
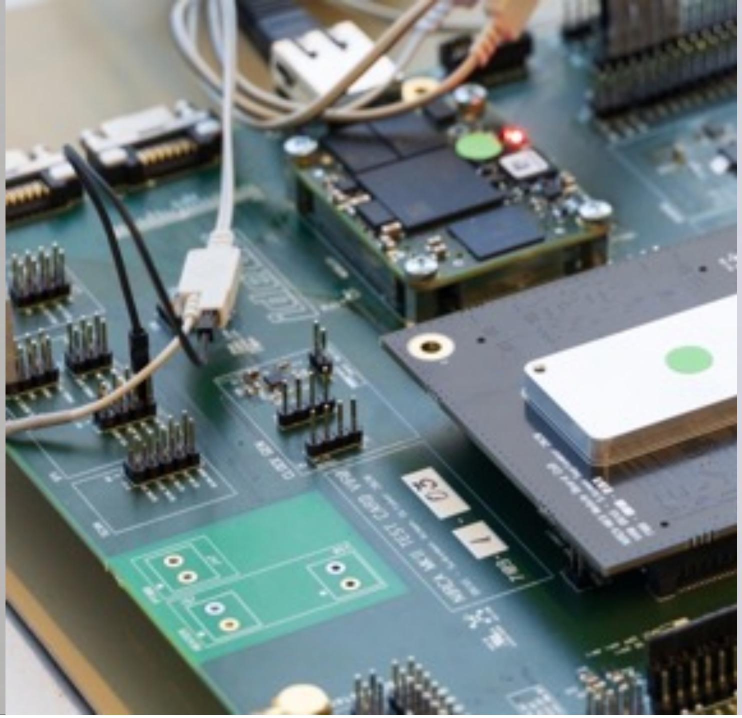
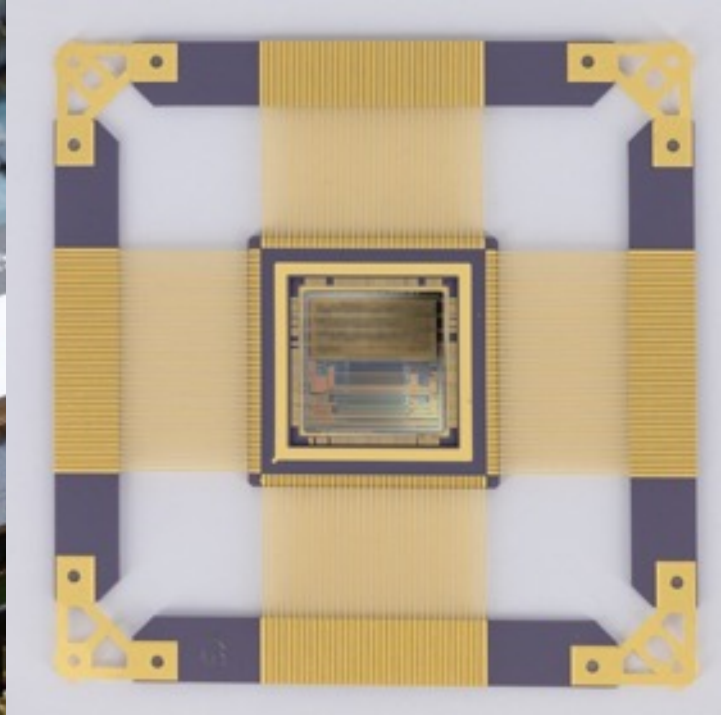

Integrated Detector Electronics AS

Microelectronics in space, challenges, and two ASICs from Integrated Detector Electronics AS

Gunnar Maehlum, CEO   gmaehlum@ideas.no Oslo 2022-10-26

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ASTRONOMY | OPINION

The Brightest Gamma-Ray Burst Ever Recorded Rattled Earth's Atmosphere

The death of a massive star far across the universe affected lightning on our planet and could teach us about the Milky Way

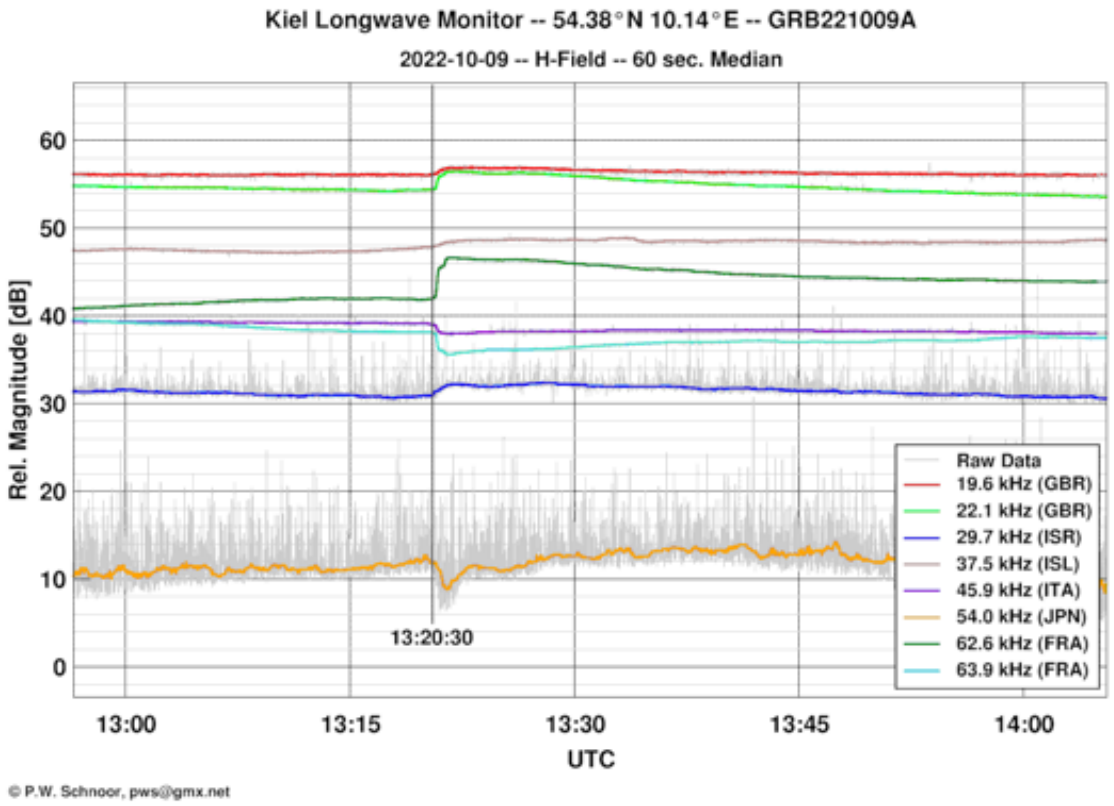
By Phil Plait on October 21, 2022

Atmospheric disturbances from the x-rays ionizing the upper atmosphere.

TITLE: GCN CIRCULAR NUMBER: 32744
SUBJECT: GRB221009A: Detection as sudden ionospheric disturbances (SID)
DATE: 22/10/13 21:42:27 GMT
FROM: Doug Welch at McMaster University <welch@physics.mcmaster.ca> P.W. Schnoor (Kiel Longwave Monitor, Germany), P. Nicholson (Todmorden, UK), D.L. Welch (McMaster University, Canada)

A sudden disturbance of the Earth's ionosphere (SID) was observed by the Kiel Longwave Monitor (Germany) and a VLF-Monitor at Todmorden (near Manchester, UK) coincident with the detection of GRB221009A (SWIFT, #32635).
This SID was seen as a sudden increase or decrease in the signal strengths from radio transmitters below 100 kHz (19.6 to 63.9 kHz; VLF/LF) received at Kiel and Todmorden. These naval transmitting stations are located at France, Germany, Iceland, Israel, Italy, Japan (Okinawa), United Kingdom and United States.

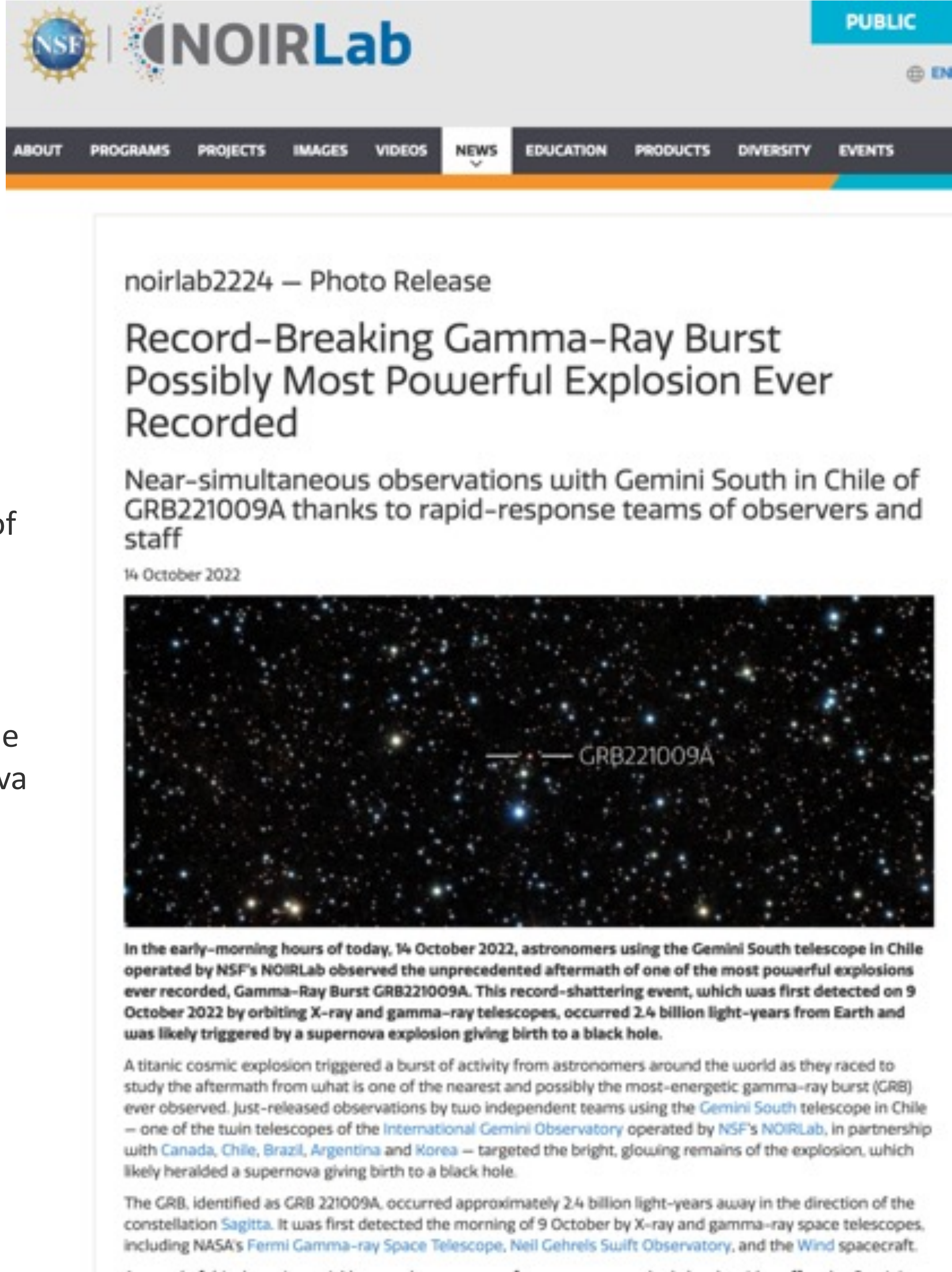
Note: This is not a radio detection of GRB221009A; this disturbance was caused by the prompt X-rays and/or gamma-rays from GRB221009A ionizing the upper atmosphere and modifying the radio propagation properties of the waveguide between ground and ionosphere.



Presented at NorCAS 2022 in Oslo

The explosion observed by ground based telescopes

- A titanic cosmic explosion triggered a burst of activity from astronomers around the world as they raced to study the aftermath from what is one of the nearest and possibly the most-energetic gamma-ray burst (GRB) ever observed. Just-released observations by two independent teams using the Gemini South telescope in Chile — one of the twin telescopes of the International Gemini Observatory operated by NSF's NOIRLab, in partnership with Canada, Chile, Brazil, Argentina and Korea — targeted the bright, glowing remains of the explosion, which likely heralded a supernova giving birth to a black hole.
- The GRB, identified as GRB 221009A, occurred approximately 2.4 billion light-years away in the direction of the constellation Sagitta. It was first detected the morning of 9 October by X-ray and gamma-ray space telescopes, including NASA's Fermi Gamma-ray Space Telescope, Neil Gehrels Swift Observatory, and the Wind spacecraft.



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noirlab2224 — Photo Release

Record-Breaking Gamma-Ray Burst Possibly Most Powerful Explosion Ever Recorded

Near-simultaneous observations with Gemini South in Chile of GRB221009A thanks to rapid-response teams of observers and staff

14 October 2022

In the early-morning hours of today, 14 October 2022, astronomers using the Gemini South telescope in Chile operated by NSF's NOIRLab observed the unprecedented aftermath of one of the most powerful explosions ever recorded, Gamma-Ray Burst GRB221009A. This record-shattering event, which was first detected on 9 October 2022 by orbiting X-ray and gamma-ray telescopes, occurred 2.4 billion light-years from Earth and was likely triggered by a supernova explosion giving birth to a black hole.

A titanic cosmic explosion triggered a burst of activity from astronomers around the world as they raced to study the aftermath from what is one of the nearest and possibly the most-energetic gamma-ray burst (GRB) ever observed. Just-released observations by two independent teams using the Gemini South telescope in Chile – one of the twin telescopes of the International Gemini Observatory operated by NSF's NOIRLab, in partnership with Canada, Chile, Brazil, Argentina and Korea – targeted the bright, glowing remains of the explosion, which likely heralded a supernova giving birth to a black hole.

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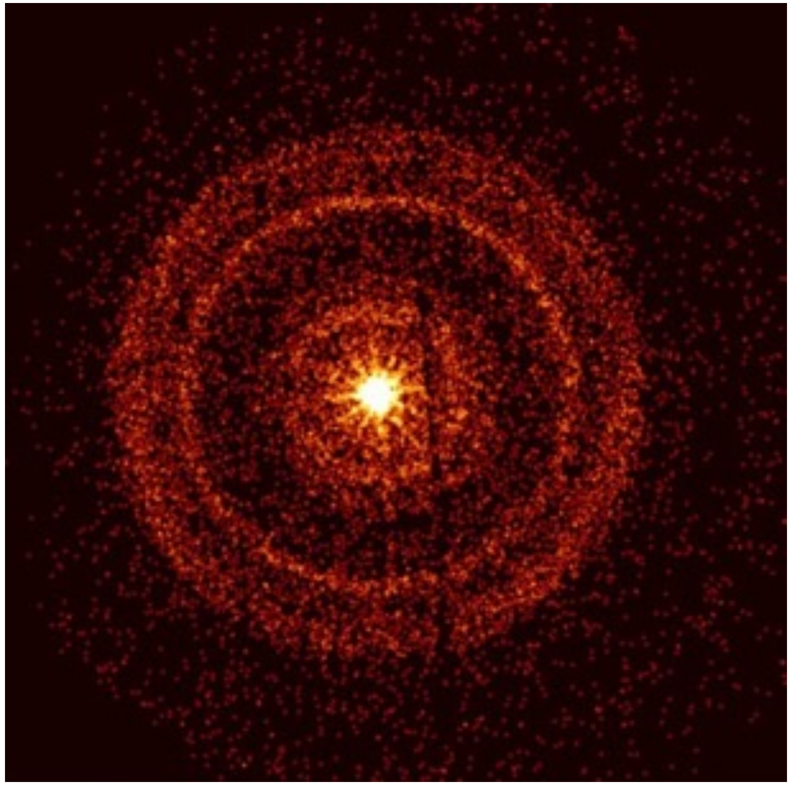
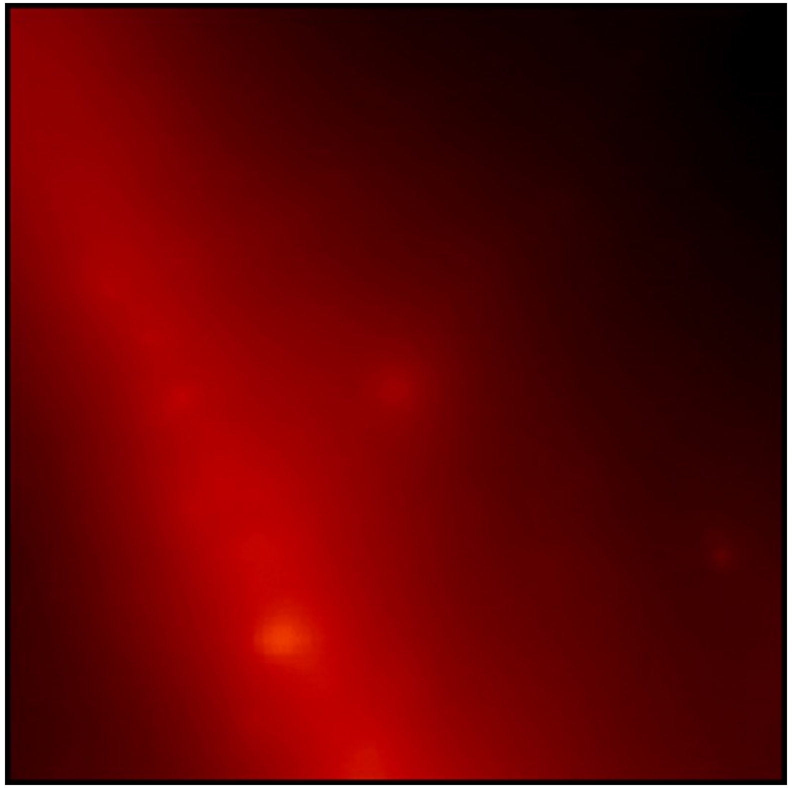
The october 09 2022 gamma ray burst.



