional multi-functional large spacecraft to distributed, networked systems of smart small satellites
  similar to information processing, which moved during the last 50 years from mainframe computers to cloud computing, making by example the information already available at internet connected smart phones
- in low Earth orbits multiple satellites are required for a continuous service
  before 2010 typically about 50 satellites were launched worldwide into orbit; during the last 2 years Starlink alone launched more than 2400 satellites
- from space agencies to commercial space
  except for telecommunication space business was earlier dominated by space agencies; now private entrepreneurs dominate, despite government remains a key customer

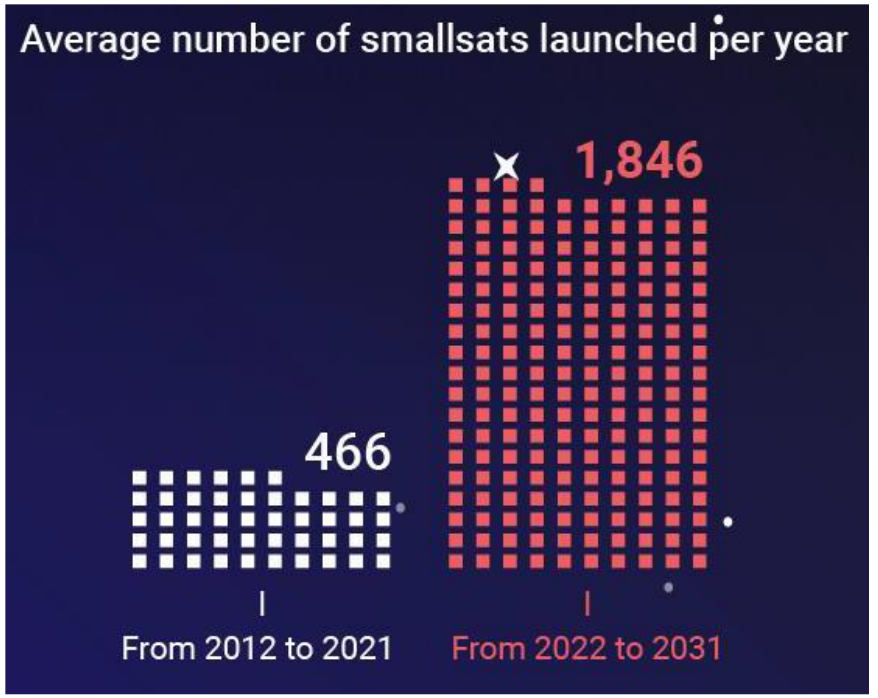
➔ **New scientific tasks, new economic opportunities, new application fields**

The next challenge: Small Satellite Formations



"23 % compound annual growth rate (CAGR) from 2009 to 2018. Even greater expansion is expected between 2019 and 2024 … five-year growth rate for smallsats to peak at 48% in 2024"

