What is new in the world of space electronics?

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Head of Studies

we think electronics.dependable

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DSI Aerospace Technologie GmbH is an **SME located in Bremen**, Germany which provides following electronic equipment:

Platform & Instruments Computers

Payload Data Handling Units (incl. MMBs)

Data Processing Units

Test Systems (EGSE)

Engineering Services

Aerospace Electronics

since 1997

A few recent projects…

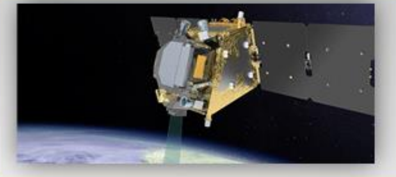
Hayabusa-II MASCOT
- On Board Computer
- Status: In Orbit

ExoMars
- Control and input/output modules incl. BSP of the Payload Data Handling Unit
- Status: In Orbit

JUICE CDMS SSMM
- Solid state mass memory board
- Status: PFM delivered

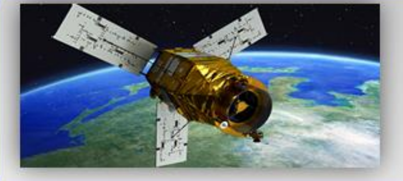
MetOp-SG ICI
- Command & data processing unit of the Ice Cloud Imager instrument
- Status: EQM delivered, PFM under manufacturing

Biomass
- Payload data handling unit
- Status: EM delivered, EQM under manufacturing



FLEX
- Payload data handling unit
- Status: under development

PLATO CDMS SSMM
- Solid state mass memory board
- Status: FuMo delivered

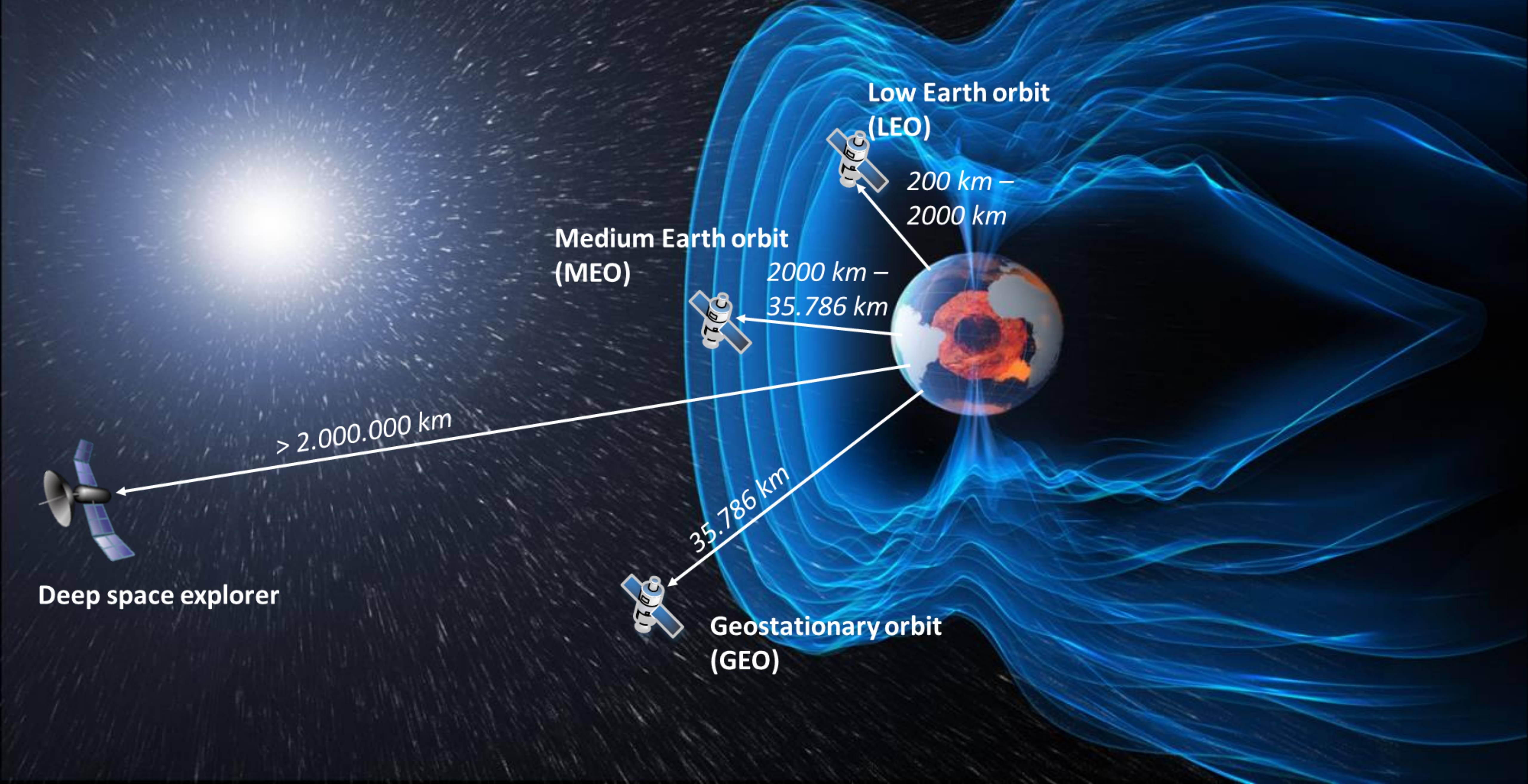


KOMPSAT-7
- Data storage and compression equipment
- Status: EQM delivered, PFM under manufacturing

Outline

- A brief introduction to space electronic
    - Design challenges
- OldSpace versus NewSpace
- Trends in space electronics
- Resume

Why is the design of space electronics somehow difficult?



Low Earth orbit (LEO)

200 km – 2000 km

Medium Earth orbit (MEO)

2000 km – 35.786 km

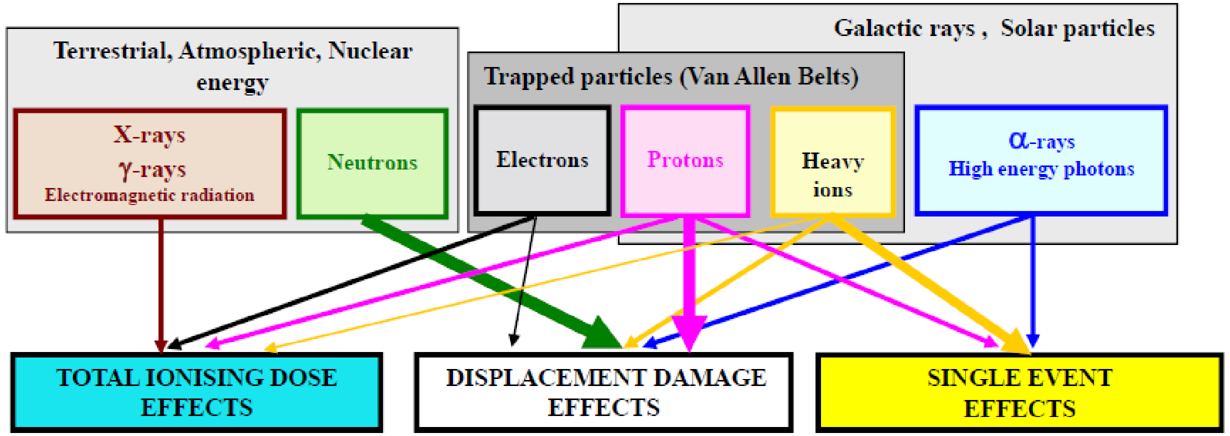
> 2.000.000 km

Deep space explorer

35.786 km

Geostationary orbit (GEO)

