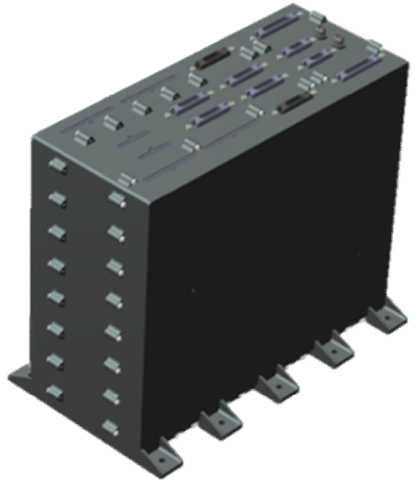
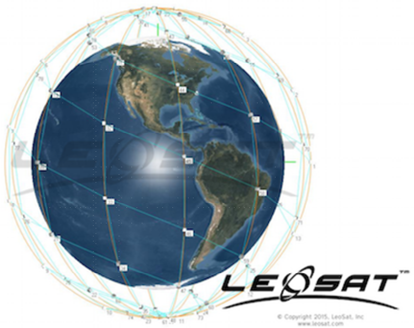
COTS Paving the Road for Global Internet Coverage

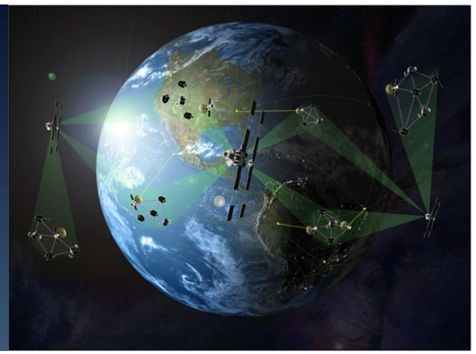
Per-Olof Lindqvist

System Engineer, Product Unit Digital

RUAG Space AB

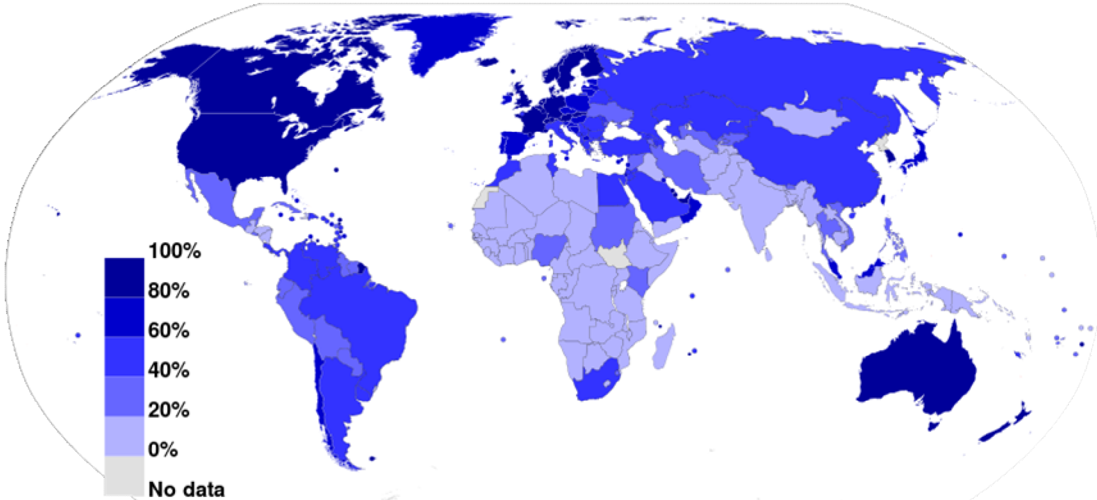






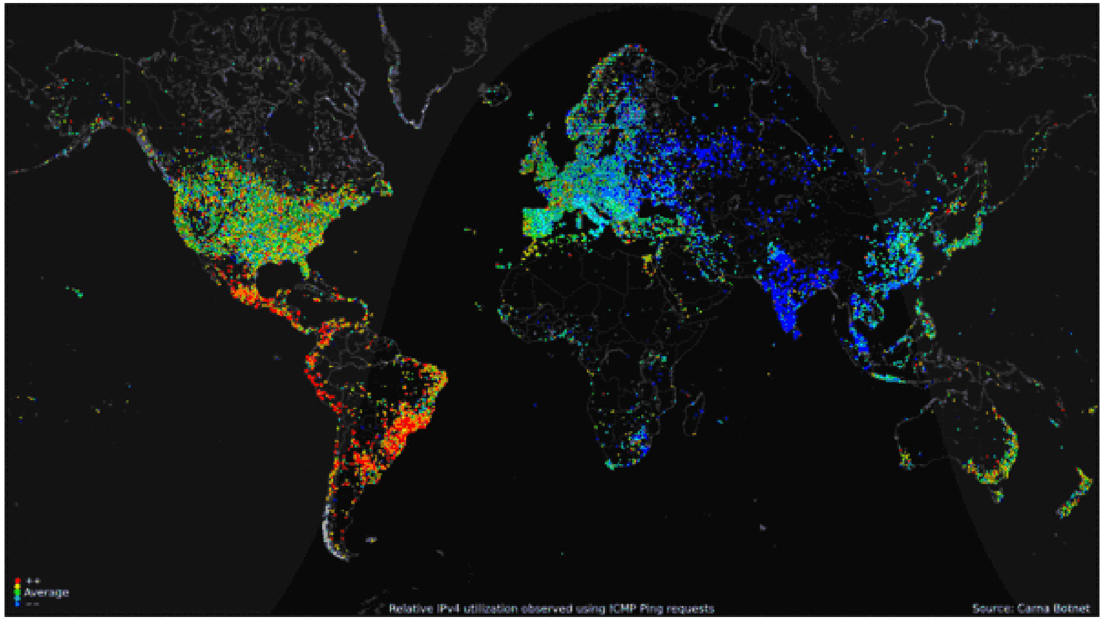
Together ahead. RUAG

Global internet coverage



Internet users in 2012 as a percentage of a country's population
Source: International Telecommunications Union.

World map of 24-hour relative average utilization of IPv4 addresses observed using ICMP ping requests as part of the Internet Census of 2012 (Carna Botnet), June - October 2012.