Source: EuroConsult / SatMagazine 2020



Source: EuroConsult 2022

New Space

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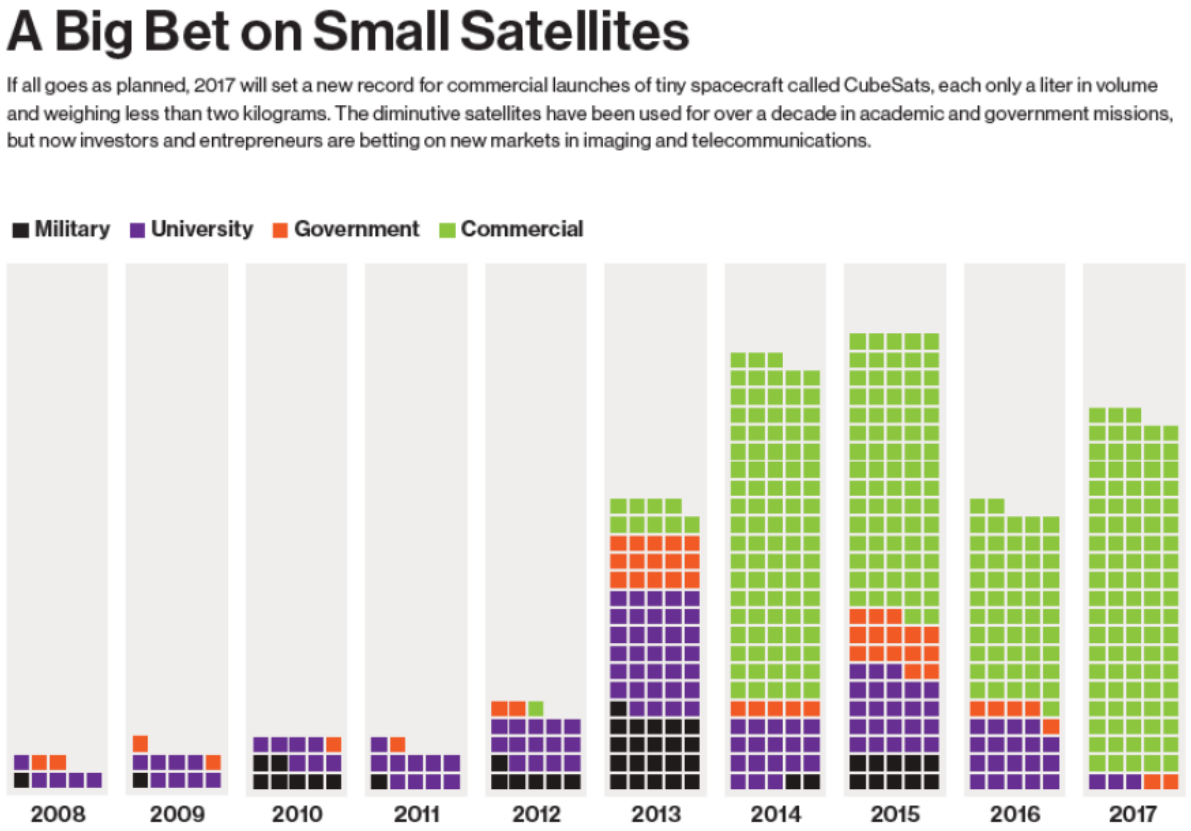
Disruptive technology developments in this decennium at very small satellites: from academia to commercial applications



Advantages of Pico-and Nano-Satellites

- short innovation cycles thanks to quick satellite realization
- at same cost of one traditional satellite many small satellites can be procured
- risk acceptance for use of high performance commercial-of-the-shelf components
- standardization supports automation to efficiently produce multi-satellite systems

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VOL. 120 | NO. 3
2017

ZfT / S^4 GmbH /Uni Würzburg: experiences in distributed networked pico-satellites

Roles:

- Uni Würzburg with emphasis in basic research
- ZfT as technology developper
- S^4 GmbH markets commercially advanced pico-satellite products

(UWE = ***U***niversity ***W***ürzburg's ***E***xperimental satellites)