Radiation Effects on Electronics: Resume Picture



Terrestrial, Atmospheric, Nuclear energy

Galactic rays , Solar particles

Trapped particles (Van Allen Belts)

X-rays
γ-rays
Electromagnetic radiation

Neutrons

Electrons

Protons

Heavy ions

α-rays
High energy photons

TOTAL IONISING DOSE EFFECTS

- Creation of electron-hole pairs
- Charge build-up, excitation, transport

→Threshold voltage negative shift in n-channel
→Threshold voltage shift in parasitic transistors in bulk or thick epi layers
→Reduction of mobility in channel conductance and transconductance
→Increase of standby / off-state / leakage current
→changes in circuit parameters: operating point, gain, impedance, drive

DISPLACEMENT DAMAGE EFFECTS

- Atomic dislocation, nuclear displacement in lattice
- Reduction in mobility
- Reduction in carrier concentration
- Increase in dangling bonds / free radicals
- Increased defect concentration
- "rapid annealing" of minority carrier lifetime
- More defects, accelerated aging (shorter life time)

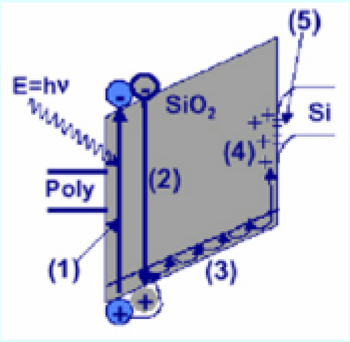
→changes in circuit parameters: operating point, gain, impedance, drive

SINGLE EVENT EFFECTS

- Local Ionisation (volume effects)

→Single Event Latch-Up (SEL) activation of parasitic npnp/pnpn structures causing anomalous switching behaviour of main transistor and large draw currents. Possible permanent failure.
→Single Event Upset (SEU) temporary "bit-flip" in memory element caused by internal charge deposition
→Single Event Transient (SET) transient current or voltage spike. If propagated and latched by memory element, may result in "bit-flip"
→Single Hard Errors (SHE) such as gate/dielectric rupture, burn-out, in high V junctions transversed by heavy ions

TOTAL IONISING DOSE EFFECTS



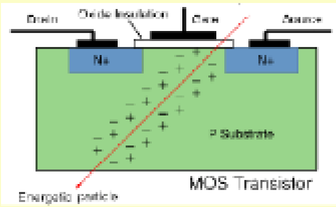
- POWER CONSUMPTION INCREASE
- DEGRADATION OF ANALOGUE FUNCTIONS / PERFORMANCE

DISPLACEMENT DAMAGE EFFECTS

Typically this only concerns

electro-optic sensors, diodes, opto-couplers, solar cells, wide-base bipolar transistors

SINGLE EVENT EFFECTS



- TEMPORARY OR PERMANENT MALFUNCTION
- LOSS OF DATA
- POWER CONSUMPTION INCREASE
- DEVICE BURN OUT

⇒ Qualification is indispensable

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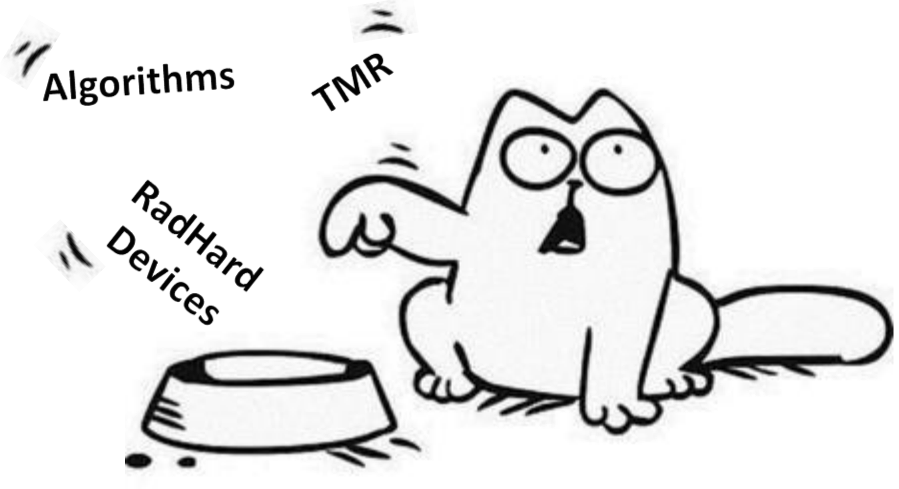
[1] Source: Courtesy of ESA

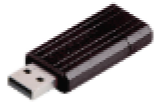
Methods for reliable space electronics

Three common ways to deal with radiation impacts to electronic systems in space

1. **Radiation hardened (by design) devices** that can operate in the planned environment
2. **Redundancy** that considers fault-tolerance, e.g. 3 copies of each functional box and a voting system
3. Extensive **Error Detection and Correction** algorithms

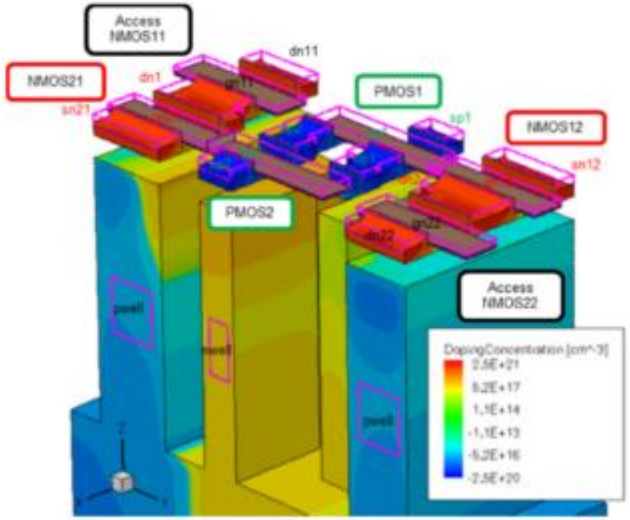
Normally, we consider a combination of each of these methods