Together ahead. RUAG

Terrestrial networks vs Satellites

Terrestrial networks

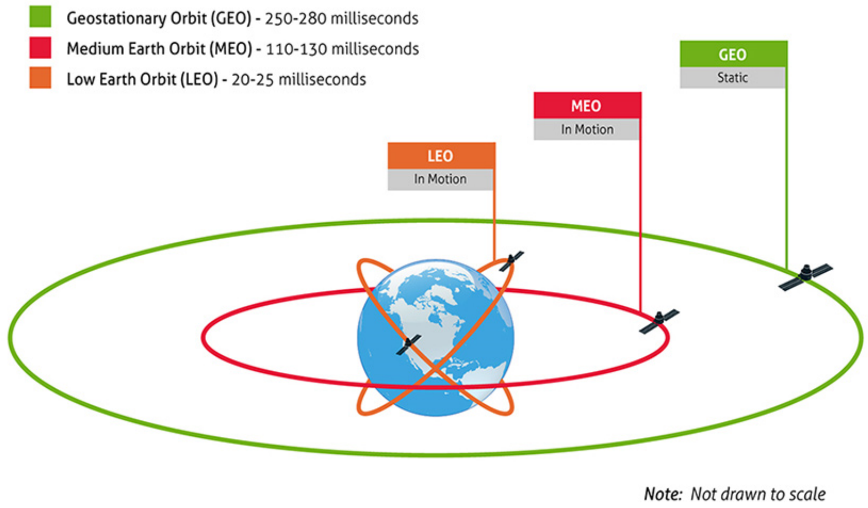
+ Fixed and mobile solutions
+ Simple low-cost consumer electronics
- Cheap in densely populated areas like cities
- Expensive in remote areas and on the countryside

Satellites

+ Global land coverage
+ Global sea coverage
+ Global airplane coverage
+ Relatively fast deployment
- Expensive electronics, launch cost, maintenance and operations
- Advanced user terminals

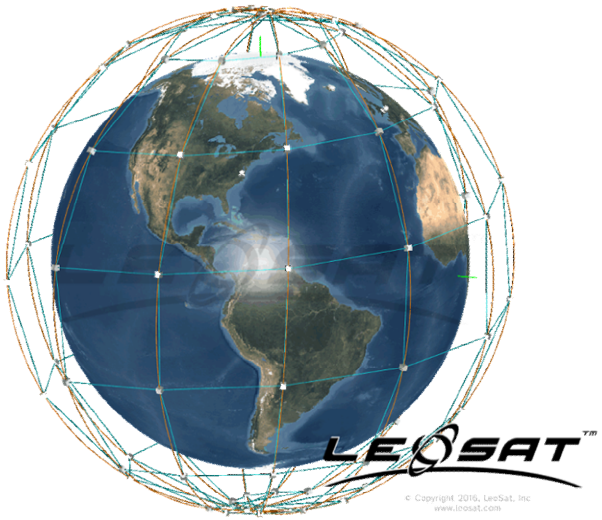
Together ahead. RUAG

GEO vs LEO for internet coverage



Geostationary internet satellites

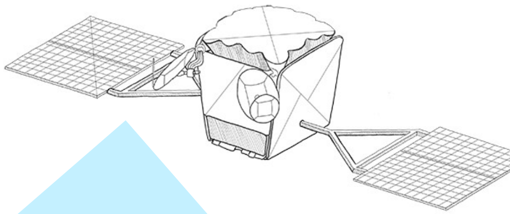
- \+ Fixed position in the sky, fixed dish antenna
- \+ Few satellites provide global coverage
- \- **High latency,** >20 times a terrestrial network (240ms orbit delay)
- \- High accumulated radiation levels
- \- Advanced and expensive satellites
- \- Sensitive to outage

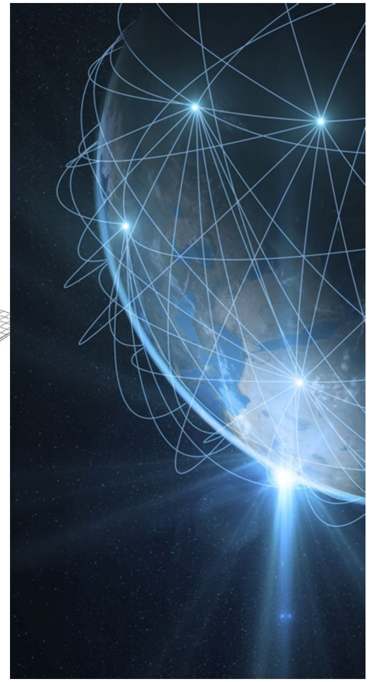


Low-earth-orbiting satellite

- \+ **Low latency**, same order of magnitude as long distance terrestrial networks (8 ms orbit delay)
- \+ Lower radiation levels
- \+ Redundancy on satellite level
- \- A moving target, tracking dish antenna with handover
- \- Many satellites needed to provide constant coverage
- \- Requires low cost satellite

Can it be done with LEO?



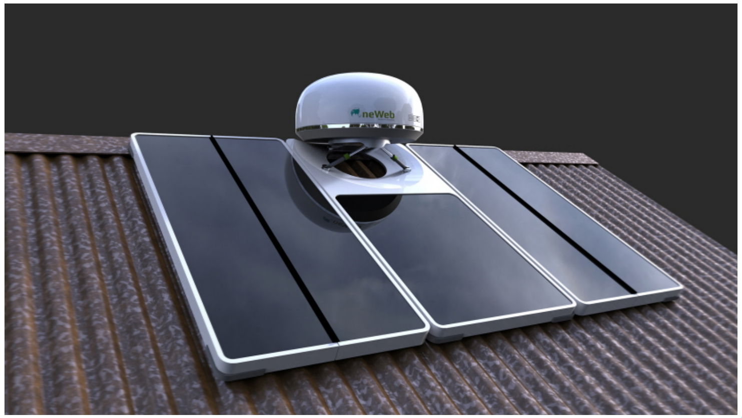


Courtesy OneWeb

Satellites

- Hundreds or even thousands satellites per constellation
- Life-time 5-7 years, replacement spares and launches
- Low-cost per spacecraft
- Mass production – at least for space industry
- Low-cost launch
  - Many satellites launched simultaneously during constellation build up
  - Cheap replacement launches

Courtesy OneWeb



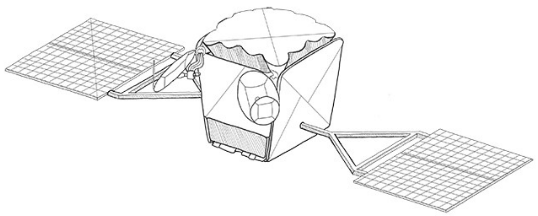
Satellite terminals

- Ground based routers connecting to satellite
  - Emit LTE, 3G, 4G and WiFi or even cable to the surrounding area
  - Still need to be small and low-cost

User terminals

- Connect to satellite terminals (not to satellite)
  - Simple affordable consumer electronics
  - Same as for terrestrial mobile networks
  - i.e. smartphones and computers

How can this be done?