2024 CloudCT: computed tomographieof clouds by 10 pico-satellites

2023 TIM, TOM satellite formations with 7 pico-satellites

- Earth observation by photogrammetric methods

2023 QUBE secure telecommunication link by quantum key distribution

2020 NetSat-1 to NetSat-4

- formation control, DTNs, MANets

2018 UWE-4

- orbit control

2013 UWE-3

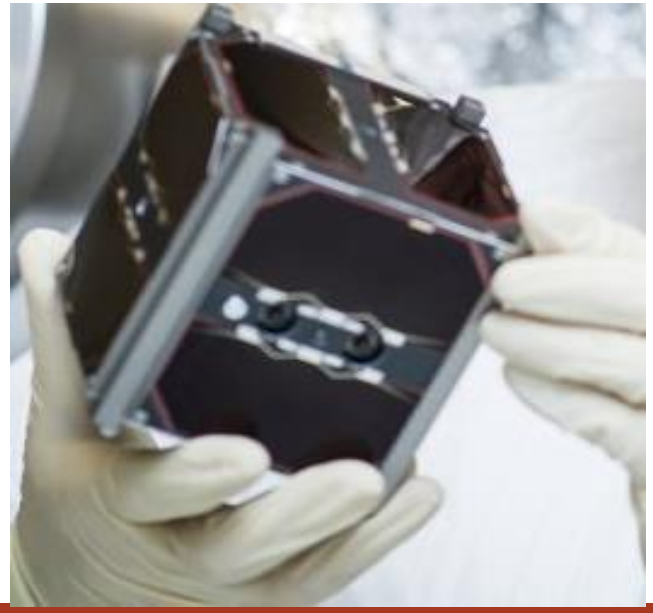
- attitude control

2009 UWE-2

- attitude and orbit determination

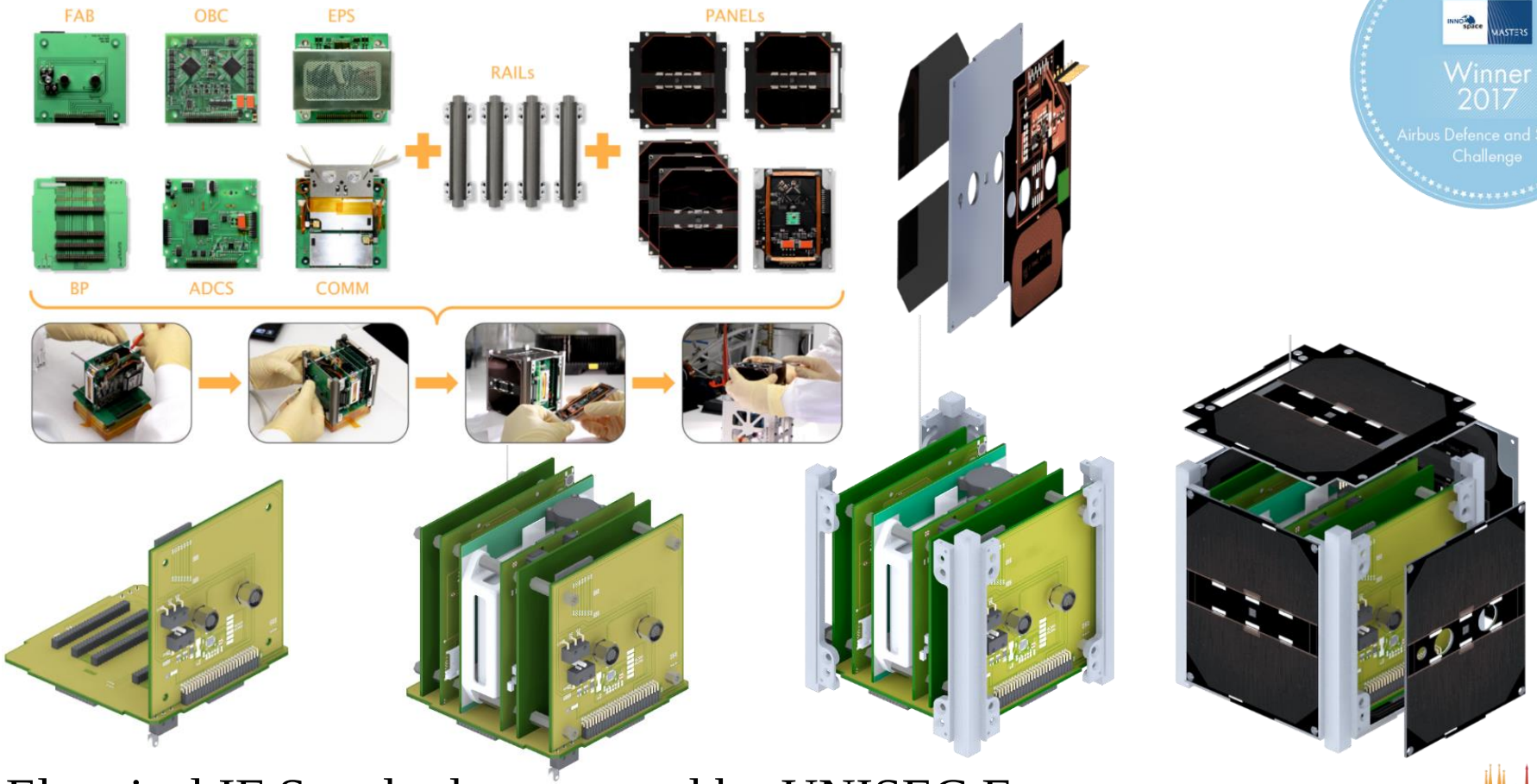
2005 UWE-1

- telecommunication "Internet in Space"