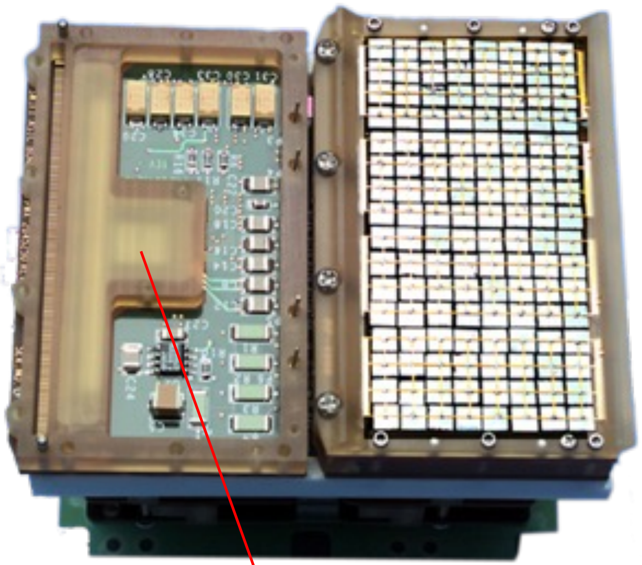
Observasjon from Swift in X rays. The image covers about 20degrees and 10 hours exposure. The rings are scatter from dust in our own galaxy

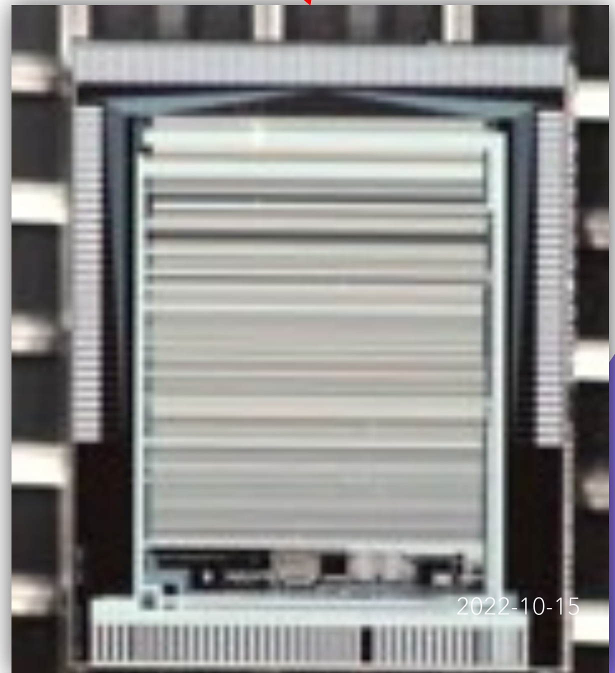
Images: NASA



Observasjon fra Fermi
Bildet dekker ca 20grader og 10 timer eksponering.

NASA´s SWIFT MISSION

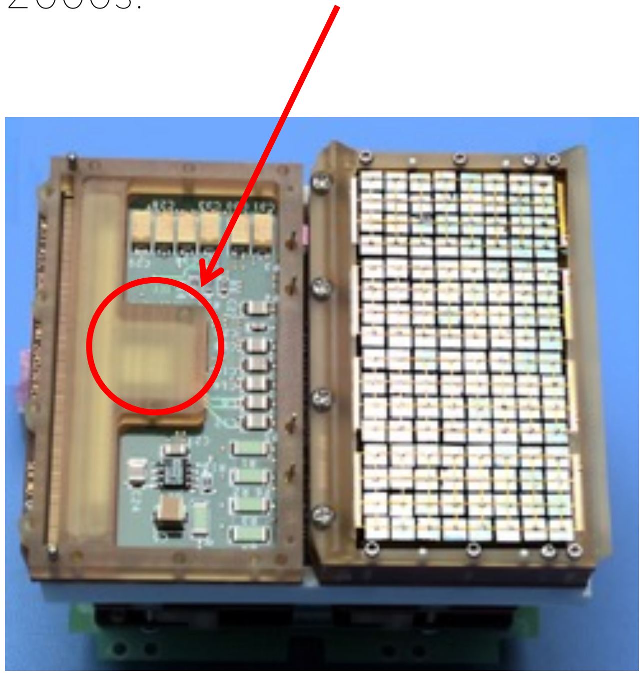


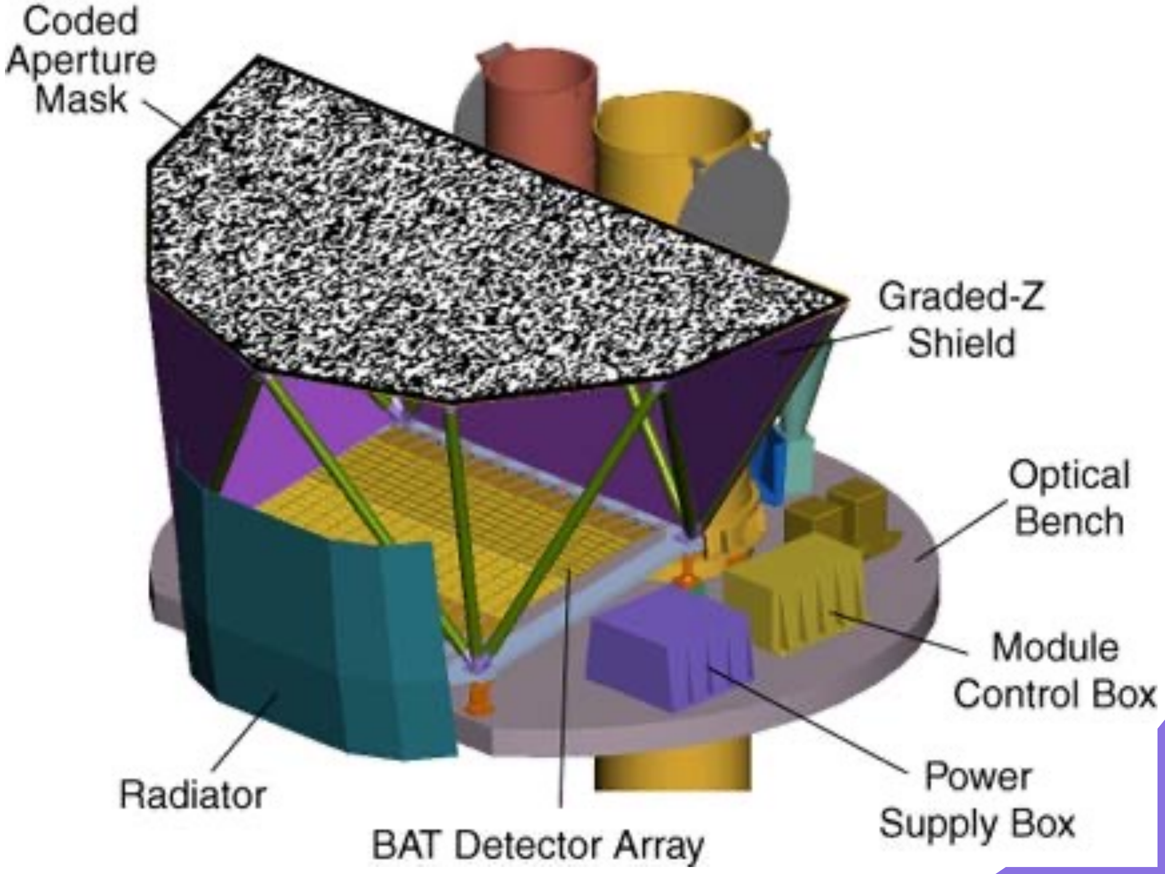


Ideas XA1.2 in orbit since November 2004

Swift Burst Alert Telescope a coded mask detector for medium energy gamma rays

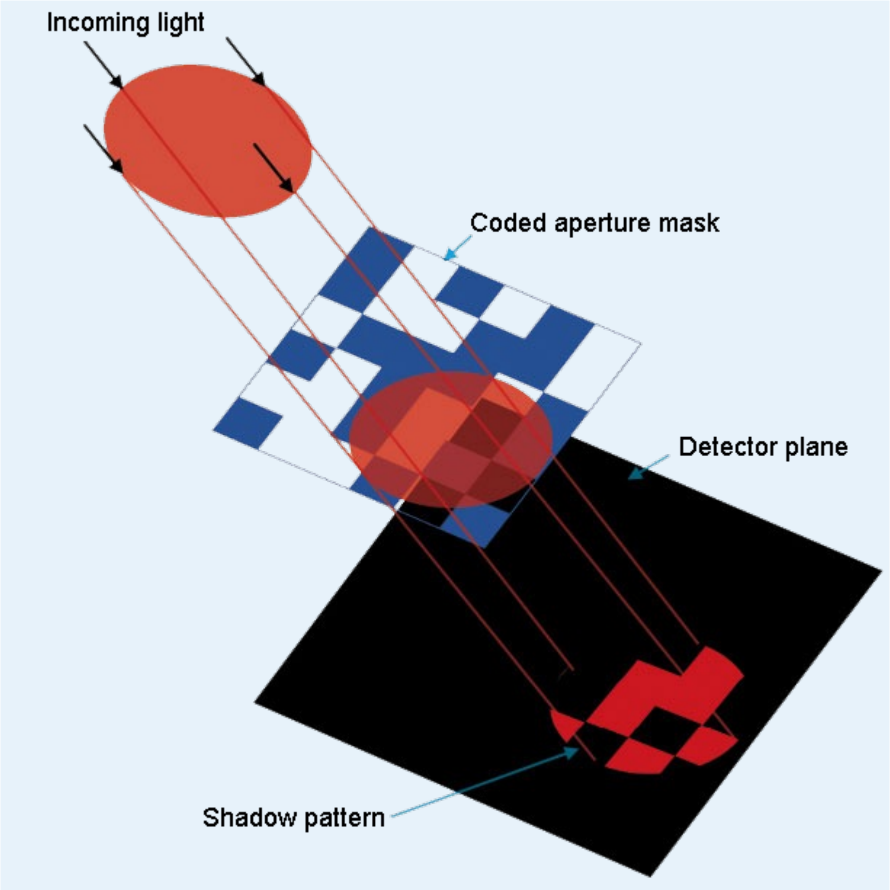
The integrated electronics of the BAT was designed and delivered by Integrated Detector Electronics, Oslo, Norway in the early 2000s.





Coded mask imaging

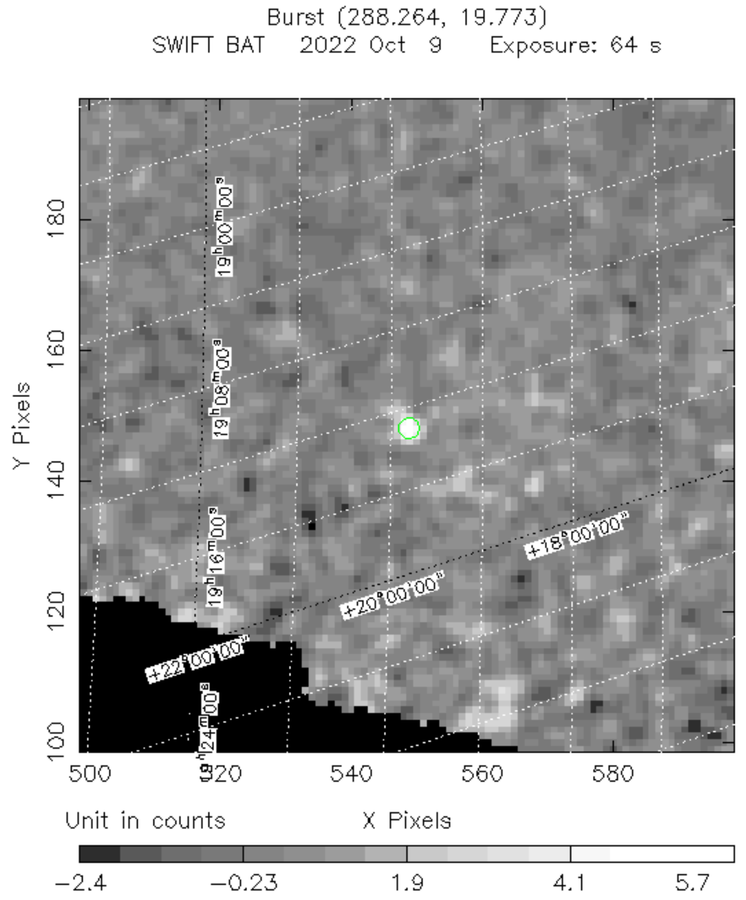
- Gamma radiation cannot be focused with lenses
- Imaging can be done with a shadow mask
- The photons are detected by an array of detectors, I SWIFT 32768 Cadmium Zinc Telluride crystals.
- Reconstruction is necessary to be able to form an image.



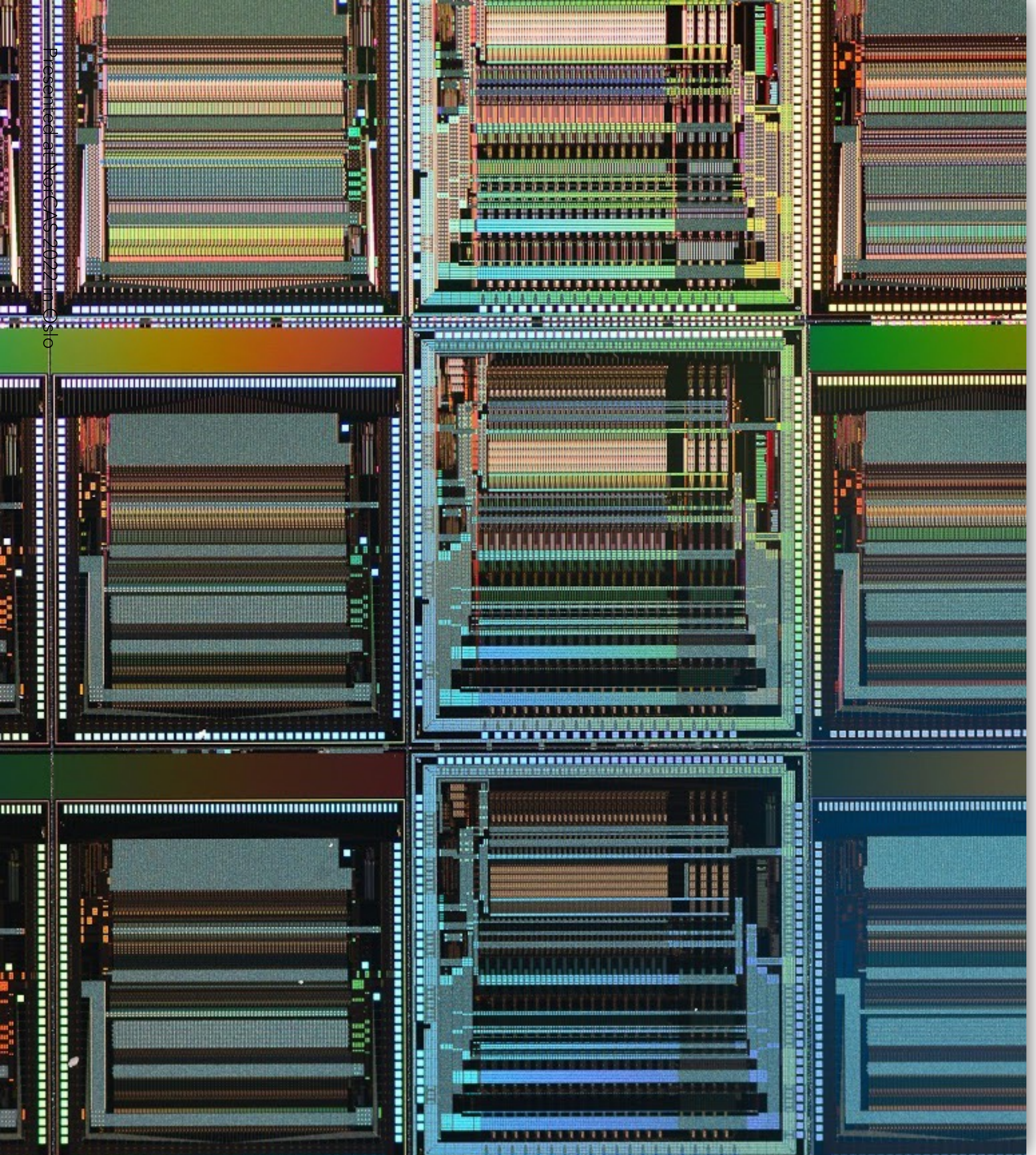
Presented at NorCAS 2022 in Oslo

Burst alert Telescope trigger

- From https://gcn.gsfc.nasa.gov/other/221009A.gcn3
-
- TITLE: GCN CIRCULAR
- NUMBER: 32635
- SUBJECT: GRB 221009A: Swift detected transient may be GRB
- DATE: 22/10/09 20:44:25 GMT
- FROM: Jamie Kennea at Penn State U <jak51@psu.edu>
-
- J. A. Kennea and M. Williams (PSU) report on behalf of the Swift Team:
-
- We provide an update on the BAT trigger 1126853, AKA Swift J1913.1+1946
- (GCN #32632). Examination of XRT data from this trigger shows strong
- fading. We also note that Fermi/LAT has triggered on the same location.
- There is also a possible association with a Fermi/GBM trigger @
- 13:16:59UT. Given this, we believe that this source is now likely a
- Gamma-Ray Burst and not a Galactic Transient. If the GBM trigger is the
- same source, this would suggest a highly energetic outburst, and therefore
- we strongly encourage follow-up of this usual event.
-
- The SWIFT BAT is the one using the XA ASICs



About IDEAS



We develop and manufacture electronics for radiation detection in space and on ground

Selected customers and partners

ThalesAlenia Space, a Thales / Leonardo company
MITSUBISHI HEAVY INDUSTRIES, LTD.
CERN
ess EUROPEAN SPALLATION SOURCE
leti ceatech
SPACE SCIENCES LABORATORY UNIVERSITY OF CALIFORNIA Berkeley
NASA
中國科學院 CHINESE ACADEMY OF SCIENCES
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DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA
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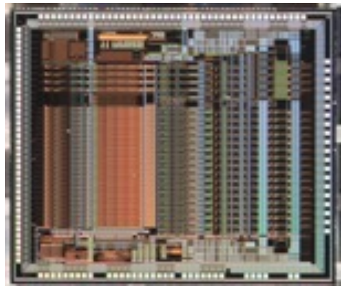
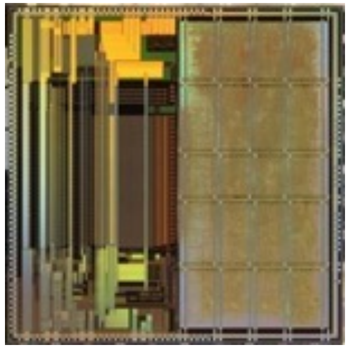
Selected products

Radiation tolerant ICs for use in space

- IDE3465 (VATA465) Readout circuit for for segmented radiation detectors. Used on several radiation monitors on satellites.