What is driving cost in a megaconstellation?

- Spacecraft hardware (e.g. OneWeb >600 satalites)
- Launcher cost (e.g. OneWeb 21 launches with 32 satellites in each launch)

Spacecraft Hardware

- Electronic Components cost is a main driver
  - Due to radiation tolerance
  - Due to the approach to achieve quality
- Manufacturing and Test must be efficient

Electronics

Space grade electronics

- Radiation hard or tolerant
- Large temperature range
- Reliable and traceable
- Very expensive

Military grade electronics

- Unknown radiation tolerance
- Large temperature range
- Reliable and traceable
- Expensive

Automotive grade electronics

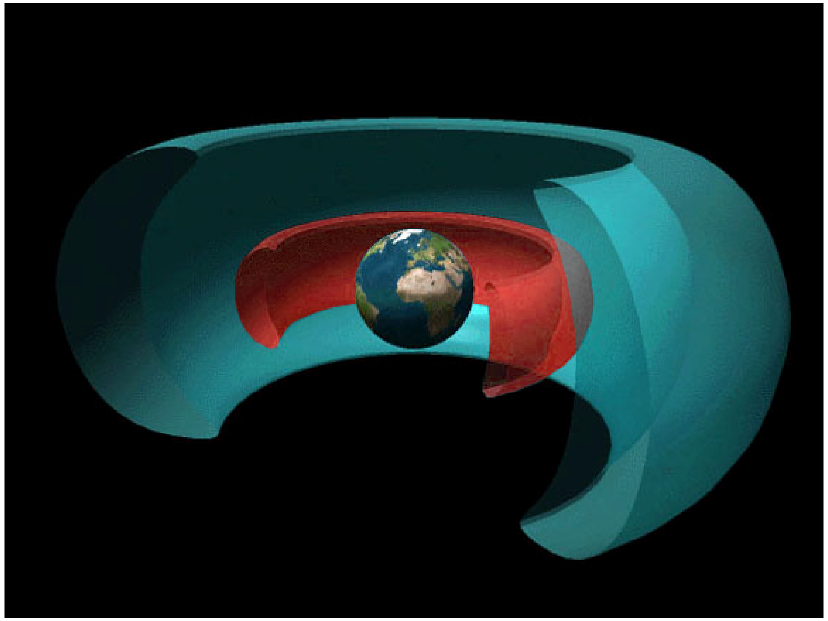
- Unknown radiation tolerance
- Reliable and traceable
- Cheap

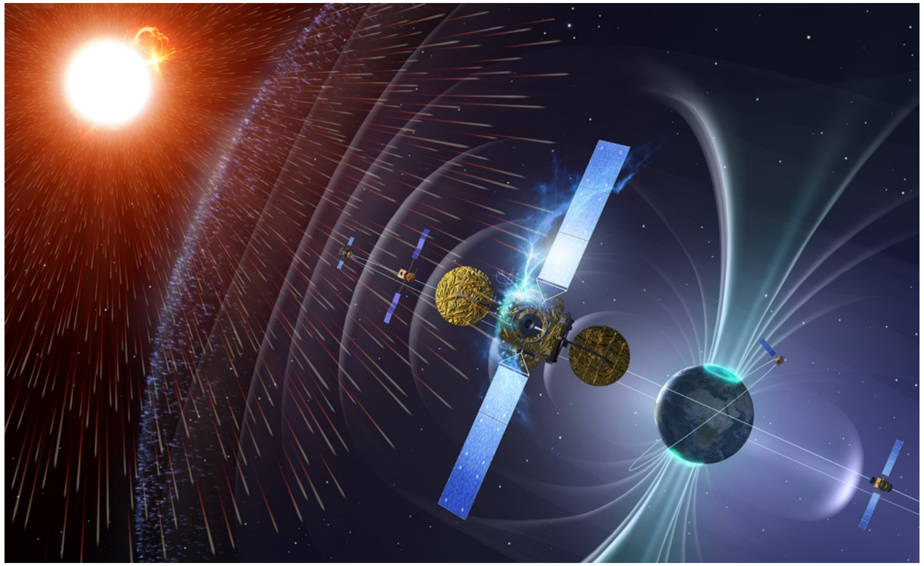
Commercial grade electronics

- Unknown radiation tolerance
- No traceability to lot
- Very cheap

Radiation

Radiation effects electronics in different ways





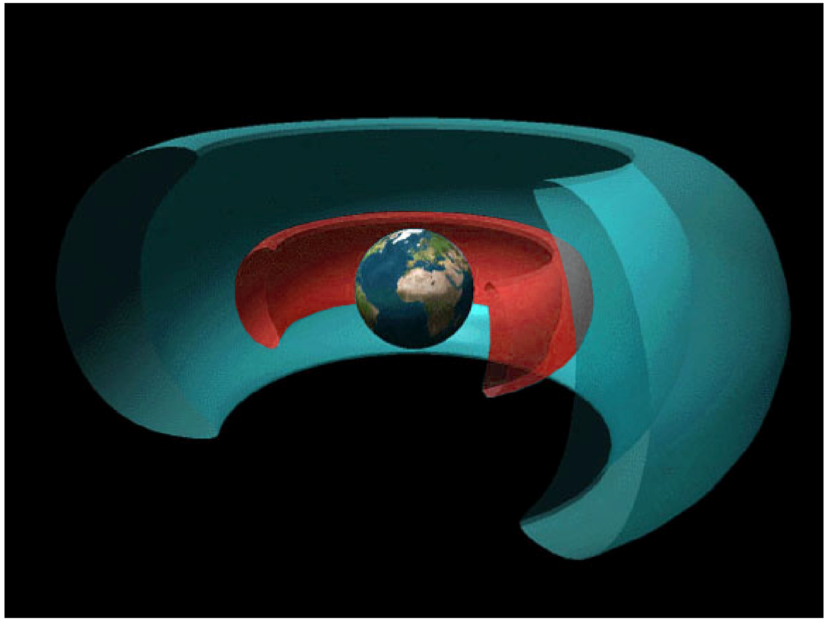
- Long term degradation –
Particles are trapped in the Van Allan Belts due to the earth magnetic field