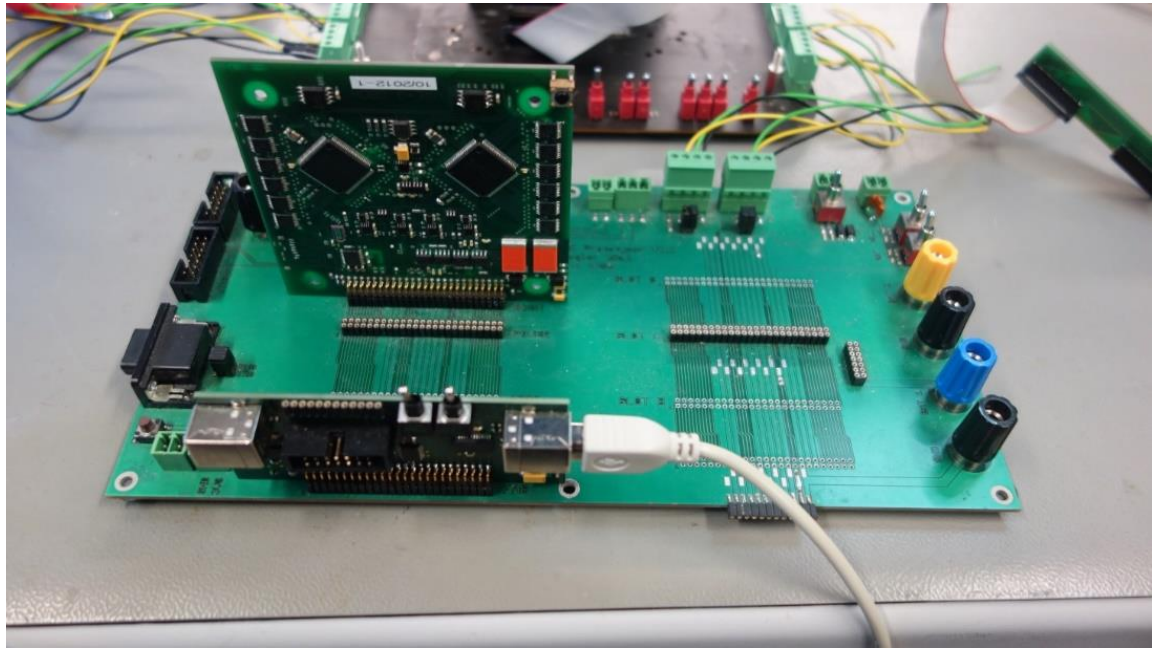
Technology Innovations: Standards

Standardization of electrical IF: no Harness,
Modular and Flexible Satellite System Design



Electrical IF Standards supported by UNISEC Europe
http://unisec-europe.eu/standards/bus/

Development Boards for UNISEC Europe Electrical Interface Standard

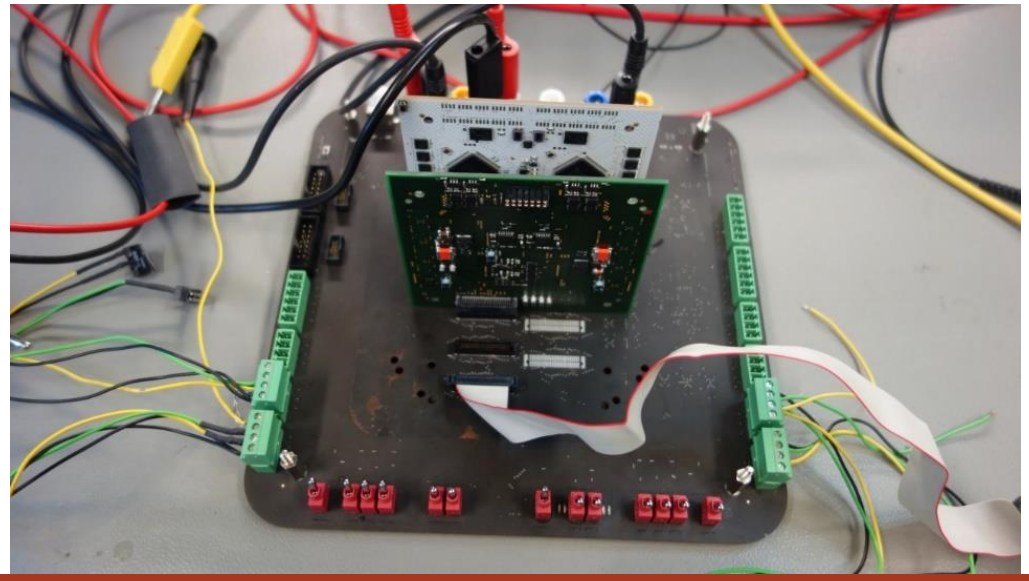


The Satellite Development board is an efficient prototyping platform which assists the implementation of the UNISEC Europe standard in an efficient and flexible way.