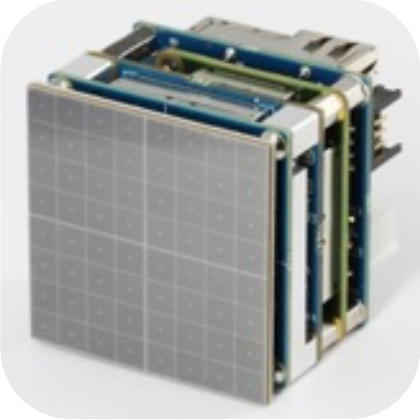


- IDE3466 (VATA466) used in RADEM an electron/proton/ion spectrometer on ESAs Jupiter ICy moons Explorer JUICE and in our own NORM for ASBM



Gamma/neutron spectrometer modules

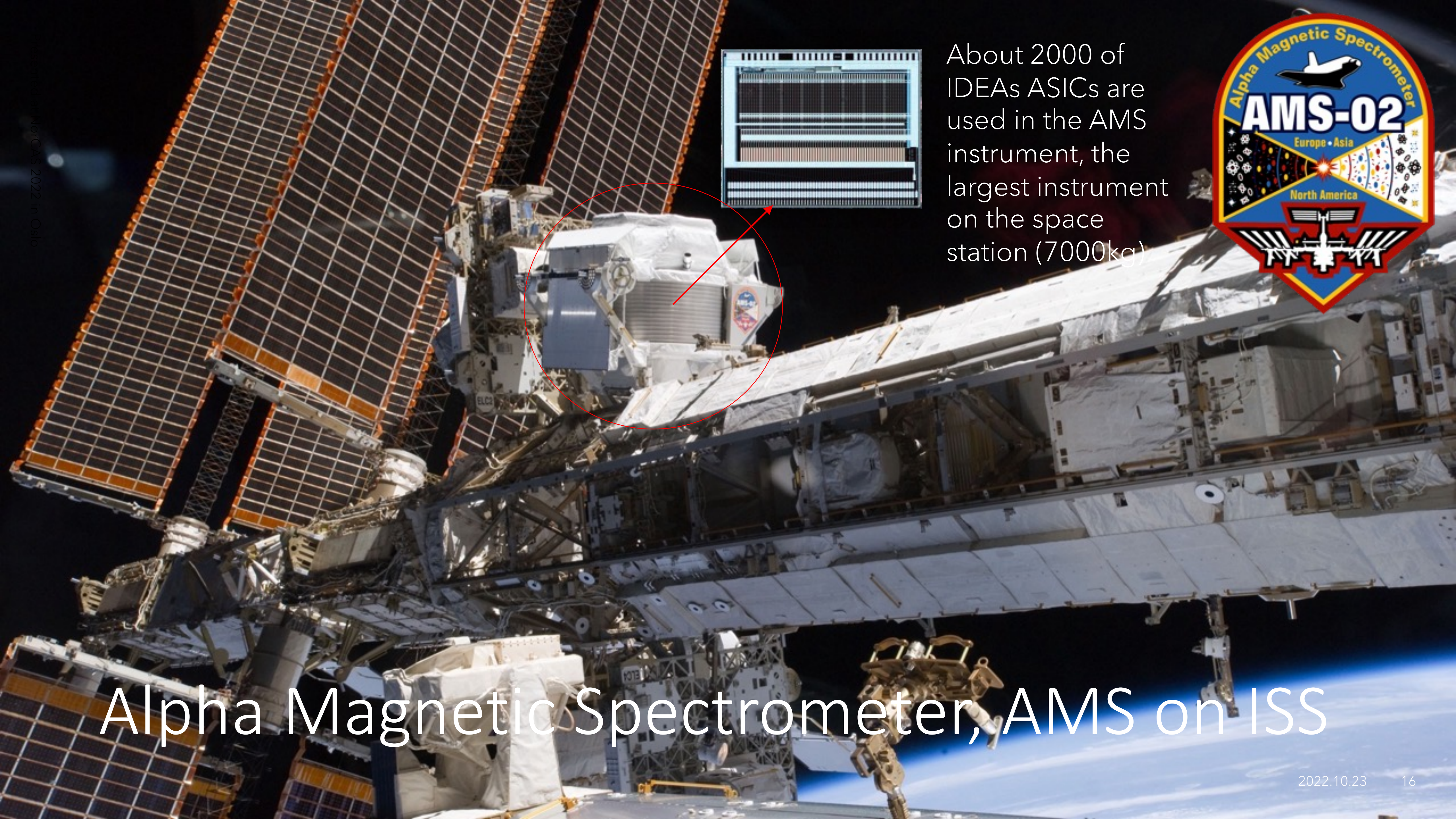
- ROSMAP/ROSSPAD,   R/O of Multi-anode photomultiplier tubes and Silicon photomultipliers.



- IDE GDS-100, high resolution gamma spectrometer module using Cadmium Zinc Telluride crystals

selected missions

April 2018, a Falcon 9 lifts off from Cape Canaveral with the ASIM instrument onboard
Foto: G. Maehlum



About 2000 of IDEAs ASICs are used in the AMS instrument, the largest instrument on the space station (7000kg)

Alpha Magnetic Spectrometer, AMS on ISS

ASIM ON THE ISS

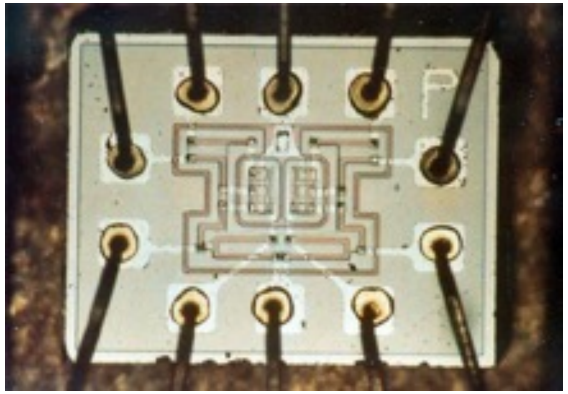
The University of Bergen chose the IDEAS ASIC and module for their gamma ray detector in the ASIM launched 2018

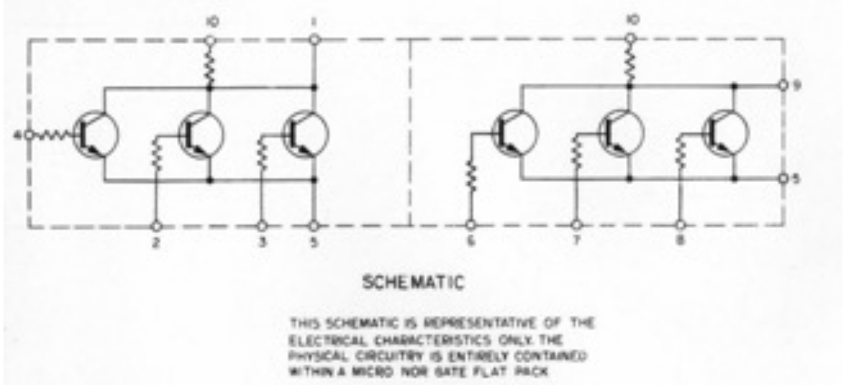
The instrument studies gamma rays from high altitude lightings.

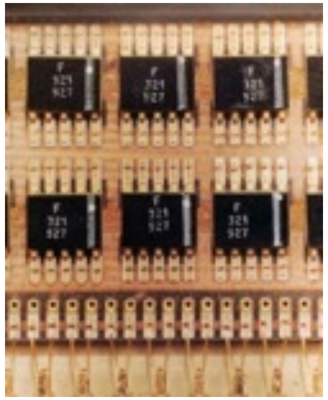
Results from ASIM were published in Nature January 2021

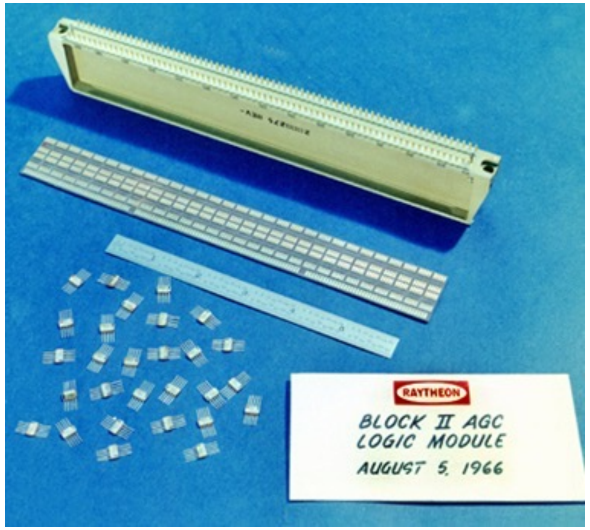
Challenges encountered when using microelectronics in in space

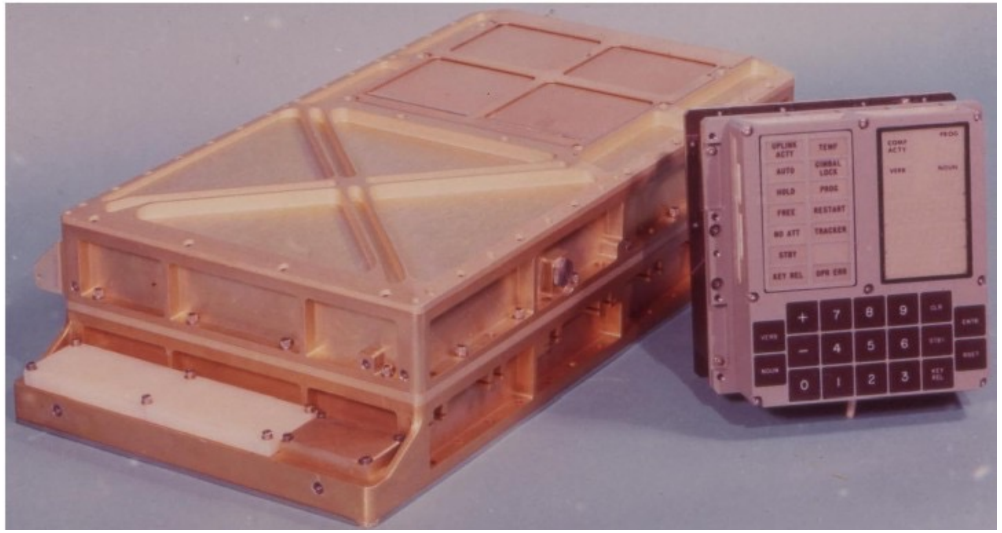
First applications of Ic´s in computers: Apollo Guidance Computer









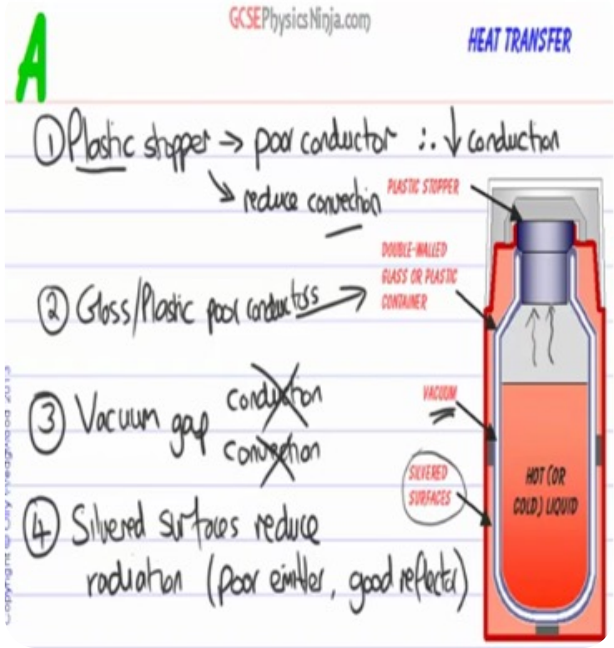


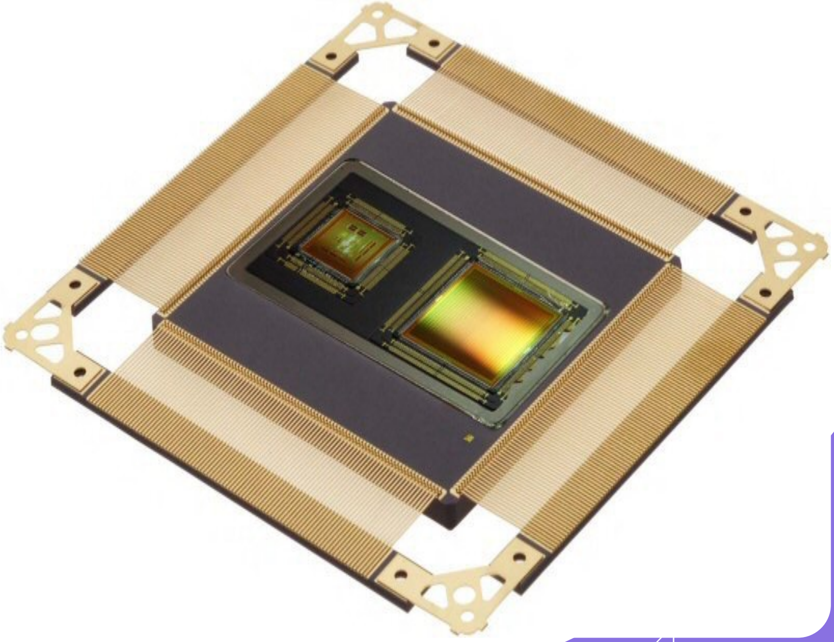
Challenges for IC´s use in space

- Vacuum implies poor heat transfer from the chip.
- Extreme and rapid changes in temperature in low earth orbit.
- Radiation from the sun and cosmic rays induces effects and damage in transistors.

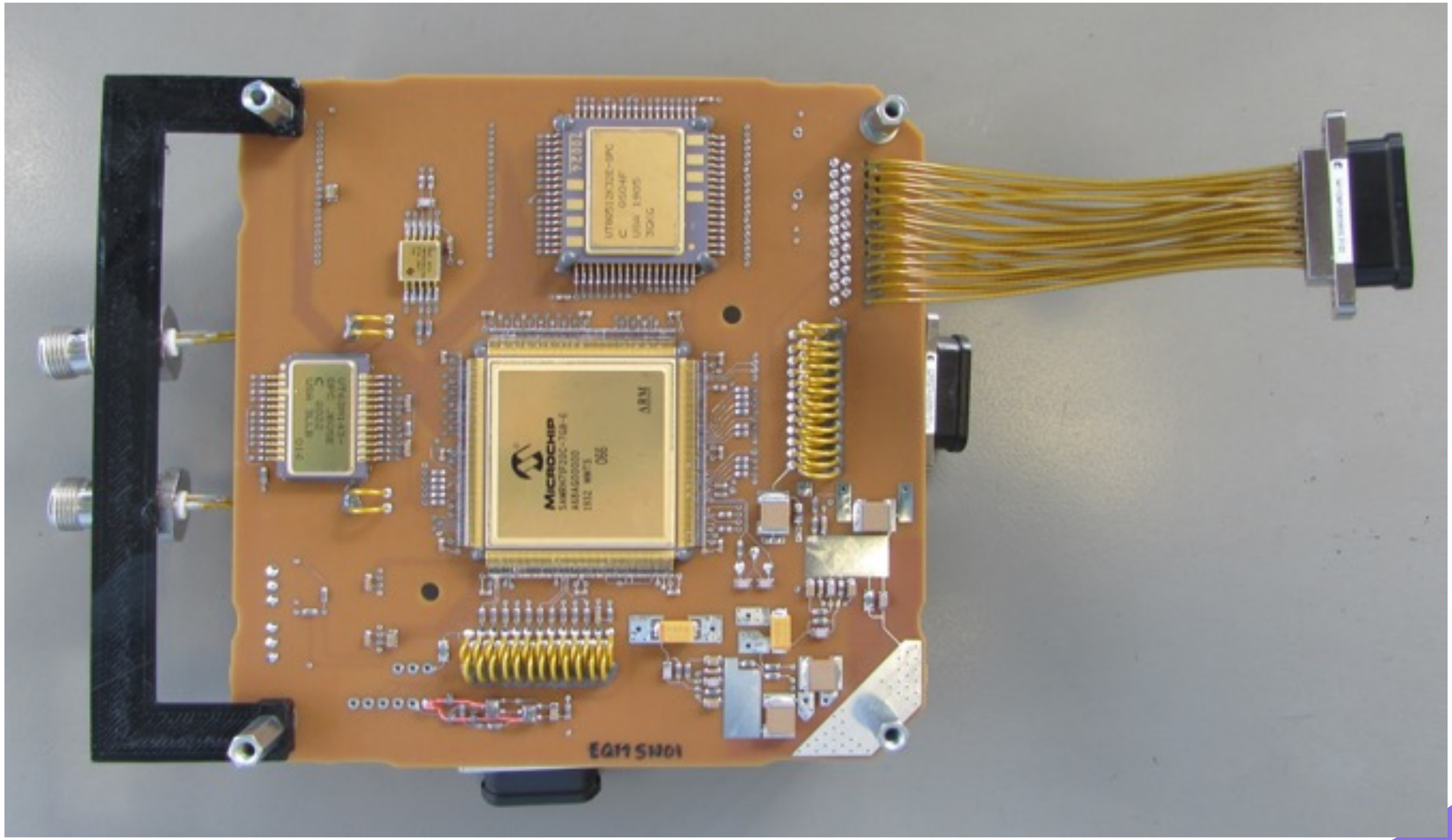
Heat dissipation

- In vacuum heat transfer is only possible by conduction in the structure and by infrared radiation to the spacecraft or to outer space.
- This is exactly why a thermos bottle keeps your coffee warm. There is a vacuum between the inner and outer walls.
- Special care is therefore required in the design of packaging and assemblies.