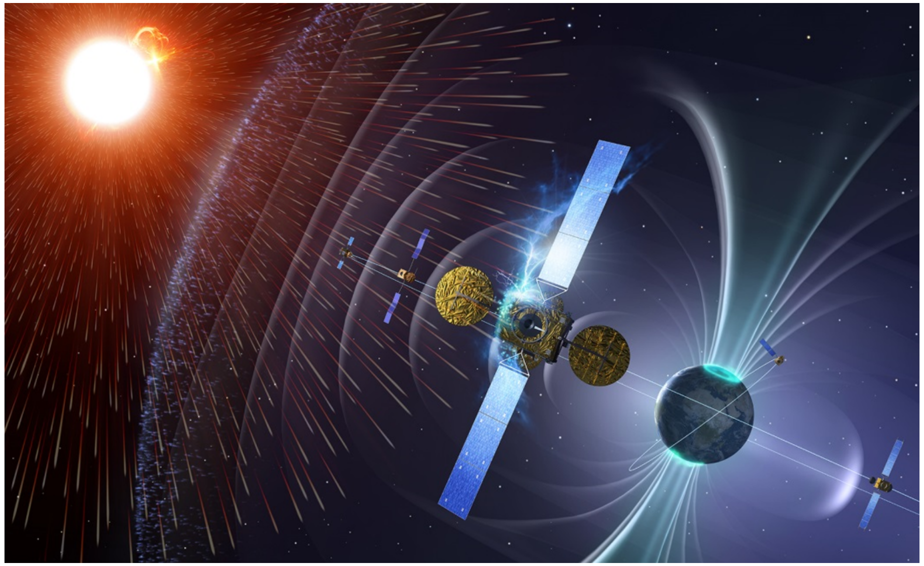
- LEO missions effected mainly by trapped protones in the inner belt
- GEO missions effeted mainly by trapped electron
- Consequences for electronics are alteration of electrical characteristics

Together ahead. RUAG

Radiation

Radiation effects electronics in different ways





- Long term degradation –

Particles are trapped in the Van Allan Belts due to the earth magnetic field

- LEO missions effected mainly by trapped protones in the inner belt
- GEO missions effeted mainly by trapped electron
- Consequences for electronics are alteration of electrical characteristics

- Single Event Effects –

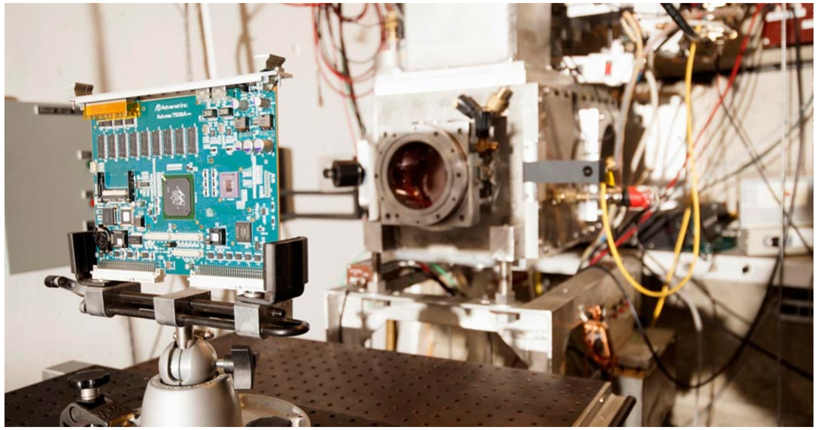
Heavy ions, protones and neutrones

- Cause memory elements to change state
- Cause glitches on analogue signals
- Caues current surge in the substrate (Latch-up)

Together ahead. RUAG

Radiation effects need to be explored and mitigated

Traditionally, only parts with an established radiation heritage are used

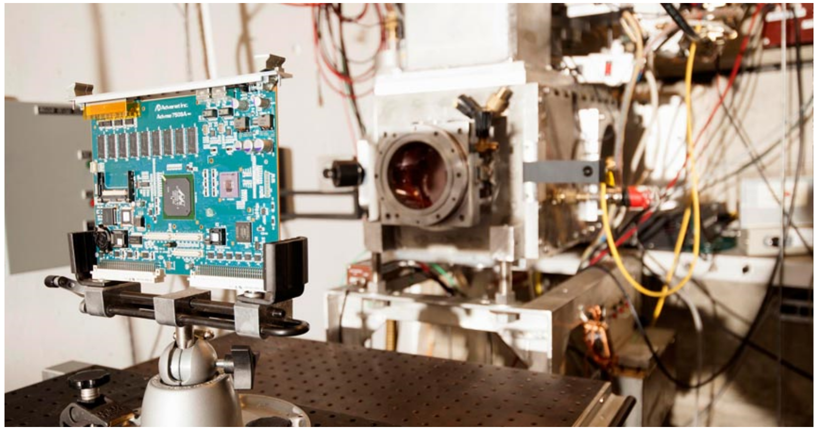


Together ahead. RUAG

Radiation effects need to be explored and mitigated

Traditionally, only parts with an established radiation heritage are used

Traditionally, many parts are designed to be radiation tolerant.



Together ahead. RUAG

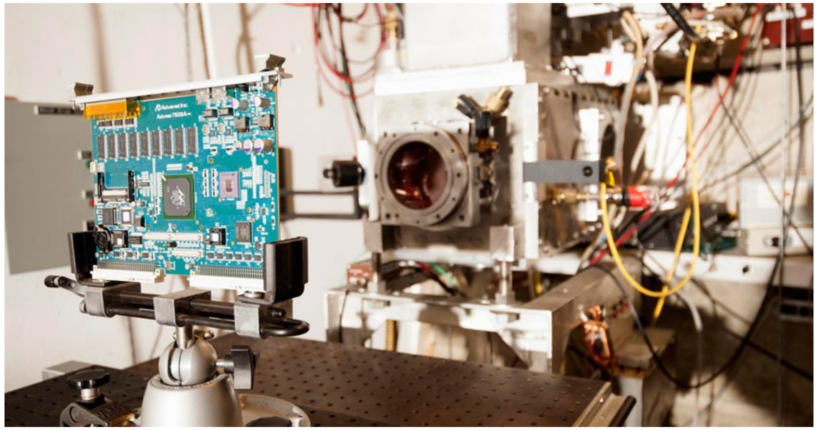
Radiation effects need to be explored and mitigated

Traditionally, only parts with an established radiation heritage are used

Traditionally, many parts are designed to be radiation tolerant.