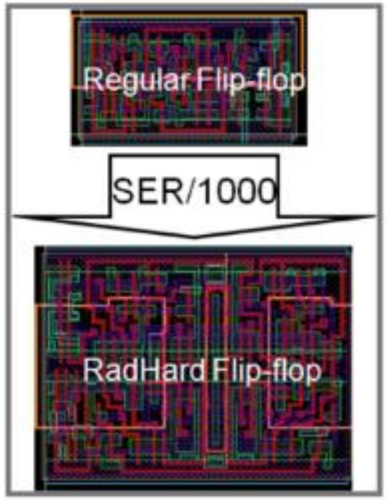



Commercial


Space-grade

Most important: Classical Space Electronics are composed of rad-hard and qualified components





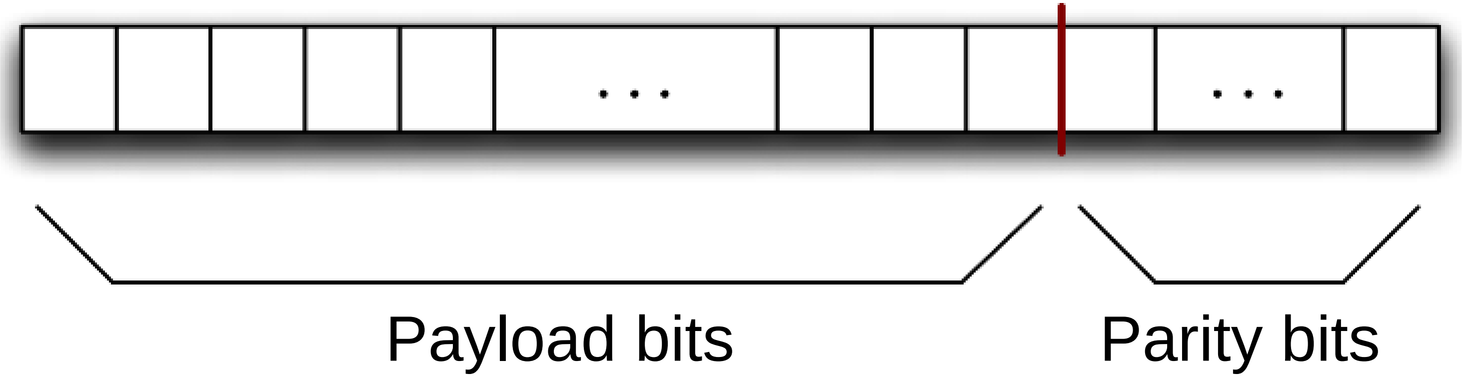
- Coarse-grained technology nodes
  - Lower frequencies (high propagation delay)
  - Higher power dissipation (heat)
- Huge footprints
- Extremely expensive

- Examples:
  - FPGA: Microchip RTAX, Xilinx Kintex Ultrascale
  - MPU: CAES GR740 Quad-Core LEON4
  - SoC: nanoXplore NG Ultra

We can not only detect errors… we can also correct them

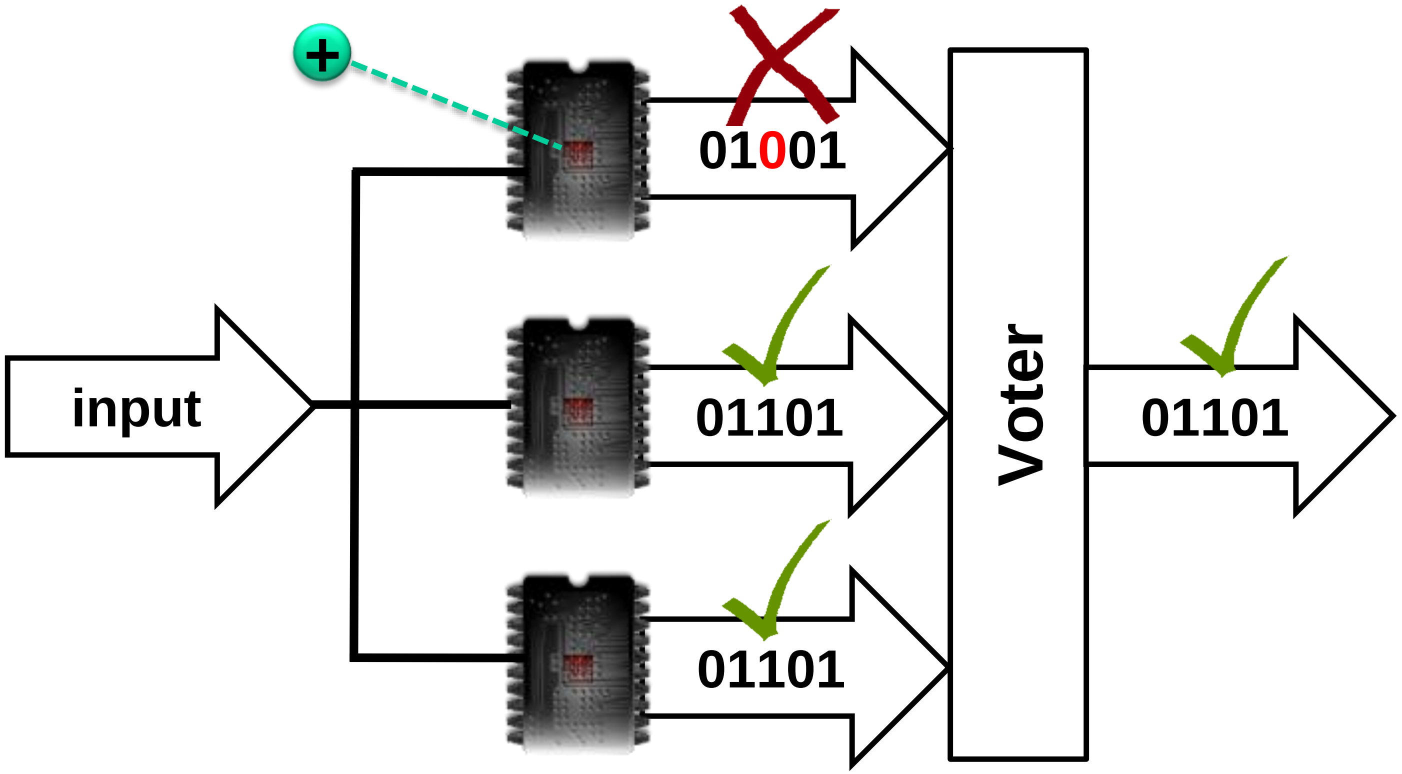
- Widely used e.g. in channel coding
- We can include Parity-Checks
- Commonly used are Reed-Solomon Codes (or Hamming codes)

Symbol	Code
A	10001
B	00100
C	01010



In order to increase reliability and fault tolerance, we can include redundancy

- Common technique is TMR/ → Triple Modular Redundancy/Dual Modular Redundancy (with parity)



TMR can be applied on **system level**, **component** level or **block level**… or even Software

- However….
  - Increased overhead (three times)
  - More power consumption
  - More complexity (weight)
  - New failure models (e.g. is the voter correct???)