It supports all development phases by providing a comprehensive FlatSat test environment at increasing complexities.

It even serves as Electrical Ground Support Equipement (EGSE) after launch.

This standard is realized for two umbilical types. Related development boards support implementation as well as EGSE functionalities.



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Relevant available technologies:

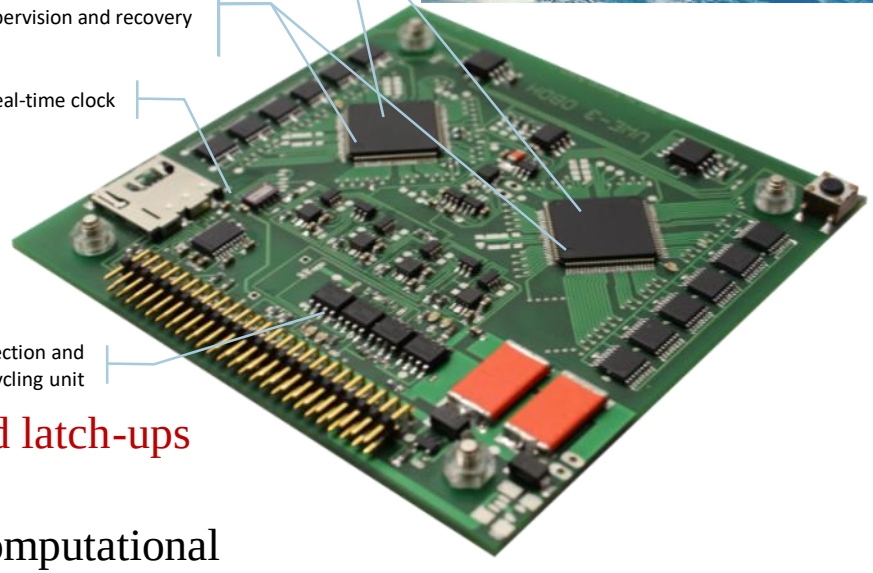
standardized electric interfaces for a modular, flexible integration

Integration of UWE-3 flight model

Technology Challenge: Reliable Robust Pico-Satellites

Reliable Data Handling by Commercial Low Power On Board Microprocessors Using Radiation Shielding by Software

- Miniaturization leads to higher susceptibility to space radiation environment
- Only commercial of the shelf electronics was used
- Fault detection, identification and recovery by software and simple watch-dog function



Despite significant radiation encountered, UWE-3 runs now since launch for 6.5 years without any interruption, despite encountered SEUs and latch-ups

Future developments address provision of distributed computational resources integrated on different spacecraft of a formation