Commercial parts can provide sufficient radiation tolerance

- But this need to be explored, tested



Together ahead. RUAG

Radiation effects need to be explored and mitigated

Traditionally, only parts with an established radiation heritage are used

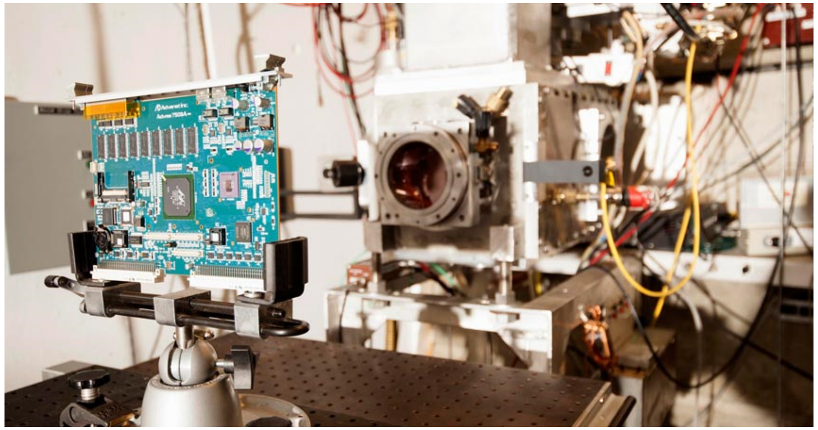
Commercial parts can provide sufficient radiation tolerance

- But this need to be explored, tested

Traditionally, many parts are designed to be radiation tolerant.

Commercial parts need to be used as is, with their behaviour

- Mitigations on component and/or system level will be needed



Together ahead. RUAG

Radiation effects need to be explored and mitigated

Traditionally, only parts with an established radiation heritage are used

Commercial parts can provide sufficient radiation tolerance

- But this need to be explored, tested

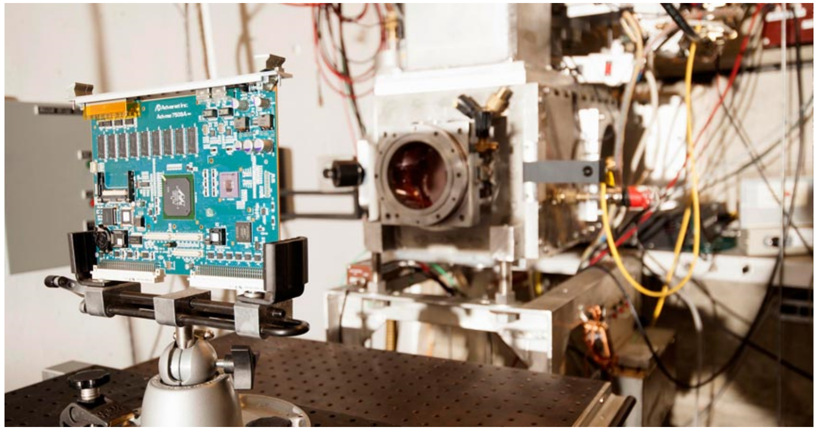
Traditionally, many parts are designed to be radiation tolerant.

Commercial parts need to be used as is, with their behaviour

- Mitigations on component and/or system level will be needed

Mitigation Techniques

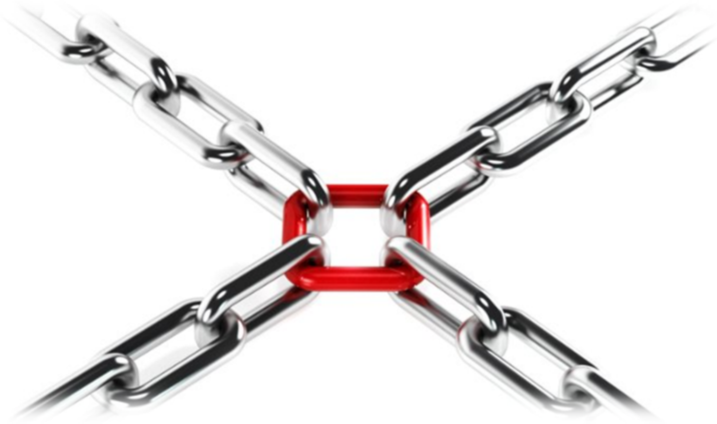
- Additional shielding (metal around sensitive parts)
- SEE Mitigation techniques, including:
  - TMR redundancy
  - software FDIR
  - Error correcting codes, EDACs
  - Supply current sensing and limiting
  - Power cycling when needed

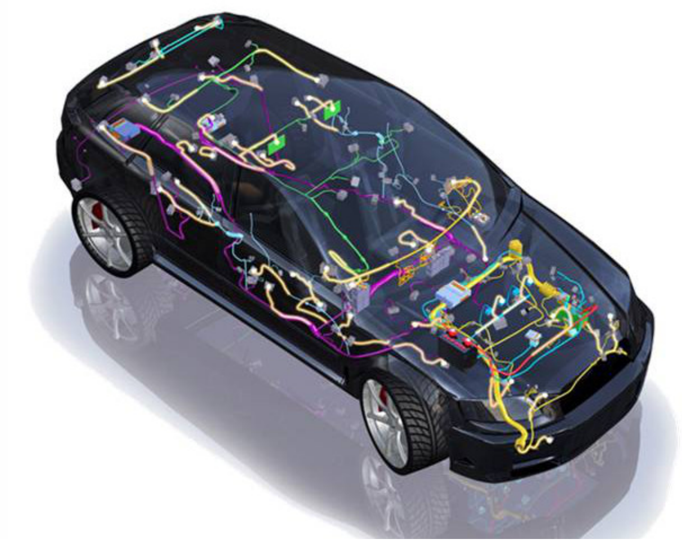


Together ahead. RUAG

Parts Reliability

Space quality parts gain reliability by extensive testing of individuals and lots

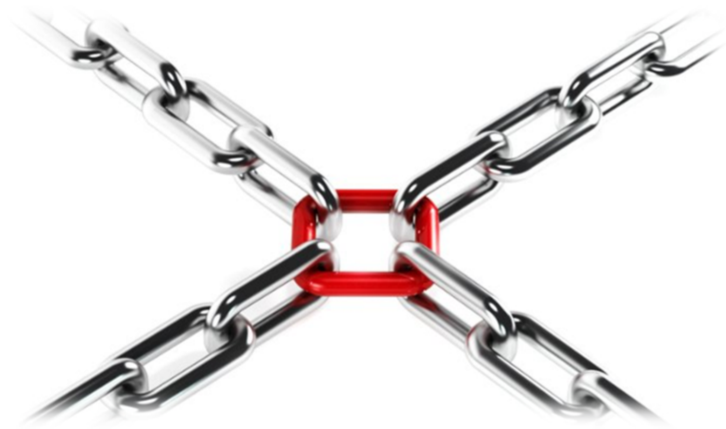




Together ahead. RUAG

Parts Reliability

Space quality parts gain reliability by extensive testing of individuals and lots