A fully qualified circuit board, CPU board of IDEAS NORM instrument

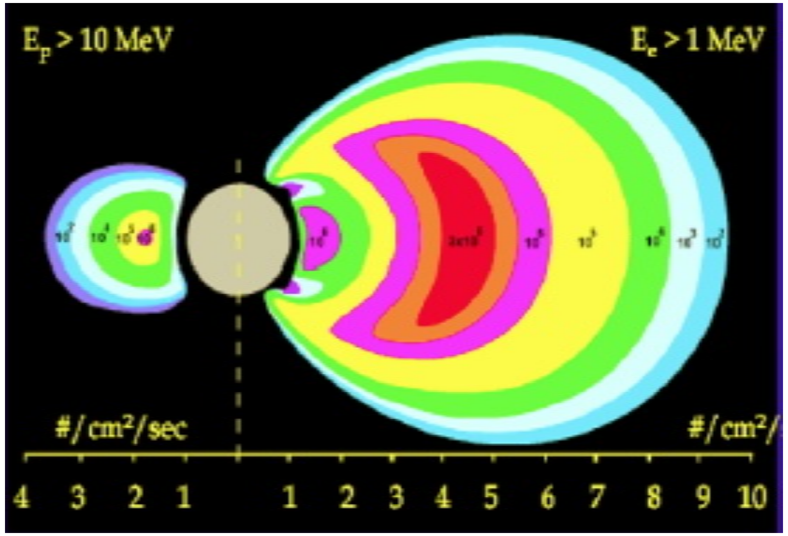


Radiation effects

Presented at NorCAS 2022 in Oslo

Radiation effects, causes

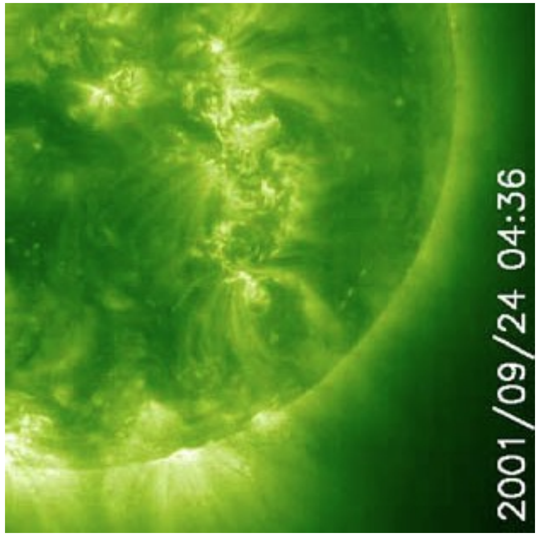
Radiation belts



Protons
keV-500MeV

Electrons
eV-10MeV

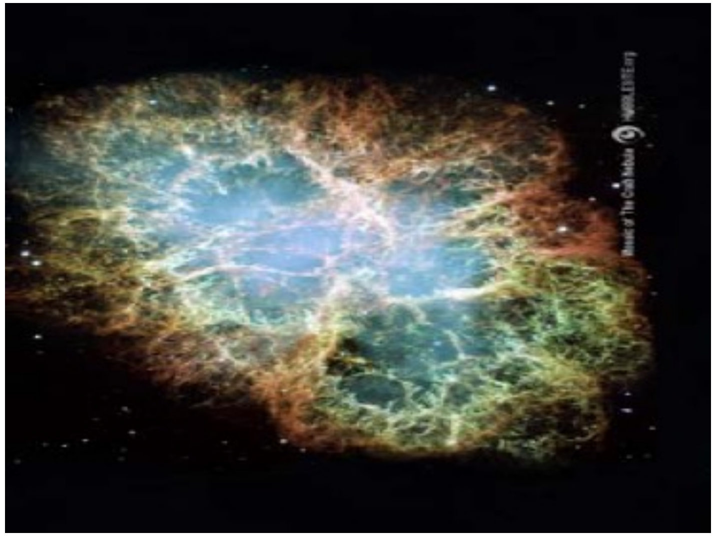
Solar flares



Protons
keV-500MeV

Ions
1MeV-10MeV/n

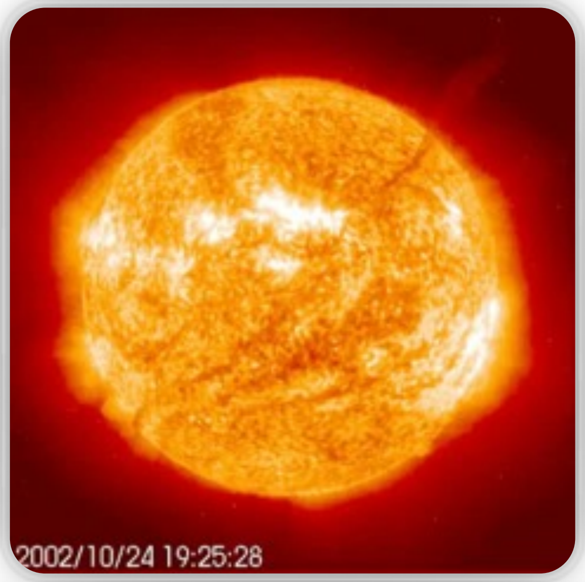
Cosmic rays

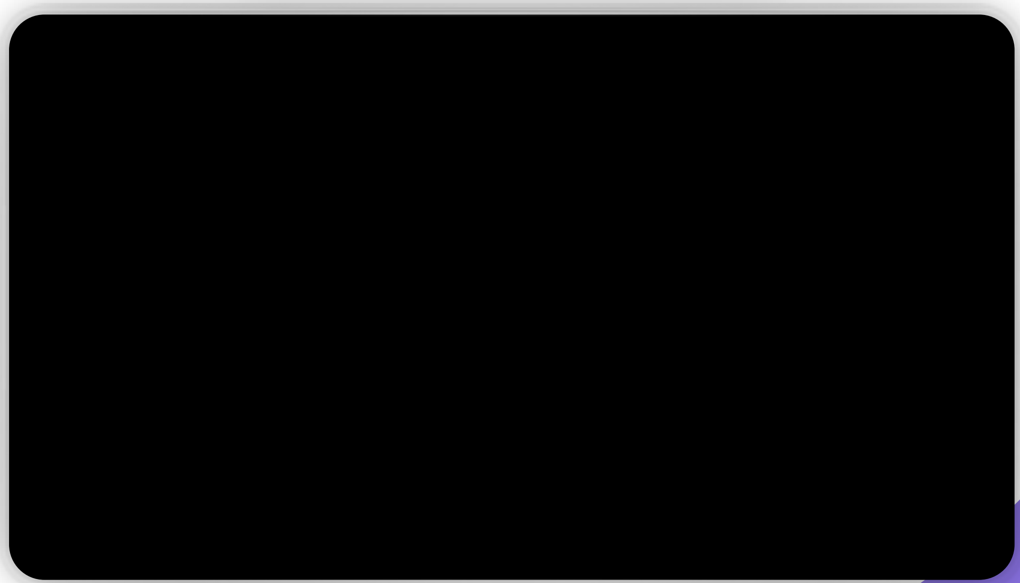


Ions
MeV-TeV/n

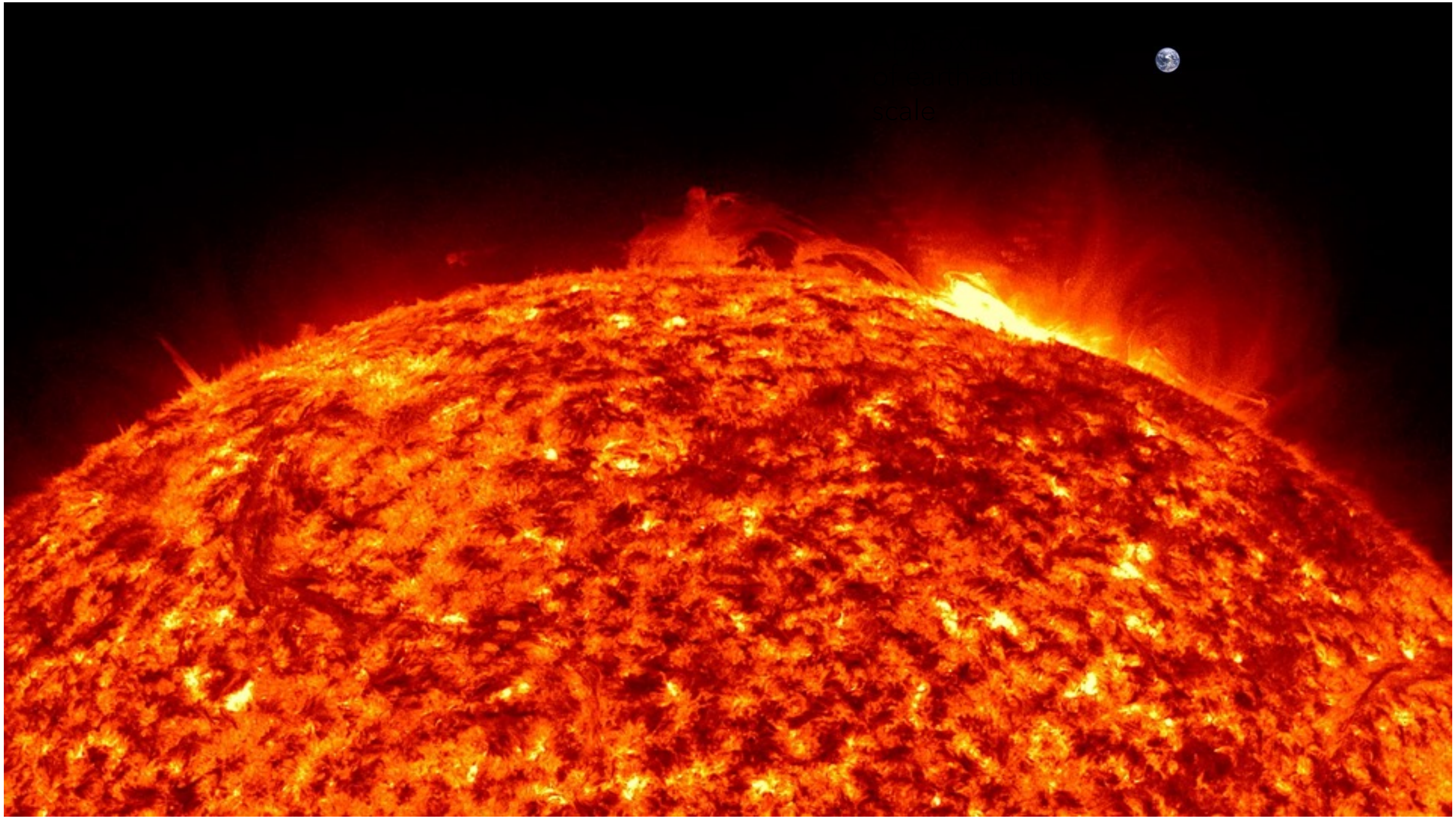
Radiation from the sun 1

- Protons and electrons are continuously ejected from the sun at a speed of about 400km/s. These hit the earth after a couple of days.
- On the surface we are protected by the atmosphere and the earths magnetic field.
- In the polar regions however particles penetrate and we observe the effect in the form of auroras.
- These particles however have a negative and possibly destructive effect on electronics in satellites
- The magnetic fields and currents created by these particles can also create problems for radio, GPS and power grids on earth.



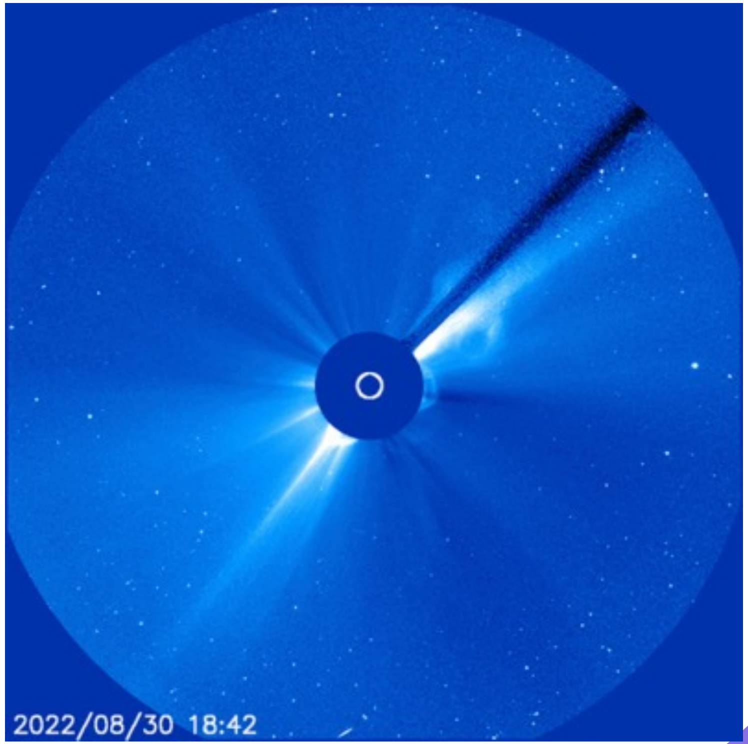


solar flare

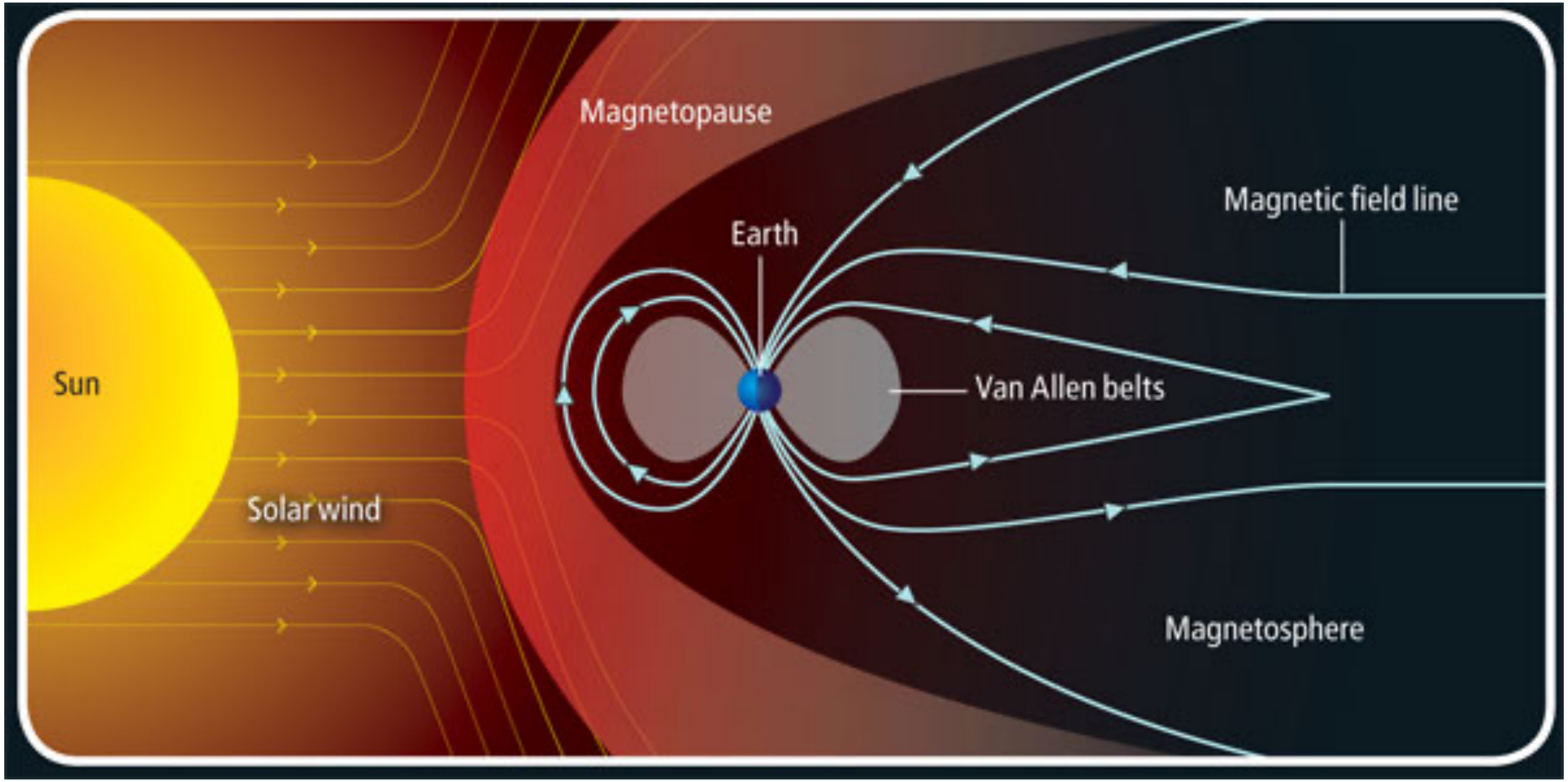


Solar Orbiter hit by a Coronal Mass Ejection, CME, imaged by SoHo

CME strikes Solar Orbiter!
And the Solar and Heliospheric Observatory (SOHO) was there to witness the CME leaving the sun on August 30, 2022.
It blasted out from the sun's far side, in the direction of the sun's 2nd planet, Venus. In this footage, you can see what's called a full halo. They are visible when a CME is either coming straight at Earth, or, as in this case, heading directly away. Image via ESA/ NASA/ SOHO



Radiation from the sun 2



Van Allen radiation belts

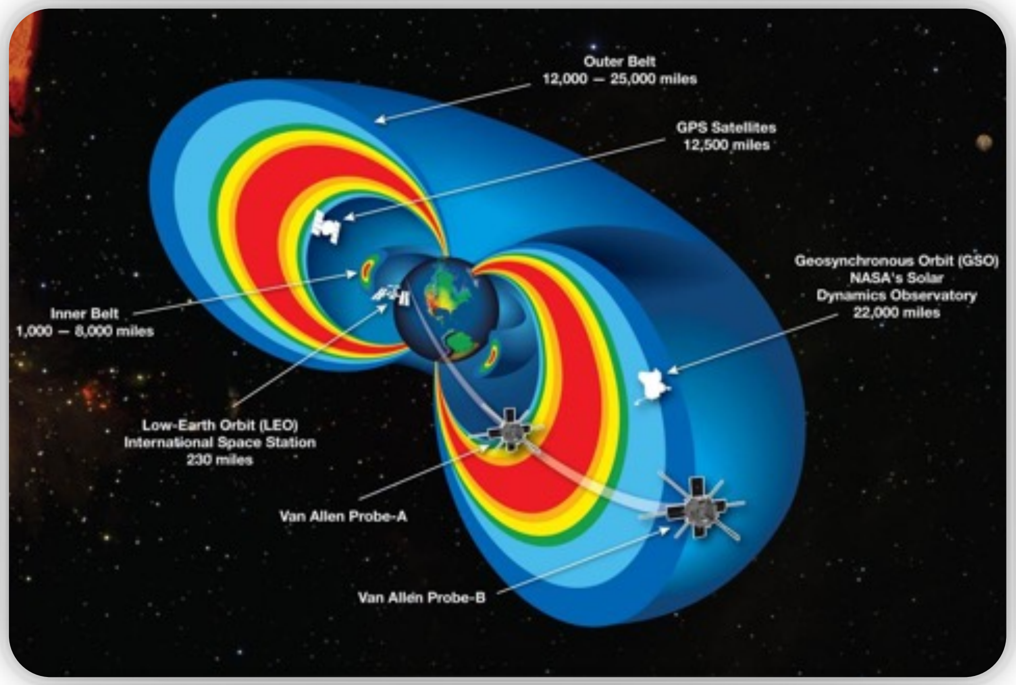
•The Earth Van Allen radiation belts are two zones of energetic charged particles, most of which originate from the solar wind, that are captured by and held in place by the earth magnetic field.