Redundancy further increases availability/reliabilty

Traditional Space vs NewSpace

Paradigm shift for established space industry (and its implications)

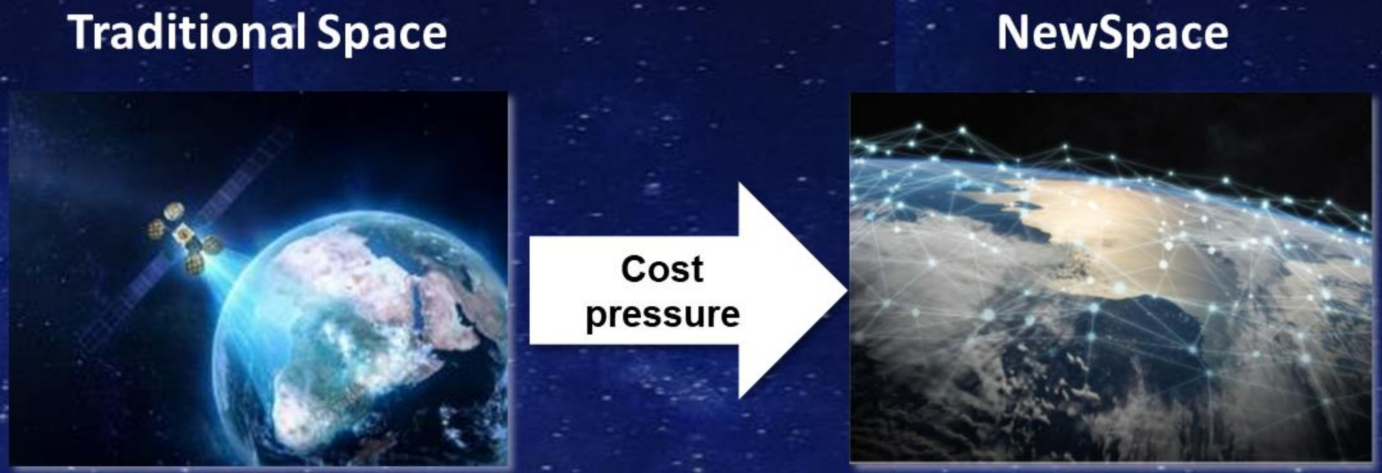
- Exploitation of commercial-of-the-shelf (COTS) products for LEO

→ Mainly for communication purposes

- Existing, evolving constellations e.g. Starlink, OneWeb2, Telesat, Amazon, …

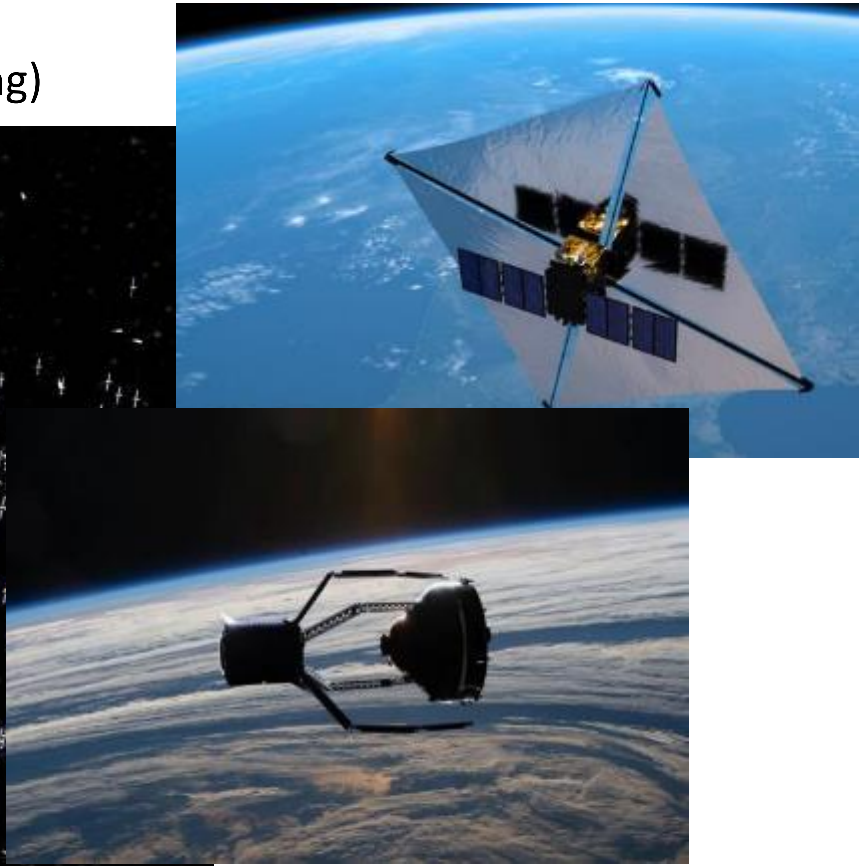
→ Up to 30.000 CubeSats

→ Commercial interest far beyond classical agency driven missions



Kessler Syndrome

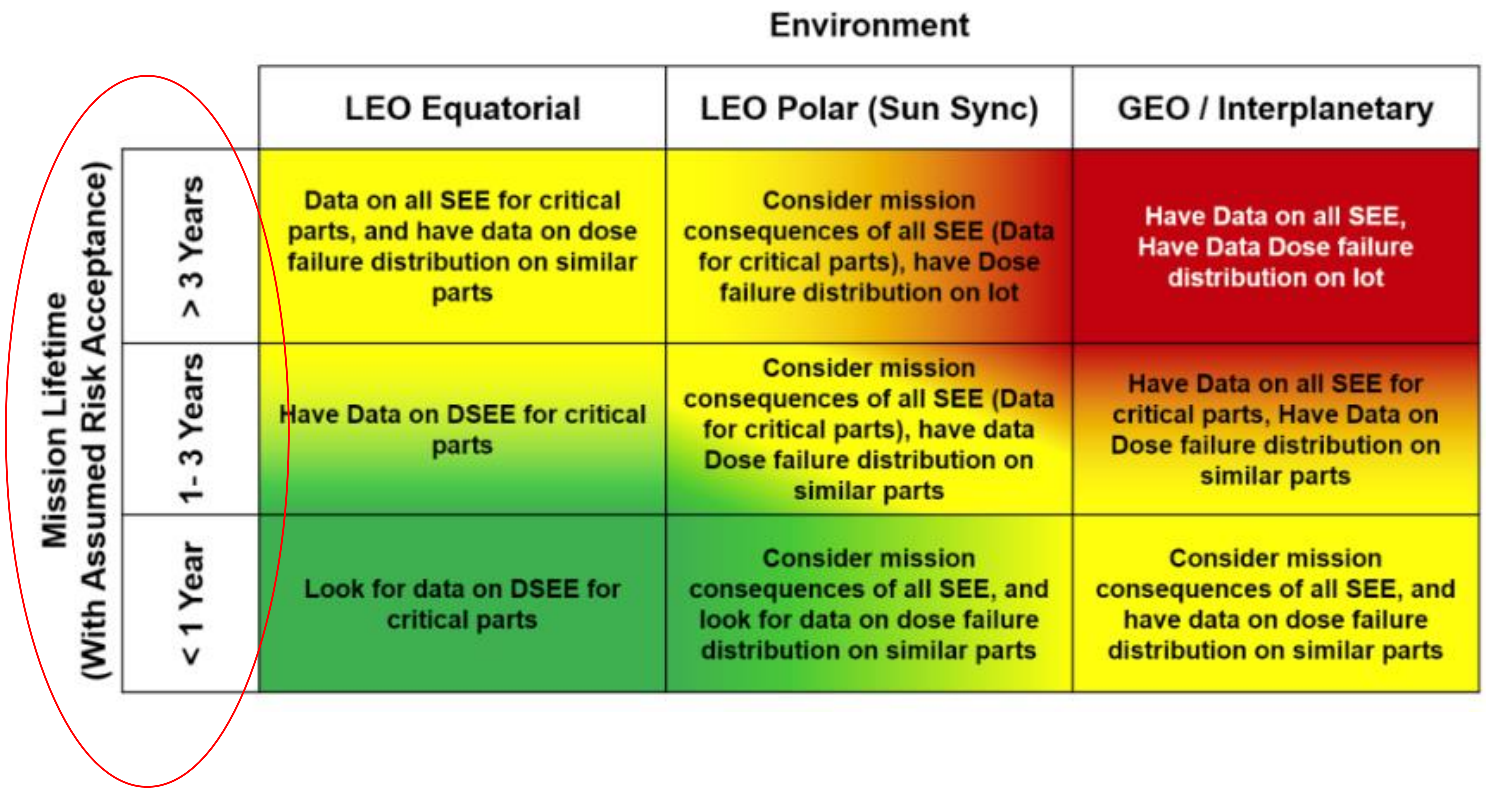
- Collisions lead to avalanche effect and uselessness of orbits
- Regulations required, as commercial interests > care taking (littering)