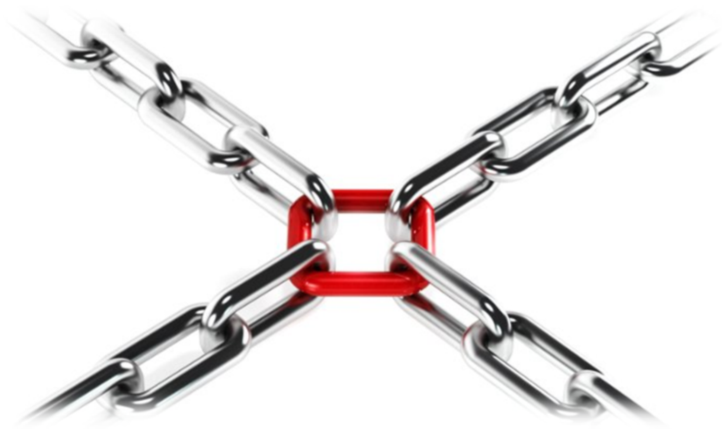


Commercial parts gain reliability by process control sample tests and by not touching the device to be used

Together ahead. RUAG

Parts Reliability

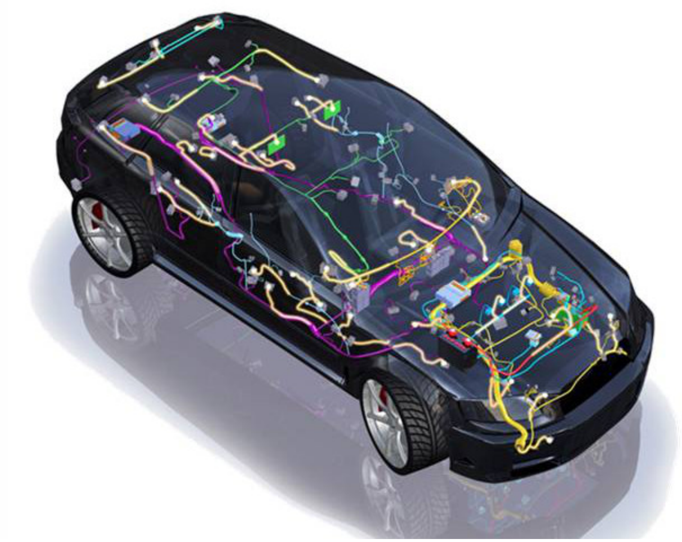
Space quality parts gain reliability by extensive testing of individuals and lots



Commercial parts gain reliability by process control sample tests and by not touching the device to be used

Commercial parts have some gaps compared to space graded parts

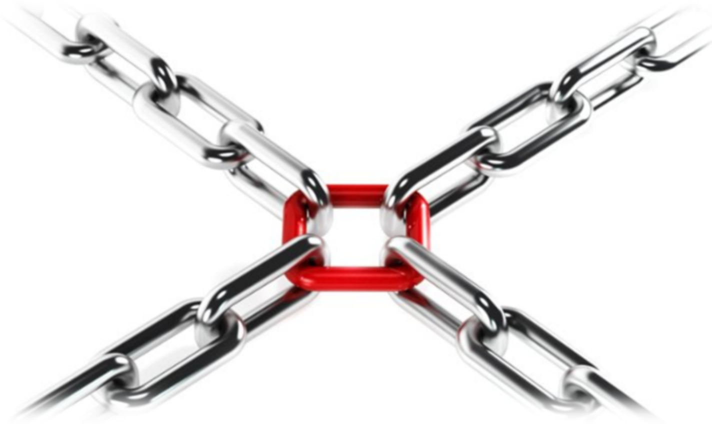
- Lack of traceability
- Testing over full temperature range
- No screening for infant mortality (burn-in)
- Different die designs has the same part number
- Lack of change control due to limited communication with the foundry



Together ahead. RUAG

Parts Reliability

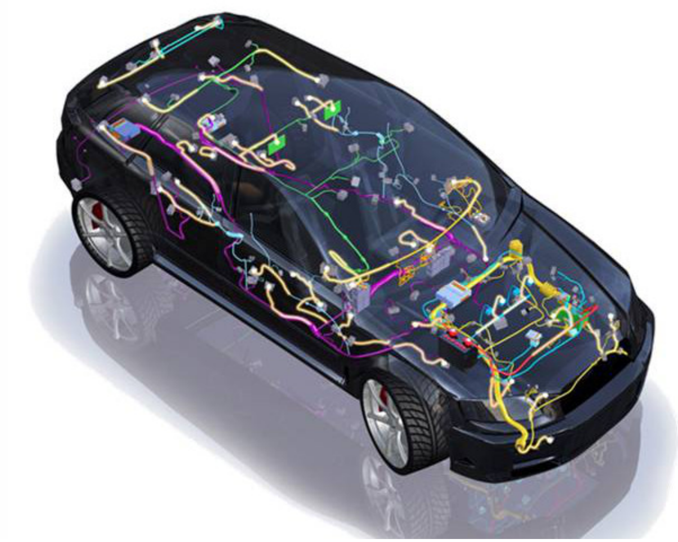
Space quality parts gain reliability by extensive testing of individuals and lots



Commercial parts gain reliability by process control sample tests and by not touching the device to be used

Commercial parts have some gaps compared to space graded parts

- Lack of traceability
- Testing over full temperature range
- No screening for infant mortality (burn-in)
- Different die designs has the same part number
- Lack of change control due to limited communication with the foundry



The gap can be partly filled by using automotive components.

Together ahead. RUAG

Electronics production

- **Manufacturing**

  Multi Chip and Surface Mount Technologies

  A combined space/military production line

  Currently producing:

  -3100 boards/year

  -2 board types/dag (batches)

- **Test**

  Electrical & Physical Testing

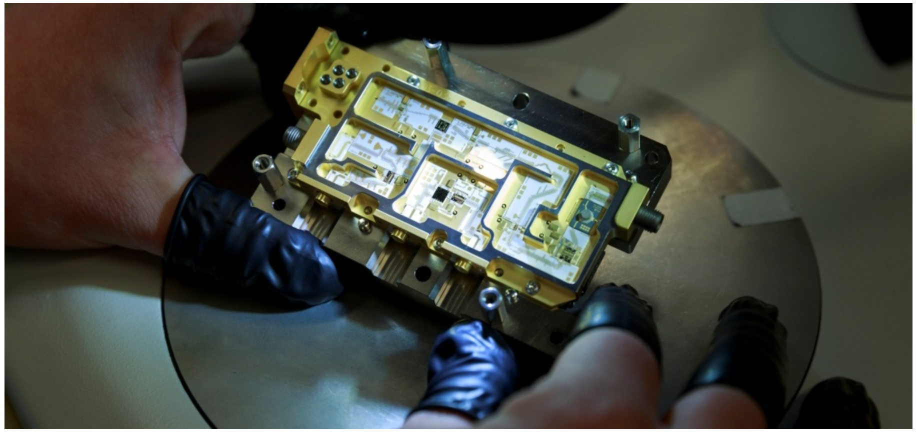
  Environmental testing:

  - Thermal Vacuum
  - Vibration
  - EMC

- **Process Development**
- **Component Technology**
- **Procurement**
- **Analysis Laboratory**
- **Clean Room**

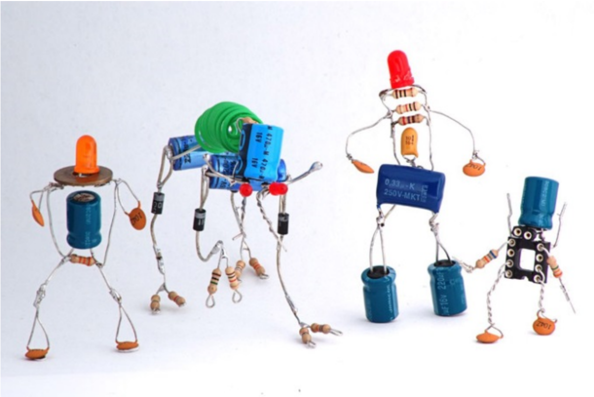
  2.700 m2 class 100.000 (ISO Class 8)

  200 m2 class 10.000 (ISO Class 7)

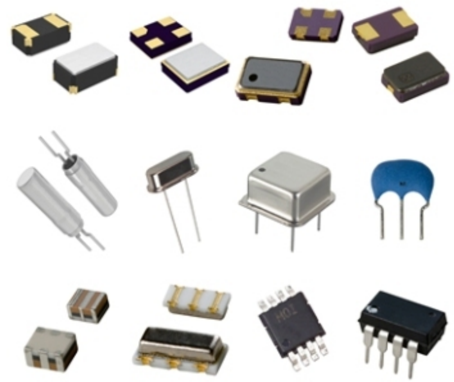


Together ahead. RUAG

Together ahead. RUAG



High-rel vs COTS



Function	High-rel implementation	COTS implementation
Processor	Rad-hard LEON 2	Commercial PowerPC or ARM
Processing memory	Space graded SRAM or SDRAM	Commercial DDR2 RAM
Non-volatile memory	Space graded EEPROM and PROM	Commercial NAND FLASH
TM & TC	Rad-hard ASIC	Commercial FPGA
Reconfiguration	Rad-hard ASIC	Commercial FPGA
I/O controller	Rad-hard ASIC	Commercial FPGA, microcontrollers
Analogue and AOCS I/O	Rad-hard transistors, op-amps, comparators, PWMs	Commercial transistors, op-amps, comparators, PWMs
Power Supply	Rad-hard MOS-FETs, diodes	Commercial MOS-FETs, power modules
GPS function	Stand-alone equipment	Integrated, commercial FPGA, GNSS RF receiver and on-board SW

RUAG Space approach to mega constellation satellite electronics

- We have heritage:
  - >35 years of experience in high-reliable launcher and satellite electronics.
  - A design database with existing & qualified SW and FPGA IP-modules
  - an internal certified design process for high-reliable electronics
  - a high quality electronics production facility already today capable of producing space electronics and large series commercial electronics

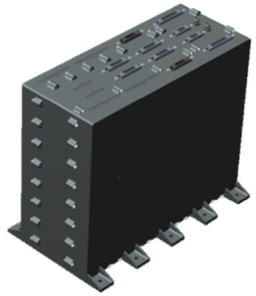
Together ahead. RUAG

RUAG Space approach to mega constellation satellite electronics

- We have heritage:
  - >35 years of experience in high-reliable launcher and satellite electronics.
  - A design database with existing & qualified SW and FPGA IP-modules
  - an internal certified design process for high-reliable electronics
  - a high quality electronics production facility already today capable of producing space electronics and large series commercial electronics
- Our approach is to be flexible:
  - reuse the existing design data-base and production facility
  - use a mix of high-rel components with up-screened COTS components.
  - Balance the mix and level of screening depending on project requirements.

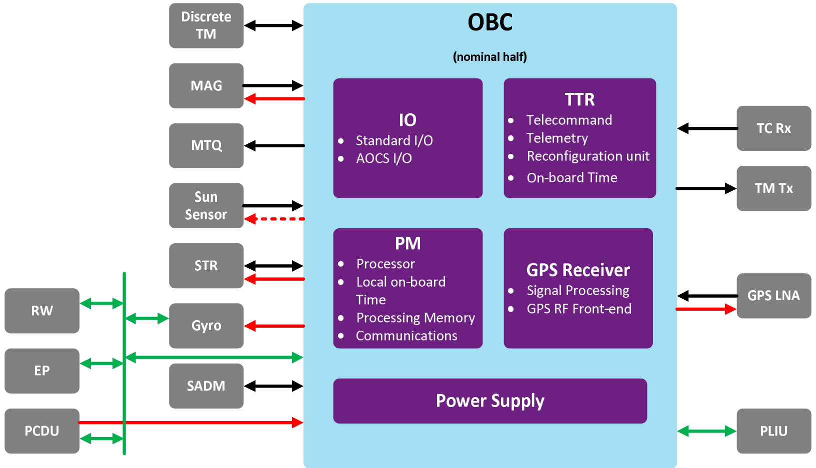
RUAG Space approach to mega constellation satellite electronics

- We have heritage:
  - >35 years of experience in high-reliable launcher and satellite electronics.
  - A design database with existing & qualified SW and FPGA IP-modules
  - an internal certified design process for high-reliable electronics
  - a high quality electronics production facility already today capable of producing space electronics and large series commercial electronics
- Our approach is to be flexible:
  - reuse the existing design data-base and production facility
  - use a mix of high-rel components with up-screened COTS components.
  - Balance the mix and level of screening depending on project requirements.
- This enables us to offer something very different:
  - Reliable data handling COTS products
  - Significantly lower prices and higher performance than the corresponding traditional space qualified products