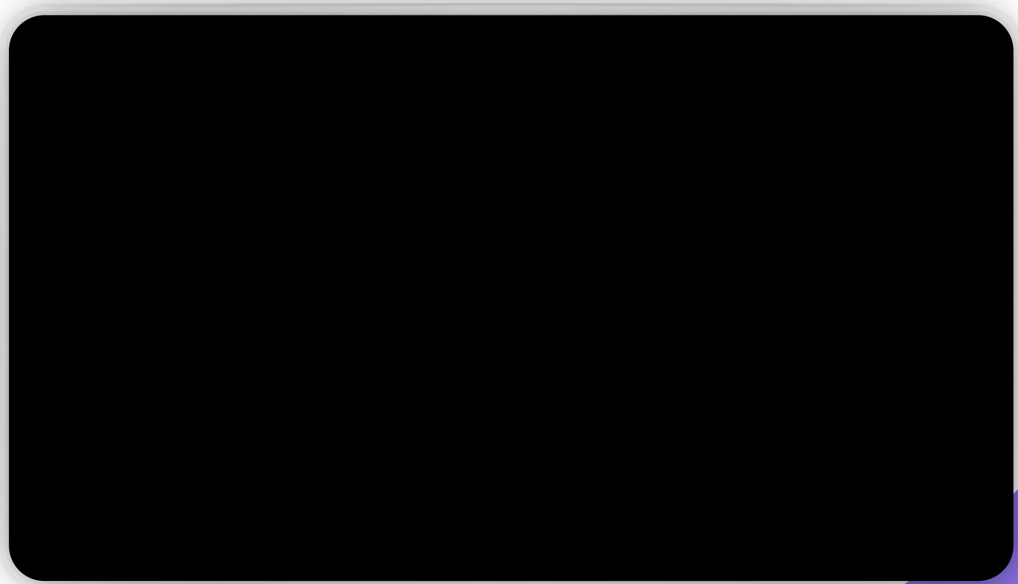
• The belts are named after James Van Allen, who is credited with their discovery. Earth's two main belts extend from an altitude of about 640 to 58,000 km above the surface.

•Most of the particles that form the belts are from the solar wind By trapping the solar wind, the magnetic field deflects those energetic particles and protects the atmosphere from destruction.

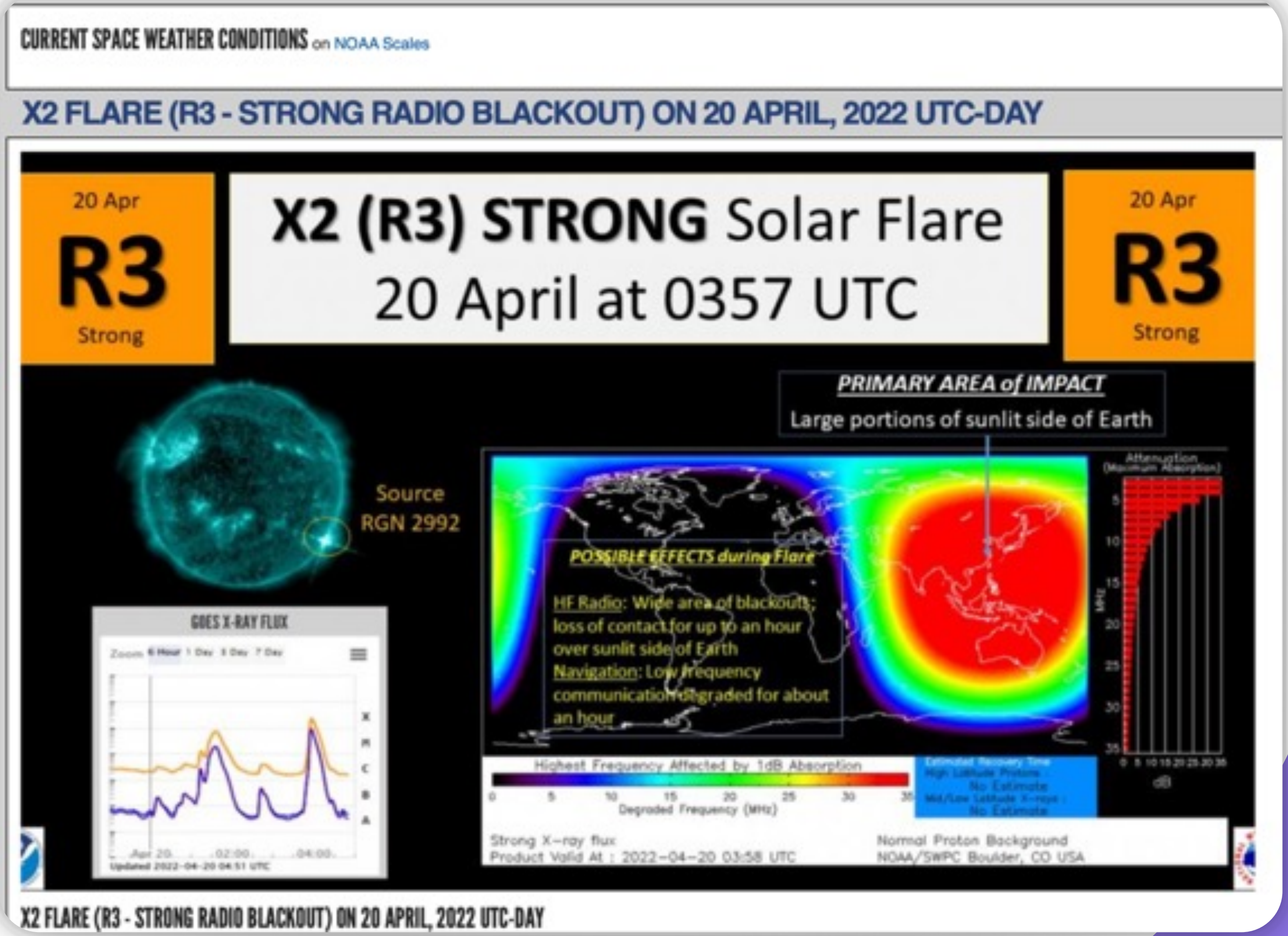
•The belts may endanger satellites, which must have their sensitive components protected with adequate shielding if they spend significant time near that zone.

Presented at NorCAS 2022 in Oslo





Radio blackout from solar radiation



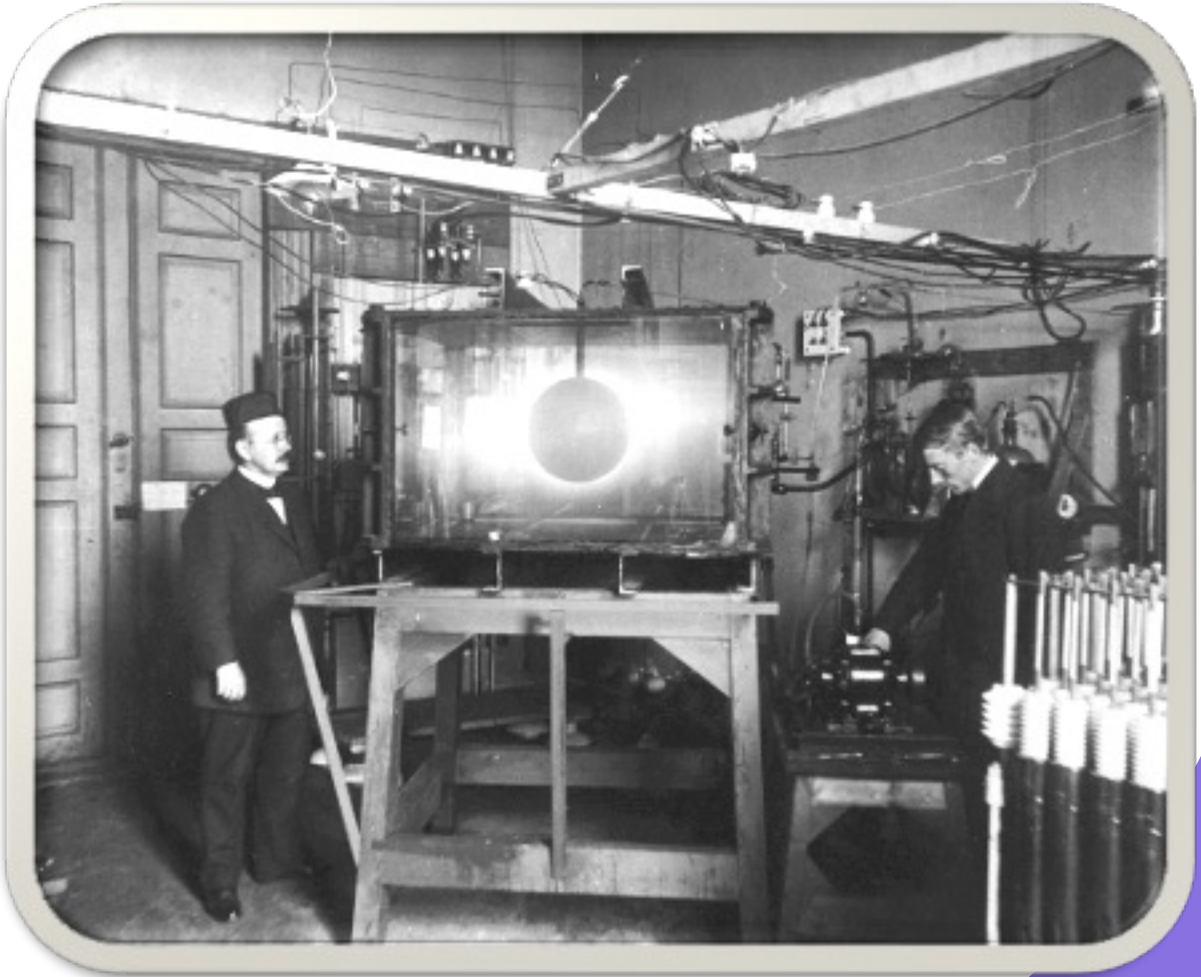
Artificial radiation belts

The history of radiation belts surrounding the Earth begins in 1896 with experiments by Birkeland with beams of electrons in a vacuum chamber (cathode rays) directed at a magnetized sphere ("terrella") [Gillmor, 1997; Birkeland, 1901, 1908, 1913]. Birkeland suggested the problem to the French mathematician Poincare who solved the motion of charged particles in the field of an isolated magnetic pole (*i.e., a* magnetic monopole) and showed that charged particles were expelled from regions of strong magnetic field into regions of weak magnetic field [Stern. 1989, and references therein]. Birkeland's work captured the interest of auroral researcher Stormer who, through mathematical analysis, discovered that charged particles (*e.g.,* electrons, protons, ions) could be stably trapped within a static dipole magnetic field [Stormer, 1907]. Although mathematically elegant, Stormer theory did not prove the existence of radiation belts; it set the stage.

Based on work by Stormer, Alfven, and others, and on his experience with the Astron thermonuclear device, N. Christofolis in October 1957 suggested an experiment using a high-altitude nuclear explosion to create a persistent Earth-encircling shell of energetic beta particles (*i.e.,* relativistic electrons) trapped in the Earth's magnetic field [Christofolis, 1959, 1 1966]

The Christofolis concept led to the proof-of-principle ARGUS series of three low-yield nuclear detonations conducted by the U.S. in August and September 1958 at high altitudes above the South Atlantic [Shelton, 1988]. Data obtained by the Explorer IV satellite and rocket probes fired from the ground definitively confirmed the "ARGUS effect", persistent trapping in the Earth's magnetic field of energetic electrons produced by high-altitude nuclear bursts.

Source: Defense Threat Reduction Agency DTR-IR-10-22



Radiation effects, cost

- 1962: First known satellite losses was the Telstar and 7 other lost in 1962 within 7 months after the secret space nuclear weapons test, Starfish. The nuclear explosion left a large number of electrons creating a new radiation belt lasting until the 1970s.
- 2011: Russian mars lander Phobos shuts down shortly after launch, probably due to a malfunctioning processor. It later crashed in the ocean. Exact cause is not known but it is though to be due to inferior parts that were not radiation tolerant.

Radiation effects in semiconductors

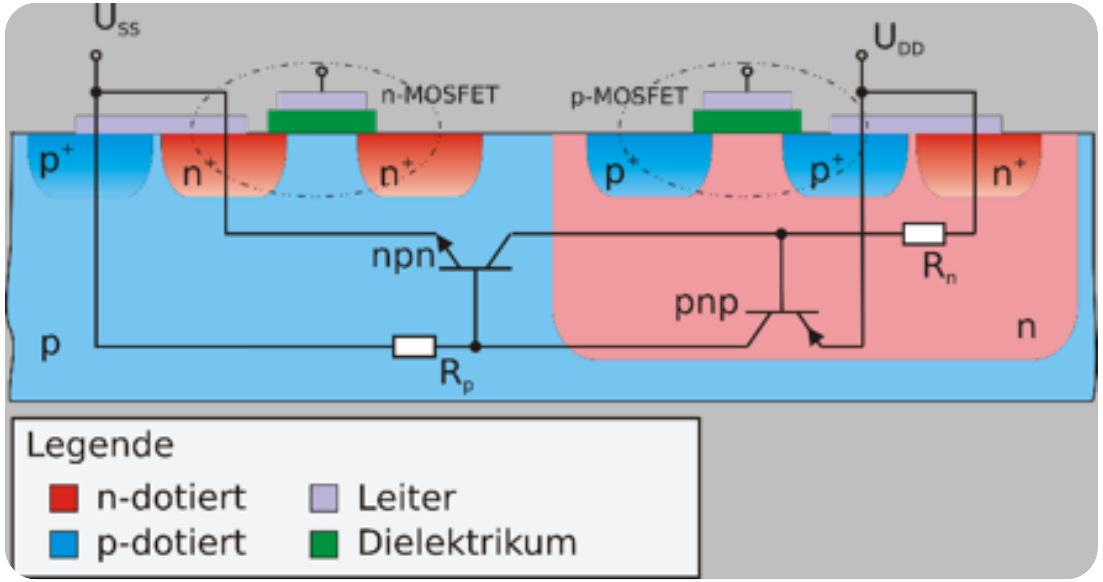
Radiation effects in Semiconductors

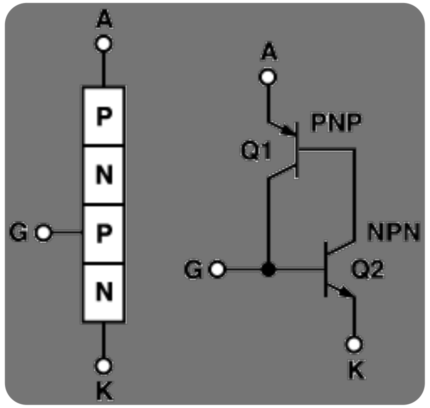
- Single event effects:
  - **Caused by single particles, electrons protons or ions**
  - **Can lead to latch-up, SEL**
  - **May cause Single Event Upsets, SEU**
- Can be mitigated by design

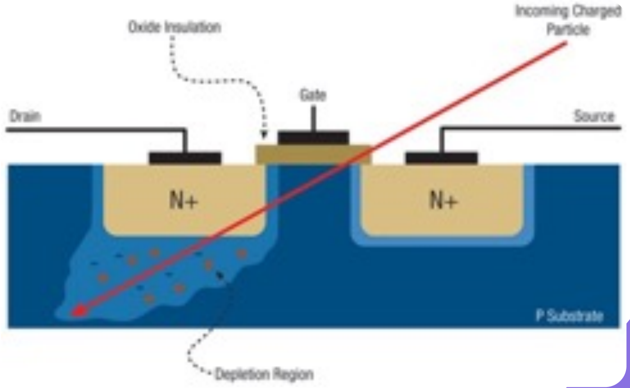
- Total Ionizing Dose effects
- Performance degradation over time due absorbed dose
- Can be reduced by selection of process

Radiation effects: latchup

- An incoming particle turns on the parasitic thyristor which stays on until power is cut or device is permanently damaged