Solutions available: Who pays the bill?

Yet another drawback…

- Lifetime of COTS is critical



Mission Lifetime (With Assumed Risk Acceptance)	Environment: LEO Equatorial	LEO Polar (Sun Sync)	GEO / Interplanetary
> 3 Years	Data on all SEE for critical parts, and have data on dose failure distribution on similar parts	Consider mission consequences of all SEE (Data for critical parts), have Dose failure distribution on lot	Have Data on all SEE, Have Data Dose failure distribution on lot
1 - 3 Years	Have Data on DSEE for critical parts	Consider mission consequences of all SEE (Data for critical parts), have data Dose failure distribution on similar parts	Have Data on all SEE for critical parts, Have Data on Dose failure distribution on similar parts
< 1 Year	Look for data on DSEE for critical parts	Consider mission consequences of all SEE, and look for data on dose failure distribution on similar parts	Consider mission consequences of all SEE, and have data on dose failure distribution on similar parts

- Higher computational performance, fast time to market
- **If hardware costs are reduced extensively, we can just send more satellites (yep)**

Trends in (traditional) space electronics

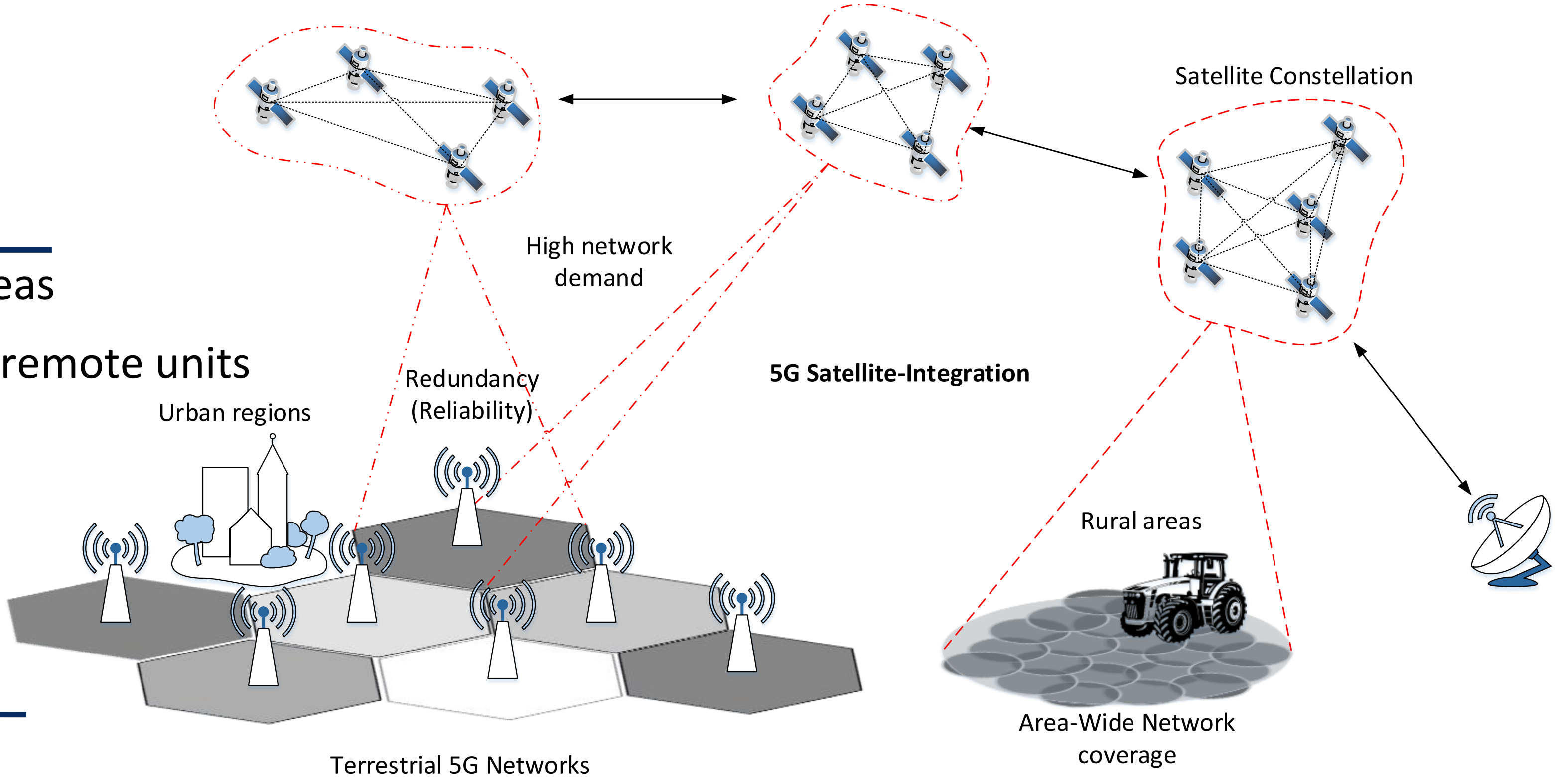
Satellite networks and mobile communications