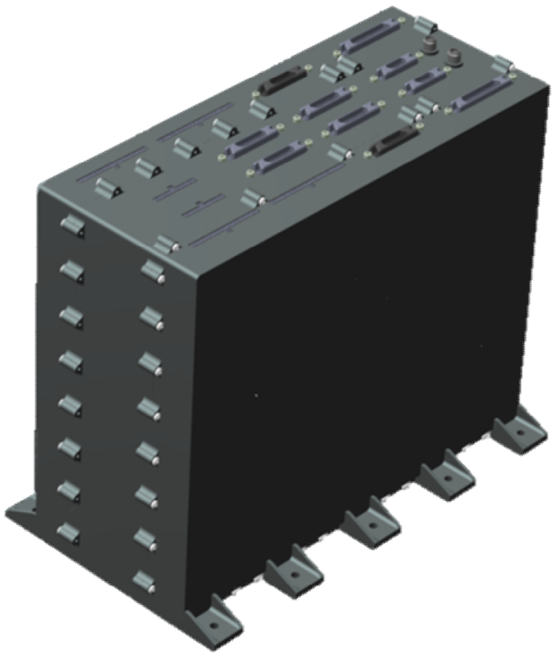
Together ahead. RUAG

Compact COTS OBC



Functions

- PowerPC processor
- Telecommand, Telemetry and OBT
- Software independent Reconfiguration unit
- Standard and AOCS I/O
- Integrated single frequency GPS receiver
- Secondary power distribution
- Platform and payload communication



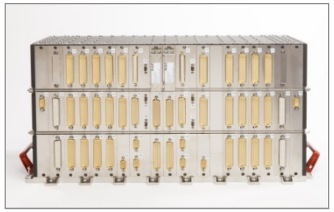
Characteristics

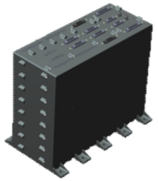
- Physical dimensions: 240x100x200 mm
- Mass: 2.8 kg
- Power consumption: 22 W
- Processing performance: 1800 DMIPS, 800 MFLOPS
- Memory resources: 512 MiB RAM, 512 MiB NVM
- GPS position error: <10 m RMS 3D
- Discrete analog TM: 20 inputs
- Designed life-time: 6 years LEO

RUAG Space Sweden – Products

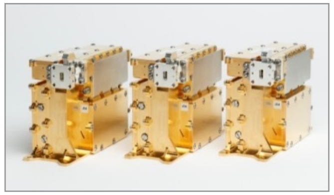
Gothenburg operations:

Space electronics

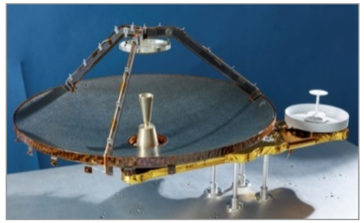




Computer Systems



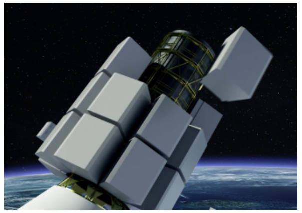
Frequency Converters



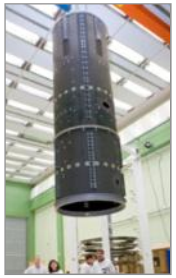
Antennas

Linköping operations:

Mechanical systems



Separation Systems

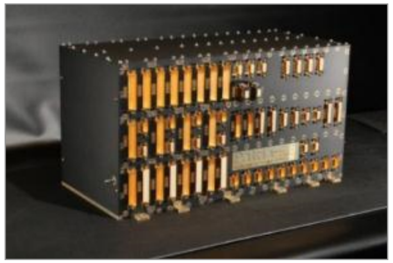


Satellite Structures

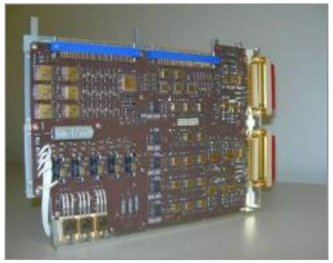
Guidance Systems

Tampere operations:

Space electronics



Interface Units



Power & Drive Electronics

Together ahead. RUAG

Digital products

- **Command and Data Handling Systems**

  Digital Electronics has been delivered to more than 128 satellites in telecom, navigation, science and earth observation applications

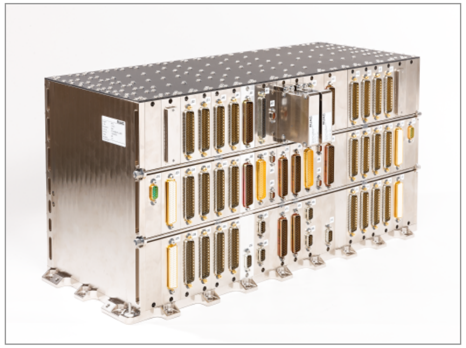
  Our most recent programs are:
  GAIA; Galileosat; GMES Sentinels 1, 2 & 3; Göktürk; EarthCare; ExoMars Orbiter & Rover; SmallGeo; Solar Orbiter; Iridium Next; EDRS-C; MeteoSat Third Generation and Euclid

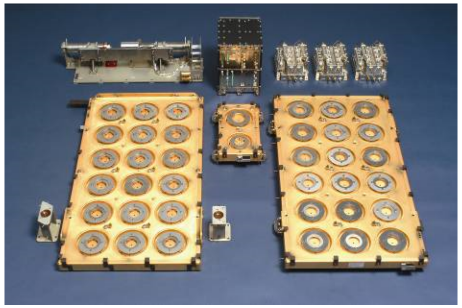
- **Guidance and Control**

  More than 235 Ariane launchers, Vega launcher, ATV collision avoidance system

- **Payload Control and Instruments**

  For Inmarsat, MetOp, Galileosat, GMES Sentinel 4/UVN; Sentinel 5P/Tropomi;
  DCAMP Single Board Computer
  Radio occultation: GRAS and GRAS-2
  Radar sub-systems: Envisat, GMES Sentinel 1





Together ahead. RUAG

Acknowledgements

- Slide 2, figure top right
  By Jeff Ogden (W163) - Own work, based on figures from the Wikipedia:List of countries by number of Internet users article in the English Wikipedia, which is in turn based on figures from the International Telecommunications Union (ITU) for 2010 (updated to use figures for 2012 on 28 June 2013). The source code of this SVG is valid.This vector image was created with a text editor. This vector image includes elements that have been taken or adapted from this: BlankMap-World6.svg., CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=19202338
- Slide 2, figure bottom left
  By Author of Carna Botnet "Internet Census 2012", PGP public key - http://internetcensus2012.bitbucket.org/images/geovideo_lowres.gif , [1]Internet Census 2012: Port scanning /0 using insecure embedded devices, Carna Botnet, June - Oktober 2012, Public Domain, https://commons.wikimedia.org/w/index.php?curid=26114329