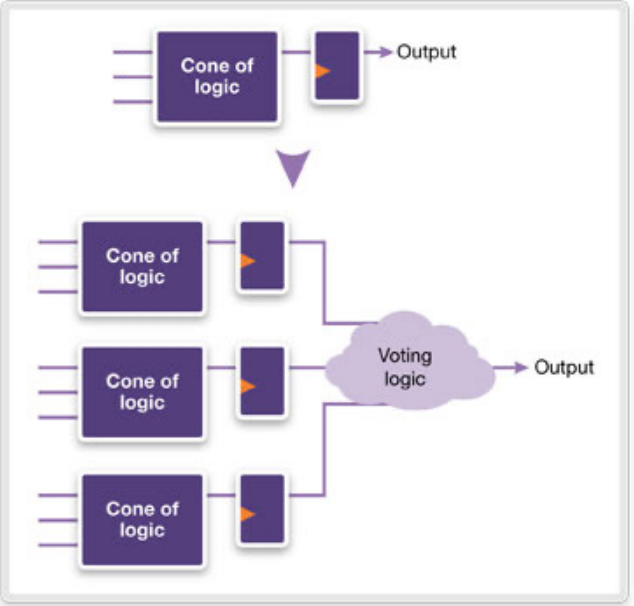


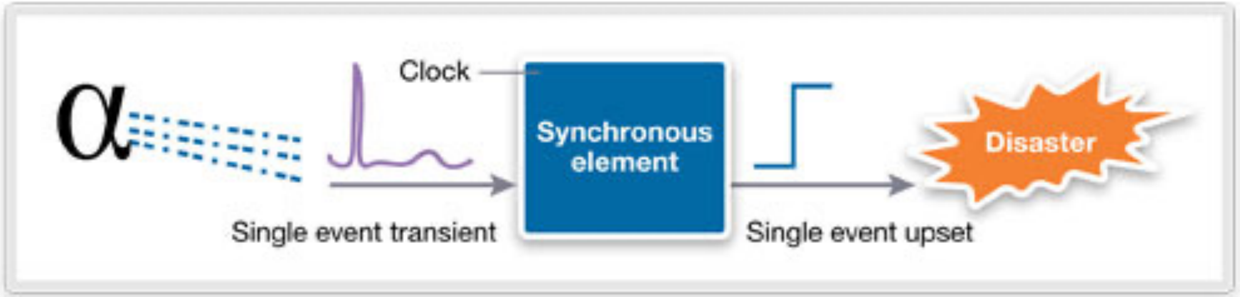


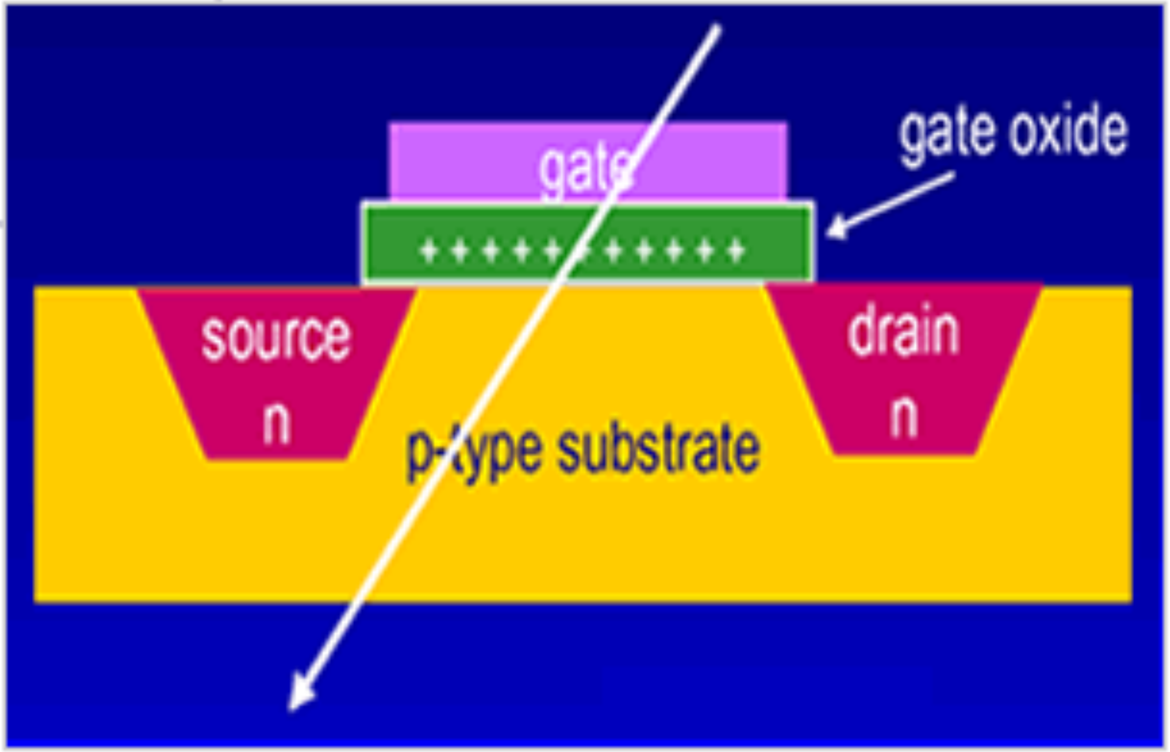


Other single event effects

- Single Event Upsets SEU
- Single Event Functional Interrupts SEFI
- Single Event Transients SET
- All caused by the same mechanism as the latchup process, but the energy is too low or distributed such that only soft error occur.
- Remedies include redundant logic design.





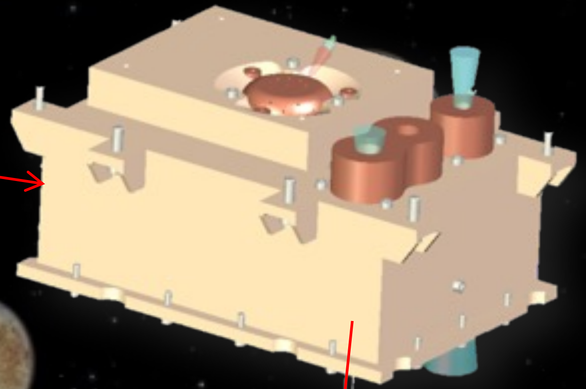


Radiation effects, total ionizing dose

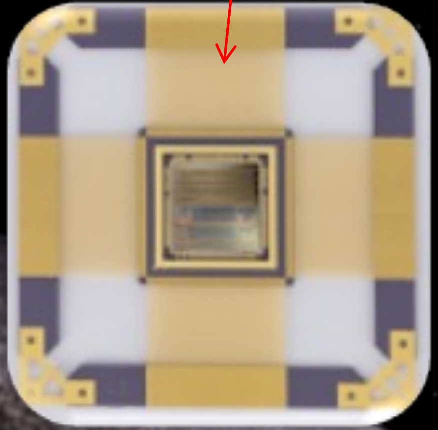
- Radiation absorbed in the surface oxide (gate oxide) leaves permanent charges that changes the electronic properties of the transistors. Leading to threshold shifts and eventually to the death of the circuit.
- Mitigation is shielding and reduction of oxide thickness.
- This effect is of less importance in modern submicron processes

Characterization of radiation in space by dedicated instrumentation

Jupiter Icy Moon Explorer, ESA´s mission to Jupiter



RADEM integrated with the JUICE spacecraft

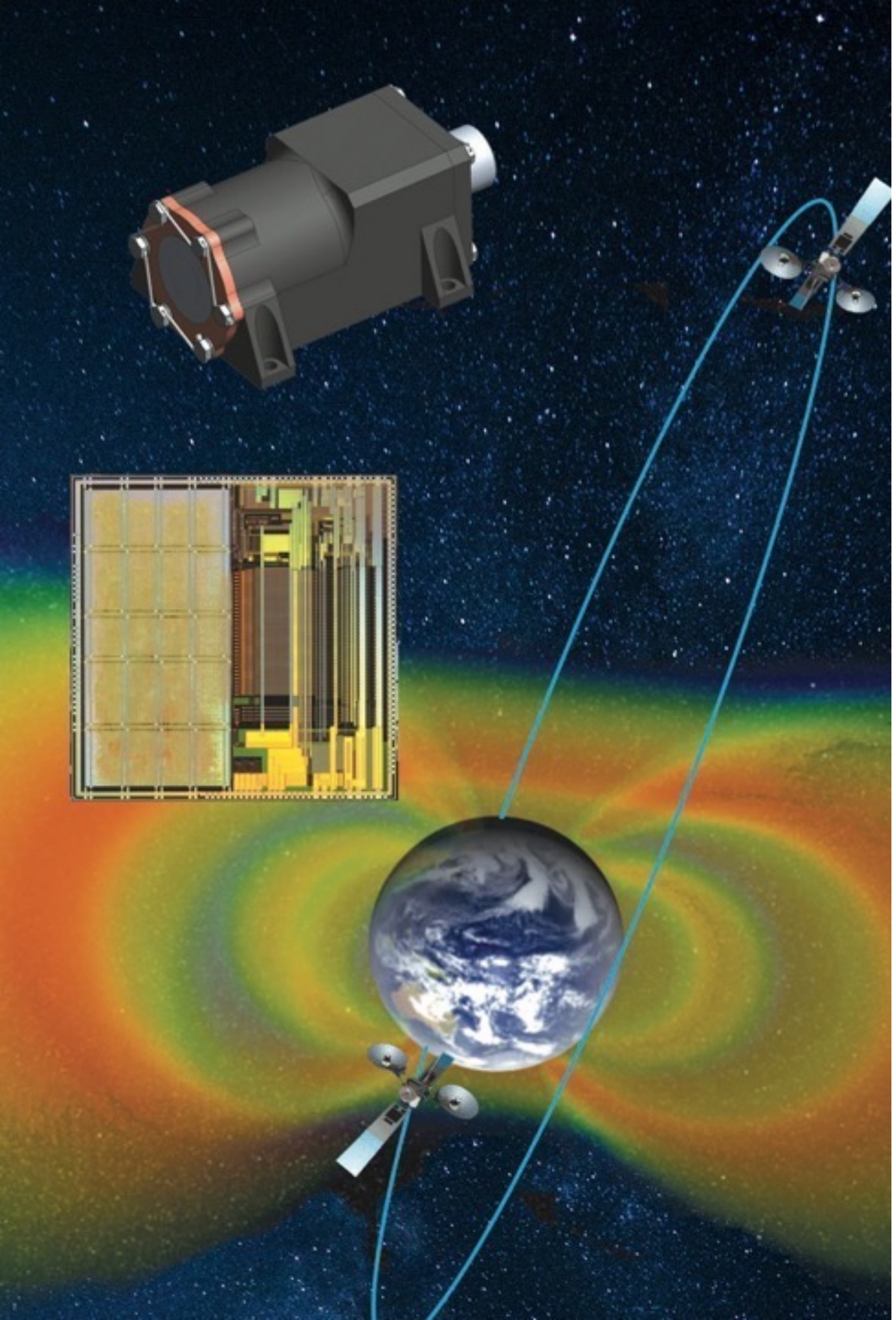


IDEAS ASICs are used in the RADEM instrument on JUICE

This ASIC was custom designed for JUICE.
It is designed for operation in 8 years interplanetary coasting and at least 3 years in the radiation environment at Jupiter.

Launch summer 2022

Image credits: ESA, EFACEC



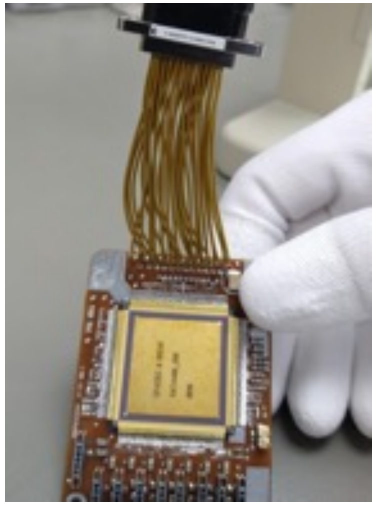
NORM

- Measure electrons, protons and ions onboard one of the Norwegian Arctic Satellite Broadband Mission satellites.
- Highly elliptical orbit.
- IDEAS delivers the complete qualified instrument February 2022.
- Satellites by Northrop Grumman.
- Launch by SpaceX 2023.
- 15-year mission.
- IDEAS and Space Norway to provide data service to the EC.

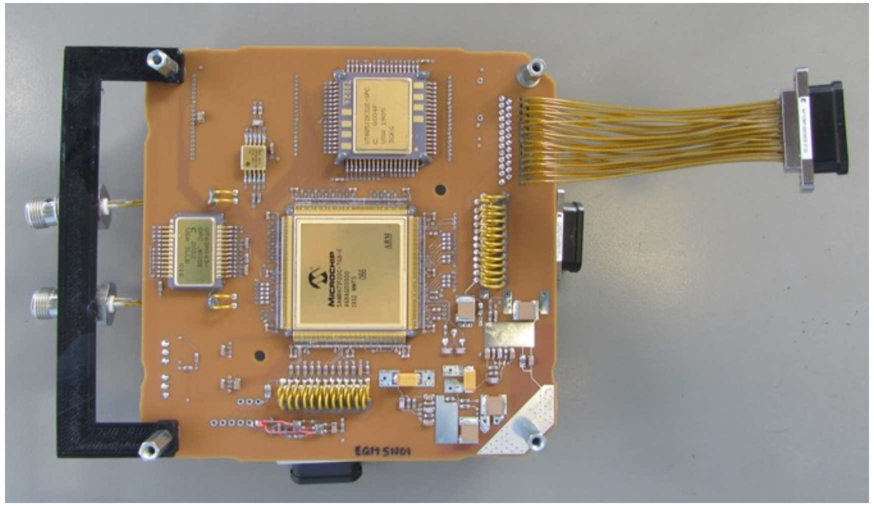
MAIT processes

Manufacturing of housing, cables, PCBs → Assembly of electronics (EM: internal, EQM/FM: external) → Integration of electronics into housing, connecting cables, software integration → Test: functional tests, calibration, qualification tests (TVac/thermal, vibration, shock, EMC)

Detector Assembly



Front-end with IDEAS ASIC

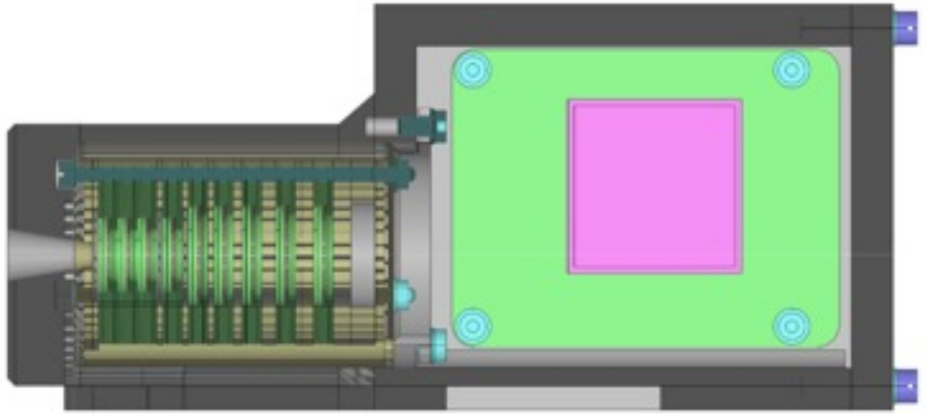


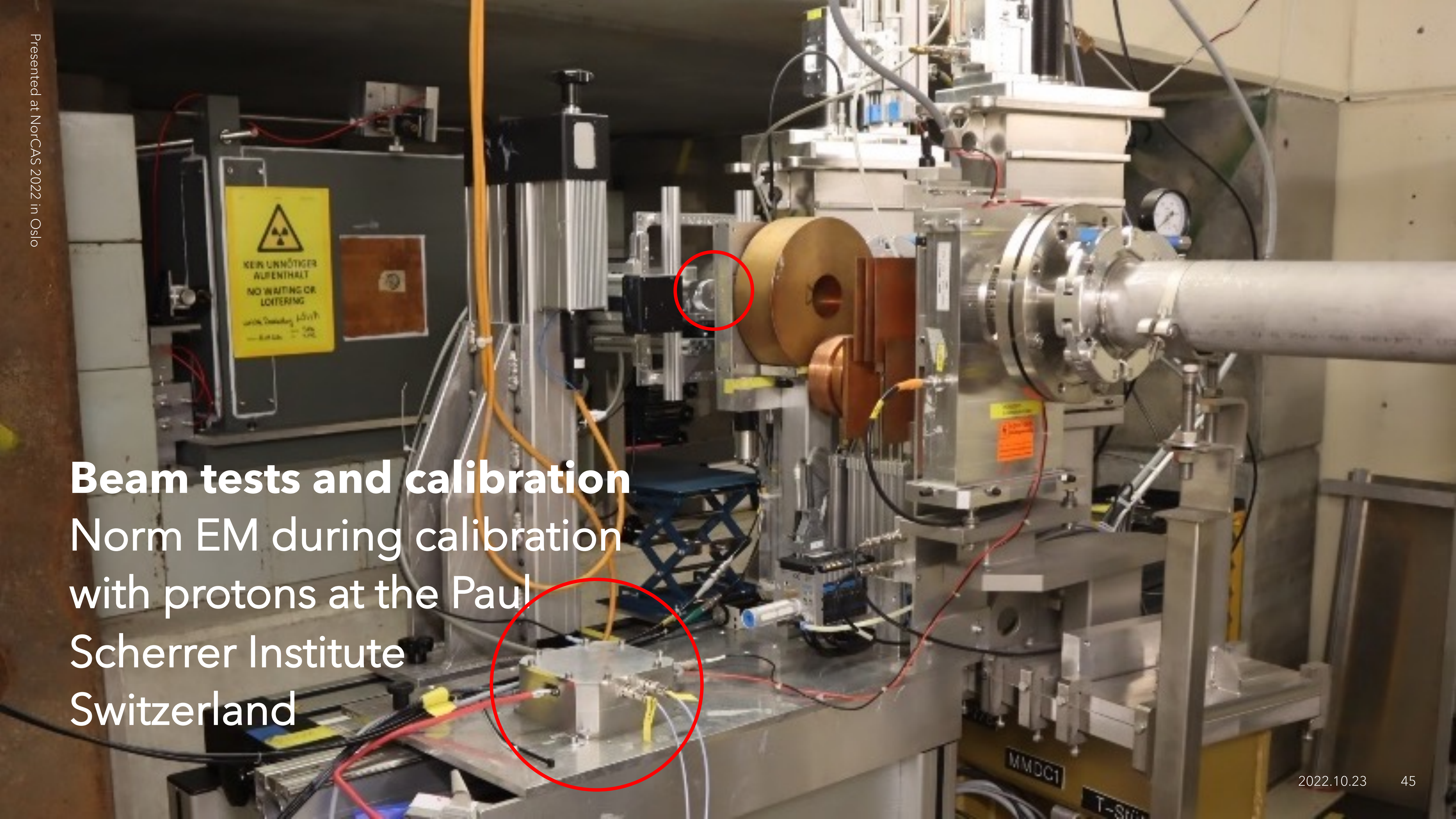
EQM/FM CPU board

AIT in cleanroom

NORM electron/proton detector

- Electrons and protons are stopped in a stack of silicon diodes and absorber.
- Depending on the type of particle and energy they leave different signatures.
- These are recorded by the ASIC
- By comparisons to model and calibrations the particle field can be calculated.