Non-terrestrial Networks

- Basic coverage of rural areas
- Satellite constellations as remote units
- Modes
  - U(LL)RC
  - mMTC

Non-terrestrial Nodes

- 3D networks
- Satellites as base station
- Resilient communication



HPDPU: High-performance data processing unit

Key features

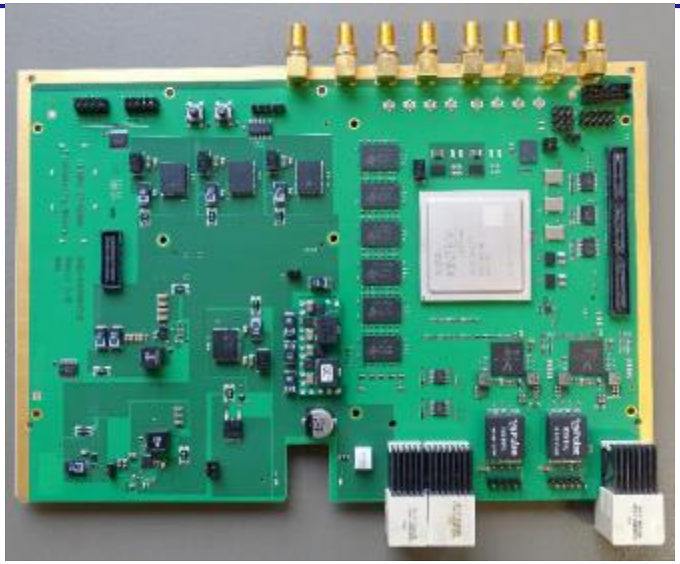
- Kintex UltraScale for Space Applications
- Various interfaces/communication protocols available

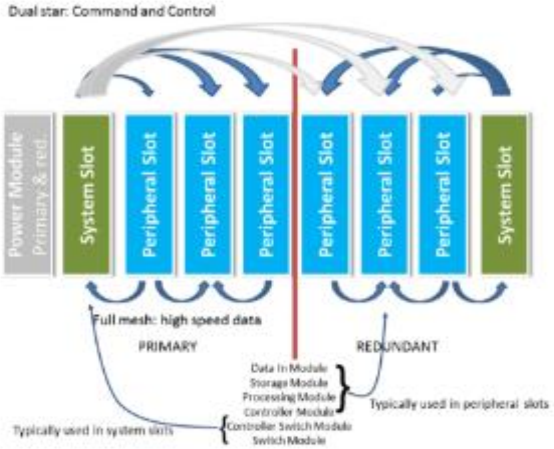
Interfaces

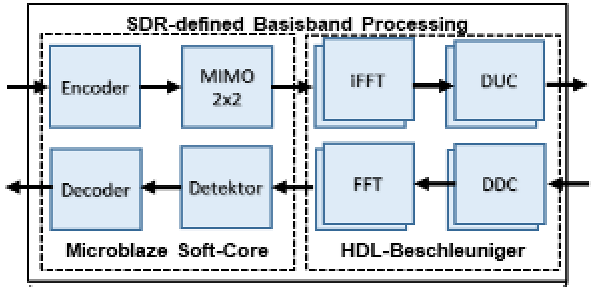
- Frontpanel: HSSL-based connectors
- Backplane: Compact PCI Serial Space (cPCI-SS)
- 2 Mezzanine connectors for expandability

Mechanical properties

- Form factor: 6U
- Mass: < 800g (without mezzanine extension)

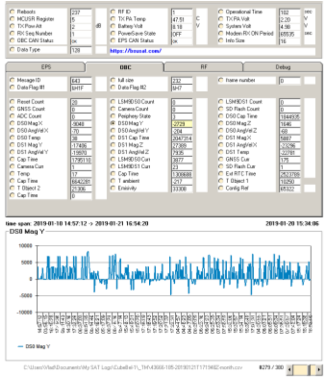






Impact of AI for Space Applications

Health Monitoring of Spacecrafts



○ Reboots 237
○ MCUSR Register 5
○ TX Pow Att 2 dB
○ RX Seq Number 1
○ OBC CAN Status ok
○ Data Type 128

○ RF ID 1
○ TX PA Temp 47.51 C
○ Battery Volt 8.18 V
○ PowerSave State OFF
○ EPS CAN Status ok

○ Operational Time 102 sec
○ TX PA Volt 2.20 V
○ System Volt 4.98 V
○ Modem RX ON Period 65535 sec
○ Info Size 16

https://bsusat.com/

○ Message ID 643
○ Data Flag #1 $H1F

○ full size 232
○ Data Flag #2 $H7

○ frame number 0

○ Reset Count 20
○ GNSS Count 0
○ ADC Count 0
○ DS0 Mag X -9048
○ DS0 AngVel X -70
○ DS0 Temp 38
○ DS1 Mag Y -17486
○ DS1 AngVel Y -15970
○ Cap Time 1795110
○ Camera Curr 1
○ Temp 17
○ Cap Time 6842281
○ T Object 2 21306
○ Cap Time 0

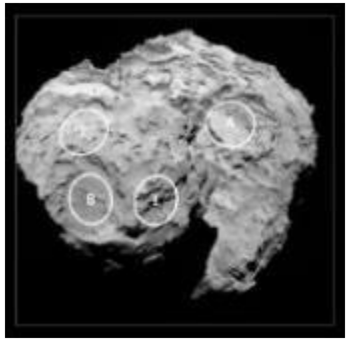
○ LSM9DS0 Count 0
○ Camera Count 0
○ Periphery State 3
◉ DS0 Mag Y -2729
○ DS0 AngVel Y -204
○ DS1 Cap Time 2047314
○ DS1 Mag Z 27389
○ DS1 AngVel Z 7935
○ LSM9DS0 Curr 3877
○ LSM9DS1 Curr 23
○ Cap Time 1308688
○ T ambient -217
○ Emisivity 33308

○ LSM9DS1 Count 0
○ SD Flash Count 0
○ DS0 Cap Time 1844935
○ DS0 Mag Z 1646
○ DS0 AngVel Z -68
○ DS1 Mag X 5887
○ DS1 AngVel X -23296
○ DS1 Temp -22781
○ GNSS Curr 175
○ SD Flash Curr 1
○ Ext RTC Time 2523789
○ T Object 1 10250
○ Config Ref 65322

time span: 2019-01-10 14:57:12 -> 2019-01-21 16:54:20 2019-01-20 15:34:06

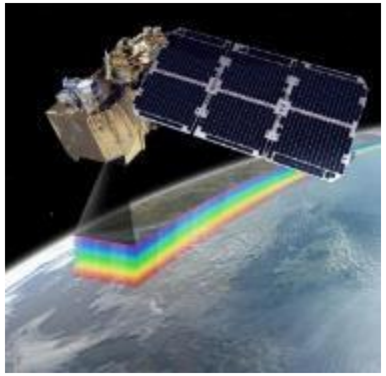
C:\Users\Vlad\Documents\My SAT Logs\CubeBel-1_TM\43666-105-20190121T171948Z-month.csv #279 / 300