Netsat satellites to demonstrate key formation technologies; launched 28.9.2020

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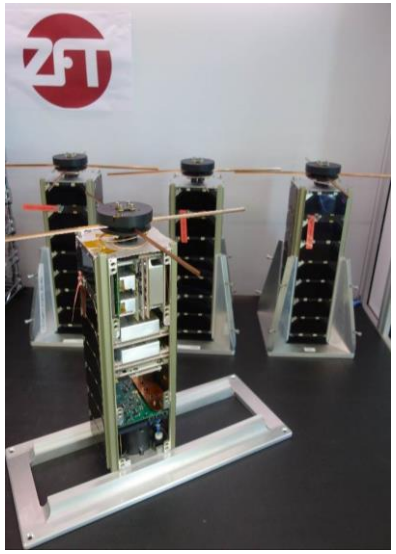
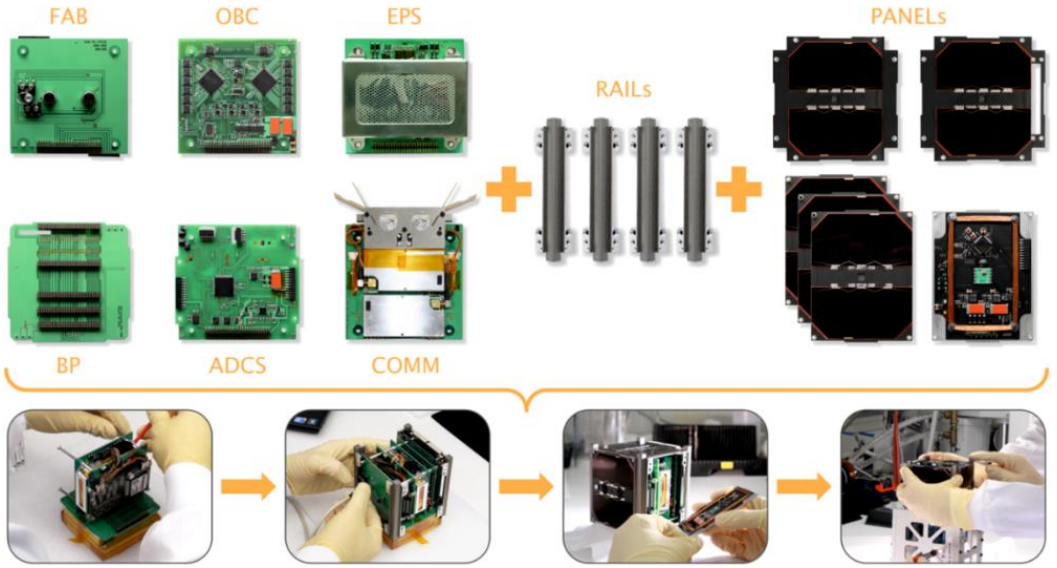
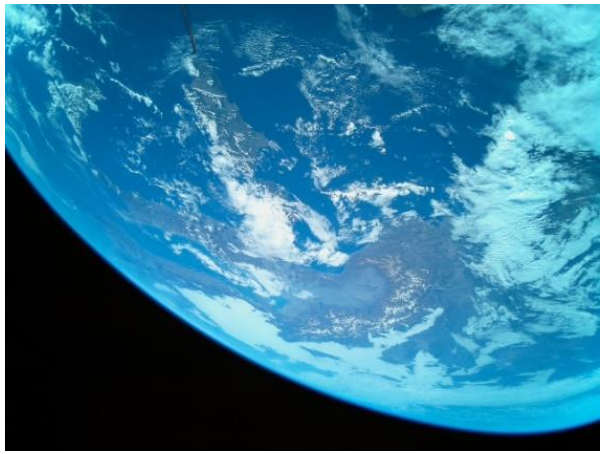
Winner 2017 Airbus Defence and Space Challenge



the four NetSats



modular, flexible integration by UNISEC Europe standard elec-trical interfaces



recent NetSat image

inter-satellite link tests in Würzburg with high precision, high dynamics turntables

Our current missions for future satellite formation applications

technology development for nano-satellite formations

NetSat (launched 28.9.2020)
networked control, intersatellite links, and relative navigation for small satellite formations

Advanced Grant 2012

NetSat image of the Mediterrean and Gibraltar

applications

QUBE (to be launched 2023)
Quantum key distribution for secure communication

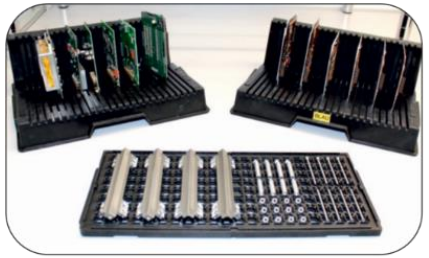
TIM / TOM (launch 2023)
3D-Earth observation by photogrammetric methods

LoLaSat (launch 2024)
small satellite systems for low latency communication

CloudCT (launch 2024)
computertomography of clouds for improved climate predictions

Synergy Grant 2018

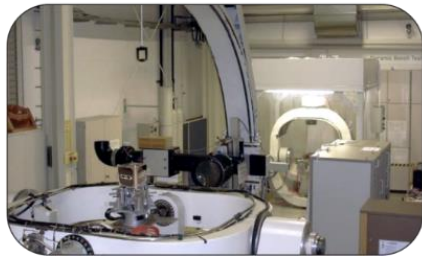
Advanced Manufacturing of "Industry 4.0" at Specific Example of Small Satellite Systems



modular satellite bus architecture to support flexible integration an production

close worker / robot cooperation for efficient satellite system integration

flexible flow of materials between integration and testing areas by transport robots



automated tests for functionality and performance of the satellite

Specific advantages include

- high flexibility to variations of standard product
- fast integration of modular components
- respecting high quality requirements due to appropriate testing
- scalable to larger satellites