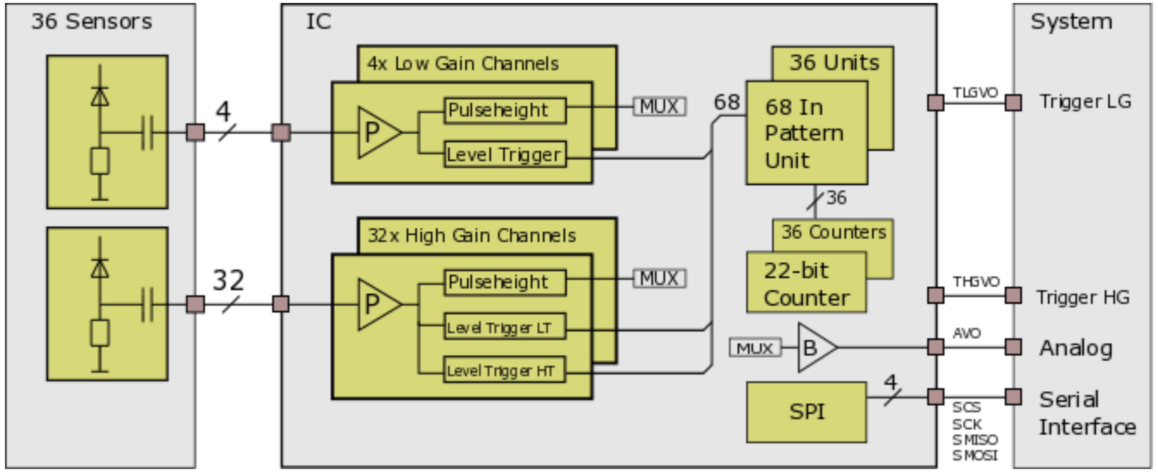




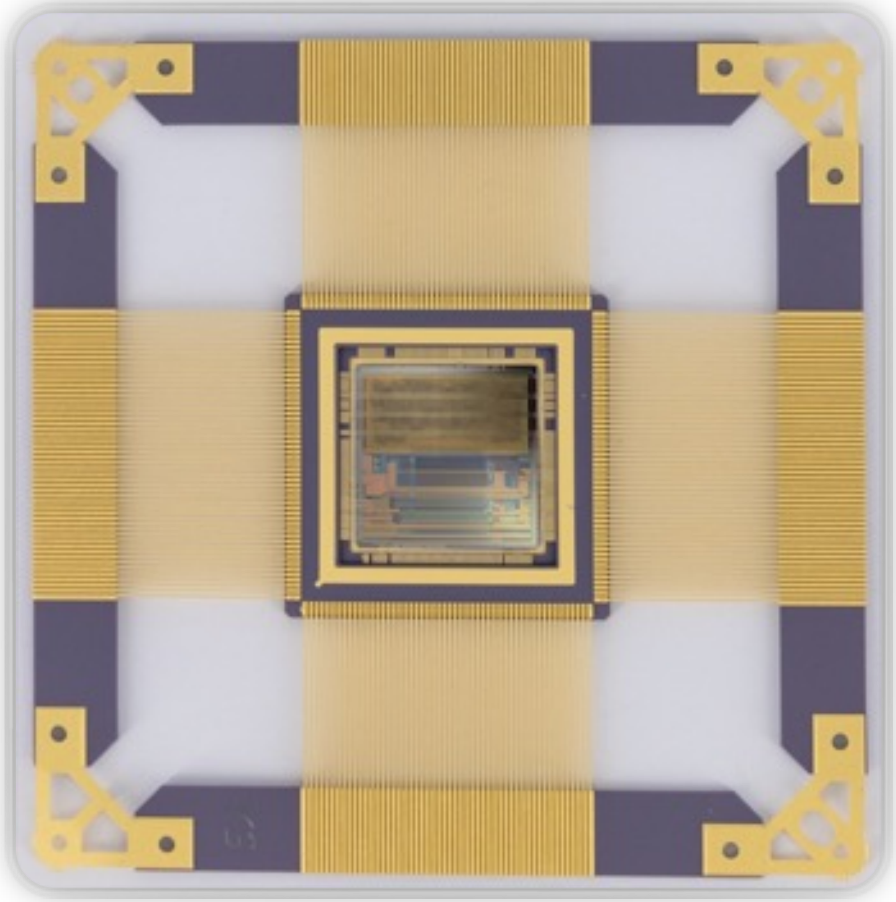
Beam tests and calibration

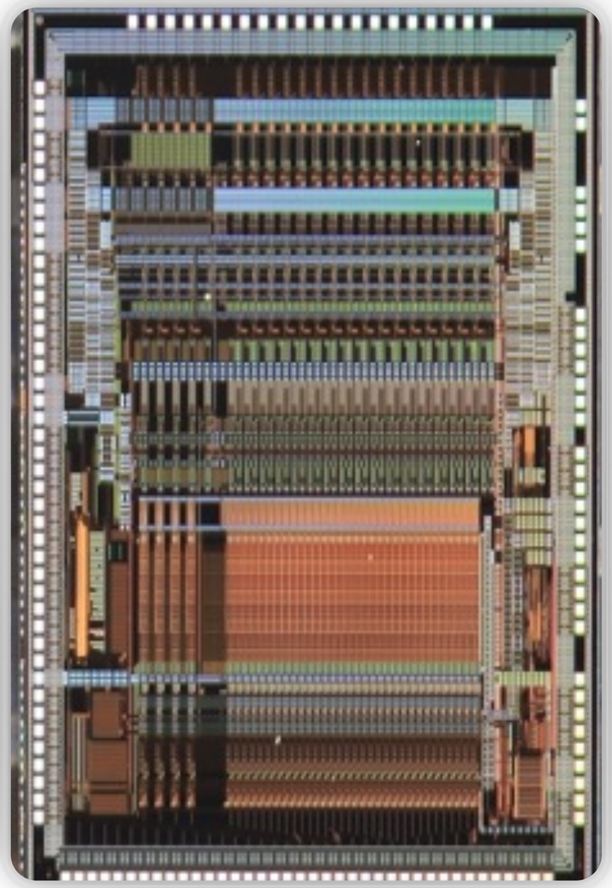
Norm EM during calibration with protons at the Paul Scherrer Institute Switzerland

The IDE3466 RADEM ASIC



- 4 low-gain channels (LG), charge sensitive inputs, spectroscopy up to +22 pC, ENC ≈ 33000 e + 3e/pF
- 32 high-gain channels (HG), charge sensitive inputs, spectroscopy up to +2.2 pC, ENC ≈ 3300 e + 9e/pF
- Energy resolved counting
- 36 digital counters read out via SPI
- 22-bit Gray code counters
- 1 Mcps/channel count rate for 600fC input charge
- 68-to-1 programmable coincidence pattern logic for every counter
- Pulse height (charge) spectroscopy
- Analogue mux. out from all channels
- 1 MHz clock analogue mux. output
- 150 mW power typical operation, 237 mW power worst-case register settings
- SEU radiation hardened, SEL immune up to 81.6 MeV·cm2/mg
- 2 SEL detection units





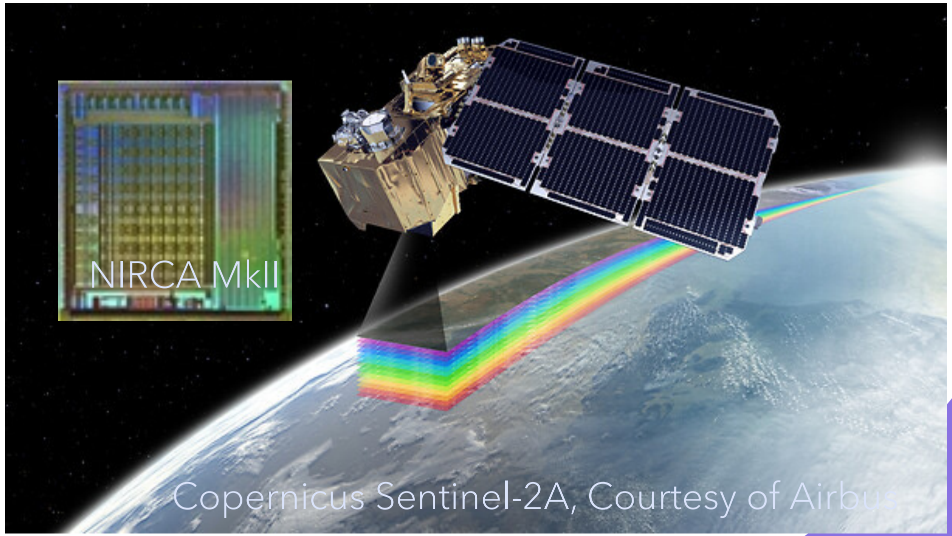
IDE3465. and IDE 3466
Two ASICs developed for radiation monitoring in space

Presented at NorCAS 2022 in Oslo

ideas

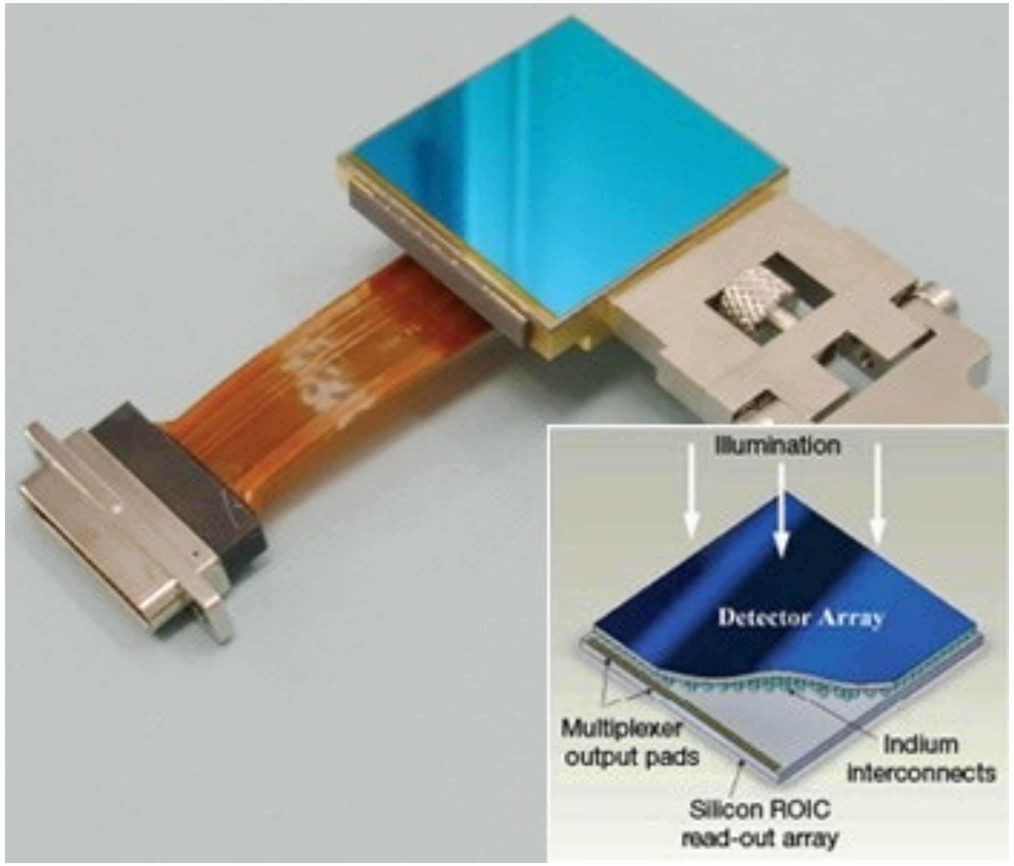
Presented at NorCAS 2022 in Oslo

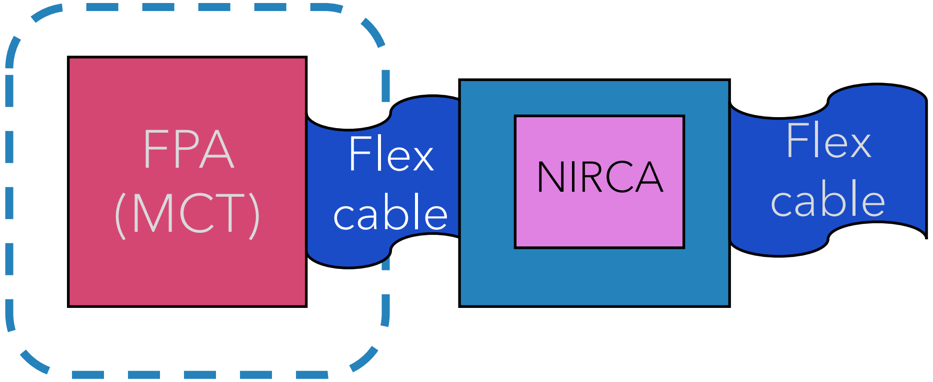
NIRCA MkII Infrared Image Sensor Readout and Controller ASIC



NIRCA MkII provides A/D conversion and control for IR sensors using a single IC

Infrared imaging for Earth Observation and Astronomy

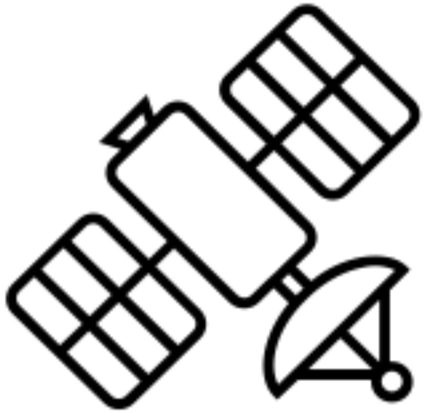




- Sensor material, e.g., mercury cadmium telluride (MCT).
- Sensor hybridized on read-out integrated circuit (ROIC).
- Cryogenic operation (20K to 77K).
- The Focal Plane Array, FPA, needs a controller circuit to provide clocks and reference voltages and analog to digital conversion of the signal
- IDEAS develops both ROICs and FPA controllers

NIRCA MkII Applications

- Earth observation
- Astrophysics
- Terrestrial



Benefits of NIRCA MkII

- Reduce SWaP

  NIRCA MkII bare die area: 1 cm^2

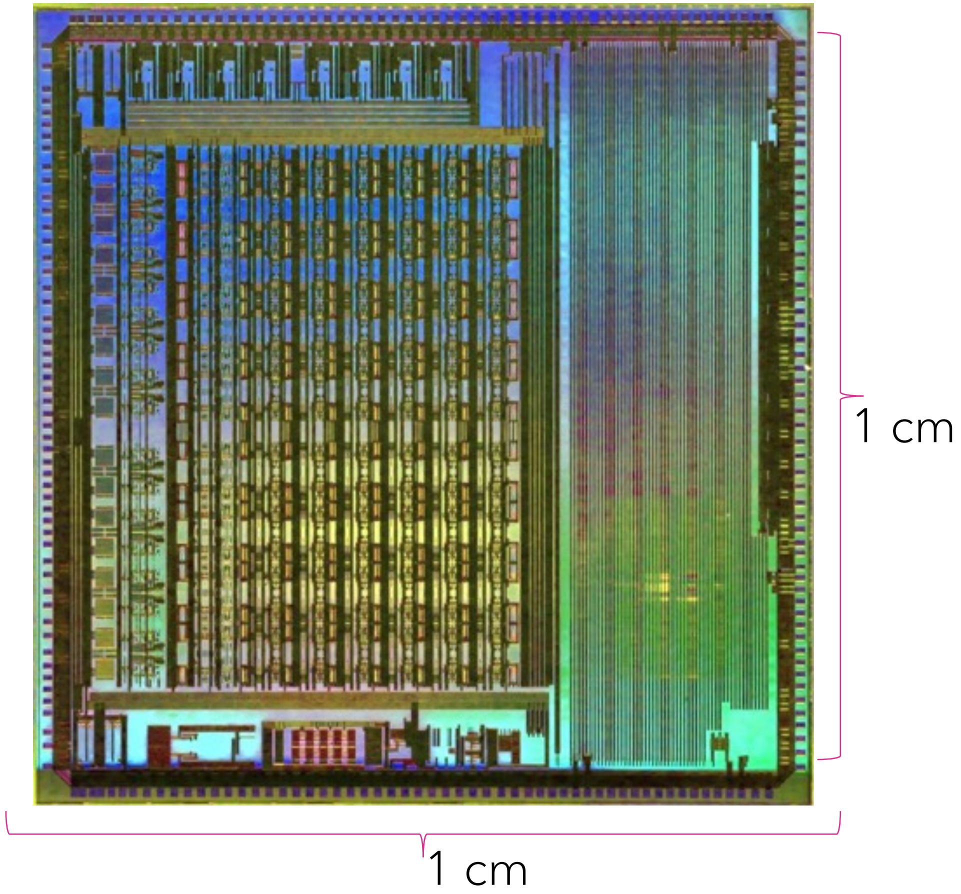
  Power consumption < 2 W

  This reduces costs

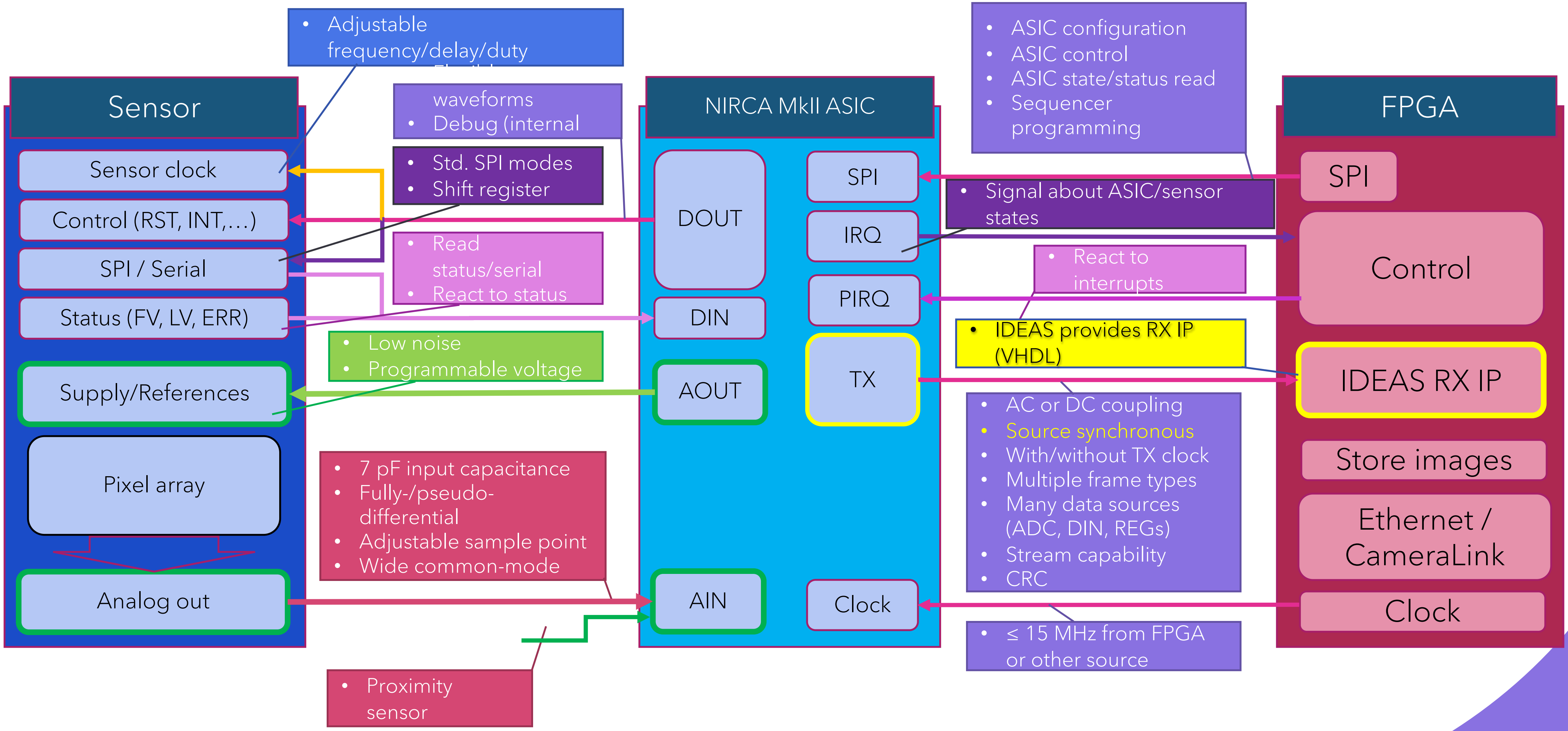
- Withstands harsh environments

  Radiation hardness (SEE/TID)