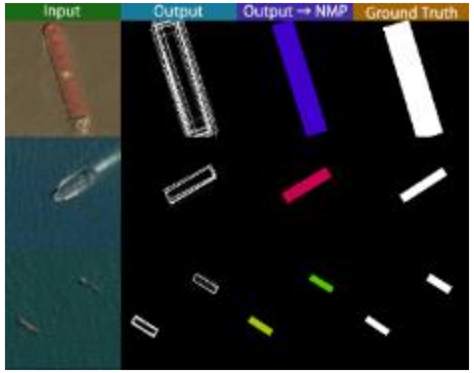
Autonomous Navigation



Communication Satellites

Feature detection for planetary exploration





Next-Generation Mass Memory Board

Architectural design

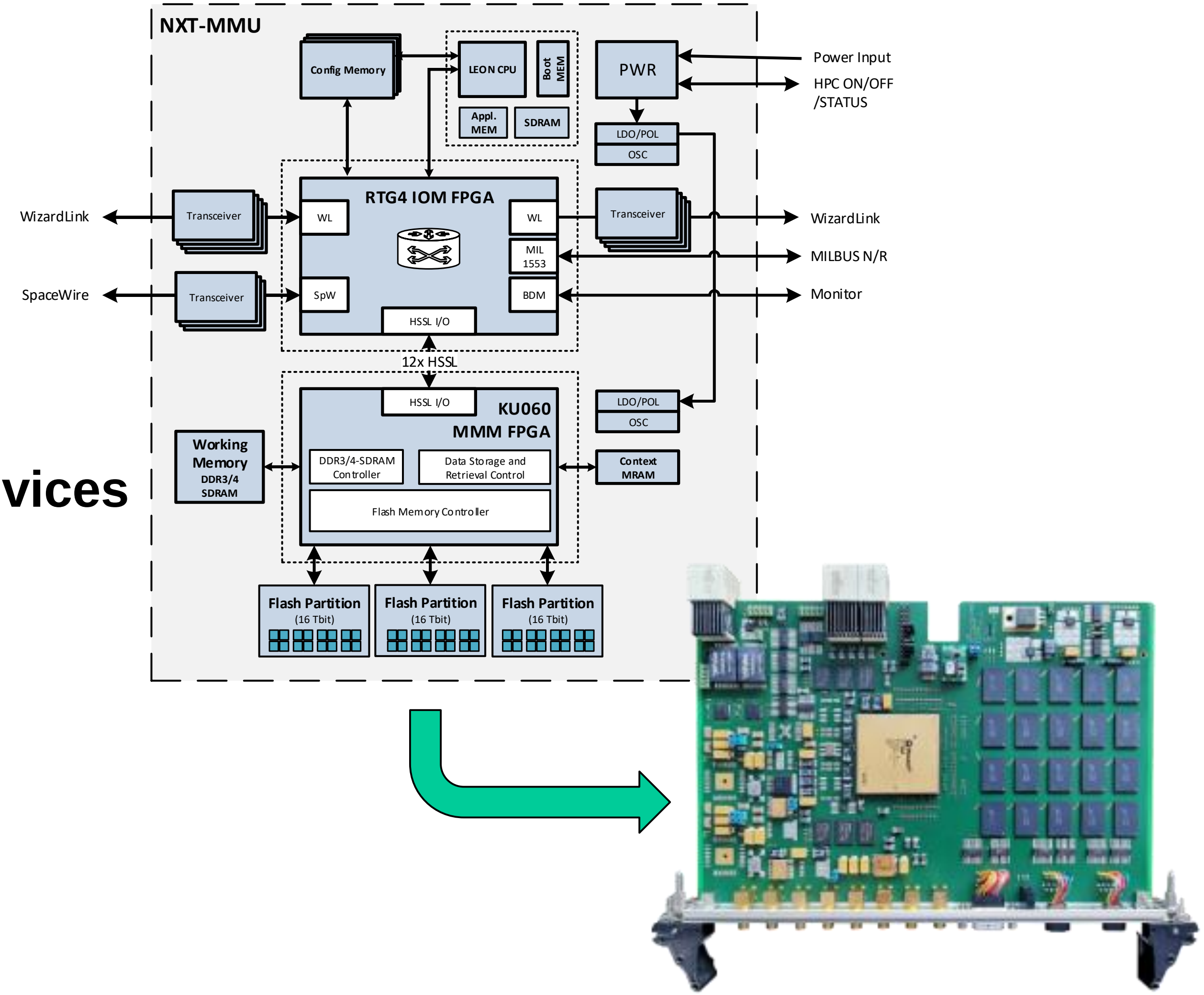
- Storage Capacity **48Tbit** BOL
- Bandwidth up to 20Gbps (recording and playback)
- Power consumption ~20W
- Mass < 20kg
- Form factor < 2x 6U

Selection and up-screening of suitable Flash devices

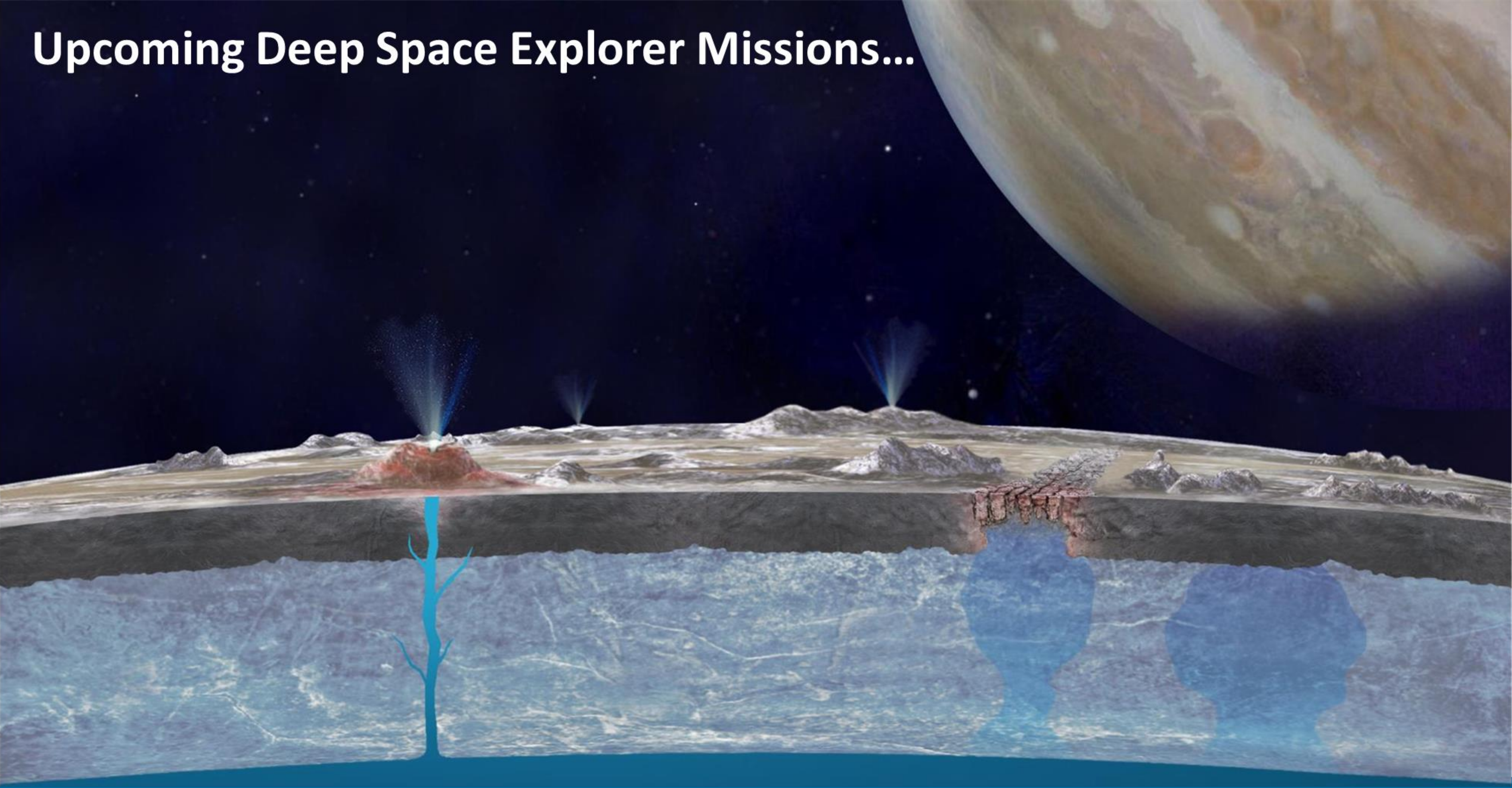
- Comprehensive NAND flash technology examination
- Up-screening

PCB manufacturing

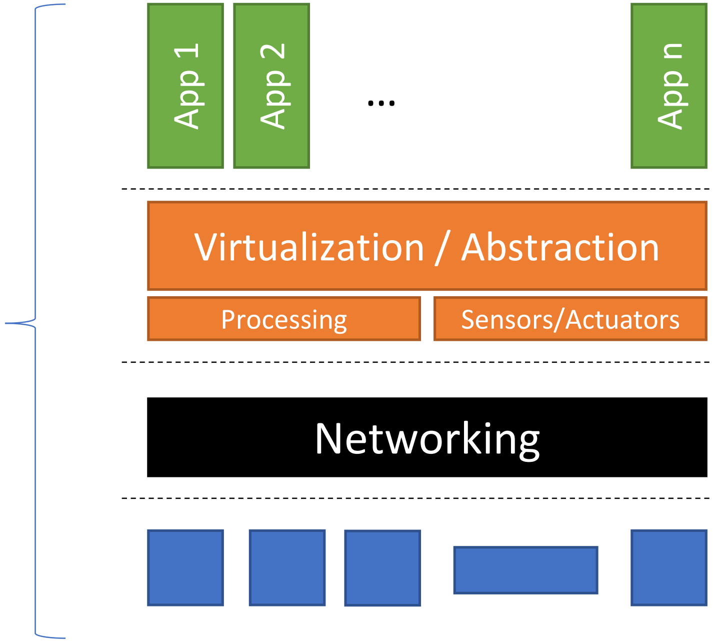
- Comprehensive NAND flash technology examination



Upcoming Deep Space Explorer Missions…



TRIPLE: Technologies for Rapid Ice Penetration and Subglacial Lake Exploration



- Actual applications on top of abstracted HW avionic
- Resource friendly, reusability of resources (e.g. sensors), …
- Execution in secure containers, updateability, flexible extension

- Hardware virtualization (shared resources)
- Increase HW utilization for processing
- Split data producer from data consumer

- Reliable (redundant) interconnection
- Traffic-Classes (RT + BE)

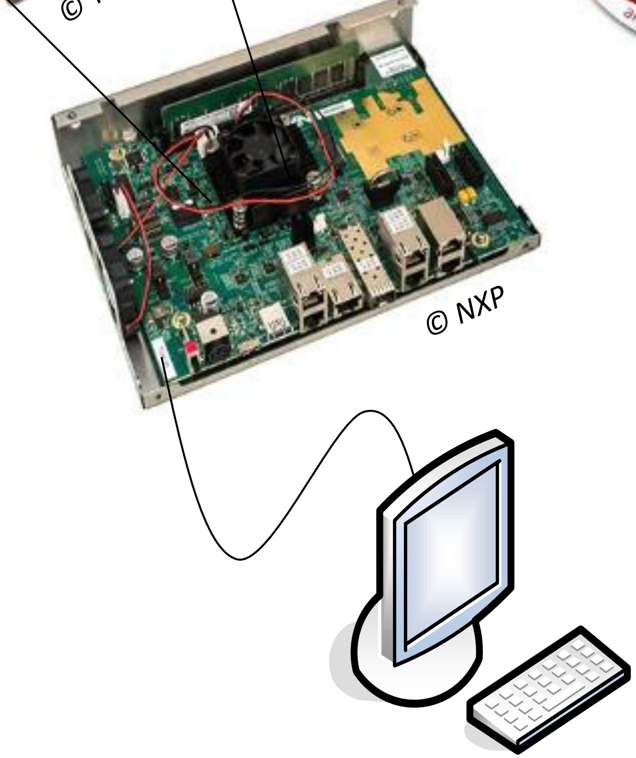
- Federated Hardware-Architecture (N+R)
- Mixed Criticality / Rad-Hard /COTS
- HW/SW-Co-Design, ARM, RISC-V, FPGA fabric

- nanoAUV Hardware
- Sensors, Actuators
- Scientific payload

VaMex: Valles Marineris Explorer

Development of a Space-Grade processor plattform

- Core unit: Teledyne LS1046-Space
- Quad ARM core (Cortex A72)
- Suitable for various applications
  - Image processing
  - LIDAR
- PCB develoment, manufacturing, validation and test
- Rapid Prototyping



What is new in the world of space electronics?

- The battle NewSpace vs Traditional Space is still ongoing
  - High performance only possible when utilizing COTS parts, but those tend to faulty behavior in space
  - Agencies are getting more and more open-minded for COTS devices
  - NewSpace will face some serious issues
- Modern applications steadily raise the performance demands of space-grade-boards and -devices
  - Novel Generation of RHBD devices, e.g. FPGAs or SoCs, will decrease the commercial and non-terrestrial gap
  - Power/Thermal dissipation
- AI is key enabler for various space-applications
  - How to efficiently perform on-board ML?

DSI will provide different space-grade PCBs to compete with these challenging goals

Thank you for your attention!

Questions?

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