  Operating temperature -40°C to +85°C



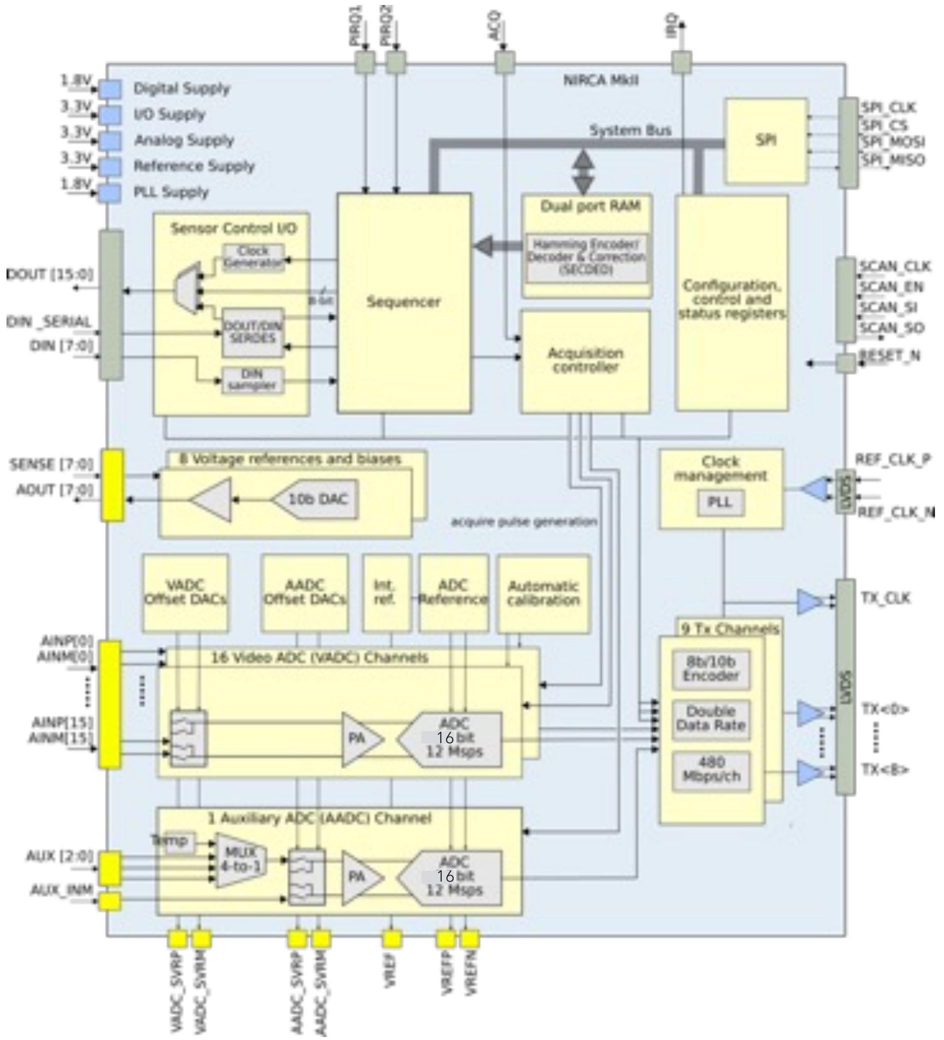
Example: NIRCA MkII in system



Presented at NorCAS 2022 in Oslo

Integrated Detector Electronics AS

NIRCA MkII Block Diagram and Features



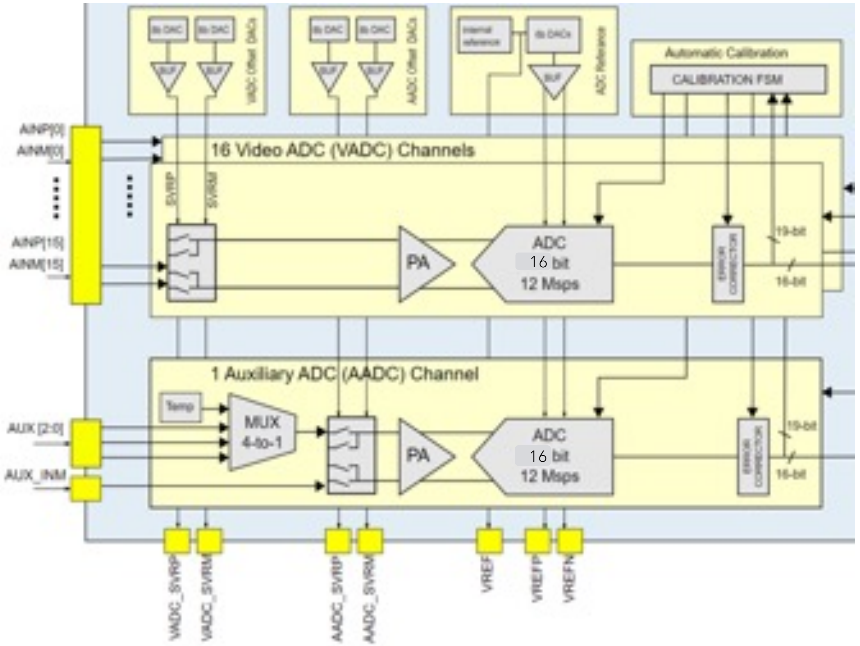
- 17 ADCs digitizing sensor data at 12 Msps
- 8 adjustable voltage references (0 – 3 V)
- I/O interface for sensor control, monitoring and sample time adjustment
- Programmable sequencer
- Instruction RAM with single error correction, double error detection (SECDED)
- ACQ capable of a wide variety of acquisition modes
- 9 LVDS links TX<0:8> with 8b/10b encoding exporting data to the FPGA at 480 Mbps/link double rate
- SPI interface for communication
- Radiation hardened against SEE and TID

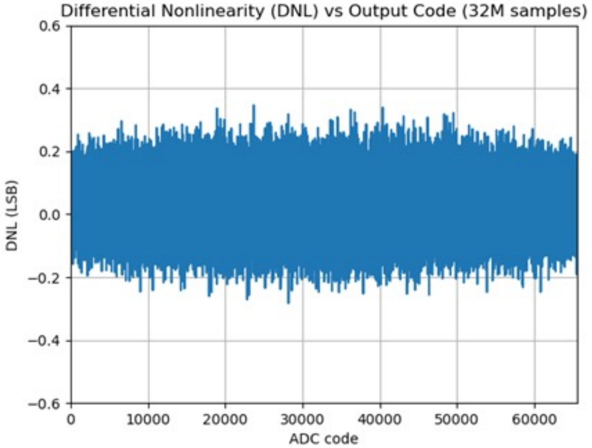
Analog front-end

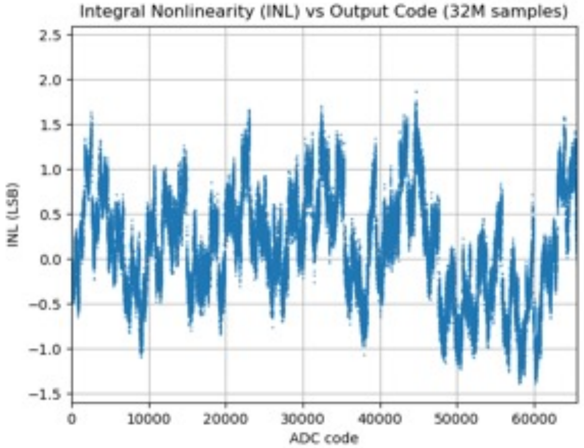
- Preamp + pipeline ADC architecture
- Supports fully- and pseudo differential mode
- 16 Video ADCs + 1 Auxiliary ADC
  - **16-bit ADCs with 12 Msps**
  - **14-bit if frame/line valid are sent upstream**
- Programmable offset and gain
  - **Gain: x1, x1.14, x1.33, x1.6, x2, x2.67, x4, and x8**
  - **Range:** ± 0.125 **V** to ± 2 **V**
- Automatic calibration of capacitor mismatch

Typical values with gain x1 and 16-bit ADC mode.

Parameter	Measured
Equivalent input noise (ENI)	3.0 LSB_{rms}
Differential non-linearity (DNL)	(-0.32, +0.35) LSB
Integral non-linearity (INL)	(-2.4, +1.5) LSB







Sequencer

- Automating the control sequences
- Microcontroller-like instruction set
- 21 instructions:

Control:	**CALL, JUMP, LOOP, …**
Data management:	**LOAD, LDTEMP, MOVTEMP, …**
Data flow:	**TXVAL, TXBR, …**
State management:	**WAIT (COMPARE / IRQ)**

Can be used in combination with flags as SYNC and ACQUIRE

- Handling of IRQ inputs and outputs

Using the NIRCA MkII sequencer

- Simple NIRCA program generating a waveform using functions, instructions and the ACQUIRE-flag

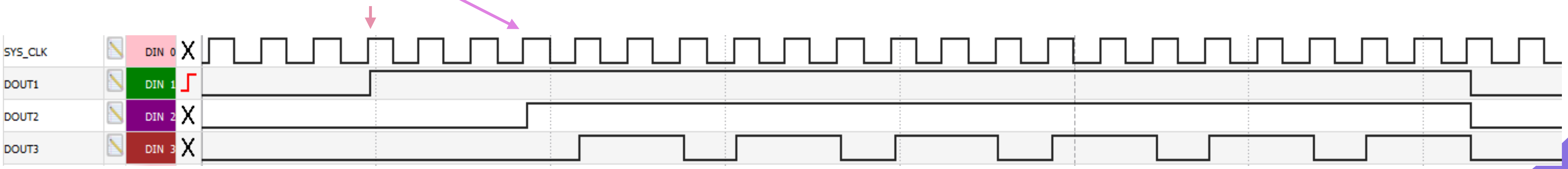
NM2 assembly program

```
@start:
    NOOP 0
    LOAD DOR 0b00000001
    LOAD NLC 5                  # Call next function 5+1 times
    CALL @f_func1
    LOAD DOR 0b00000000
    WAIT 2                      # Stops: wait for unused
                                  condition
    LOOP @start

@f_func1:
  A LOAD DOR 0b00000011
    LOAD DOR 0b00000111
    LOOPR @f_func1              # LC = LC - 1
```

Configuration

ACQ triggered by sequencer (A-flag in @f_func1)
VADC_0 enabled → sample sent on TX



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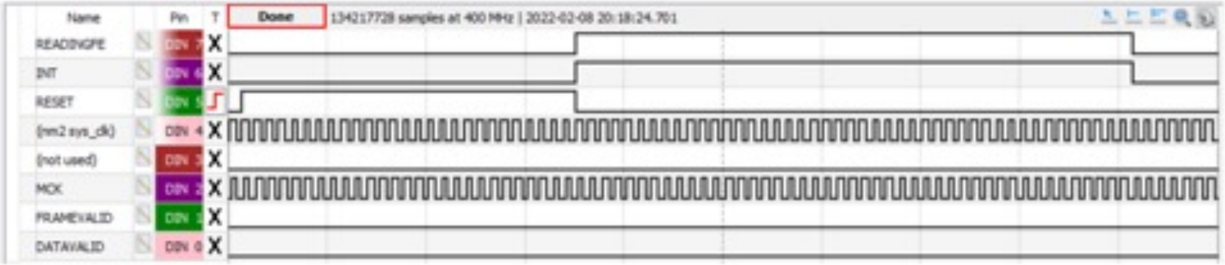
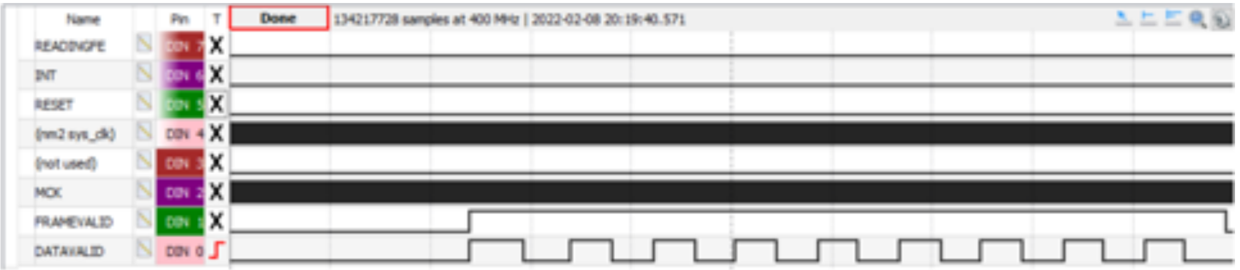
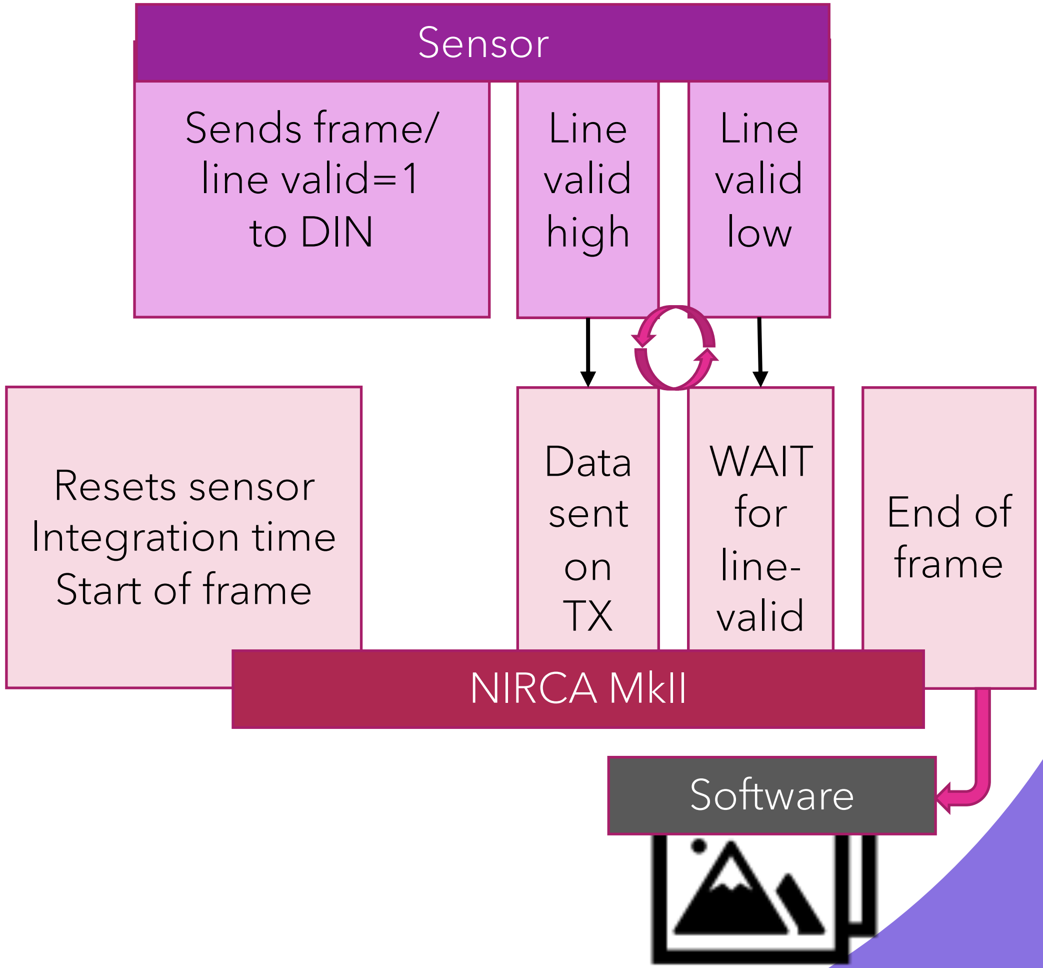
Example use case:
Sensor with Frame and Data valid

1. Reset & integration phase



2. Frame and data/line-valid sequence





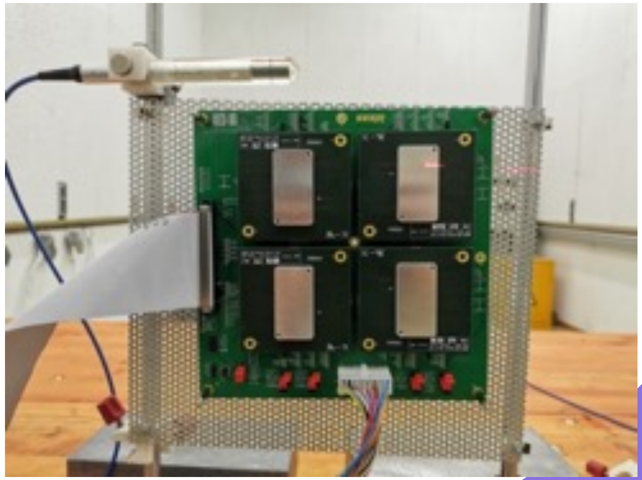
Radiation testing

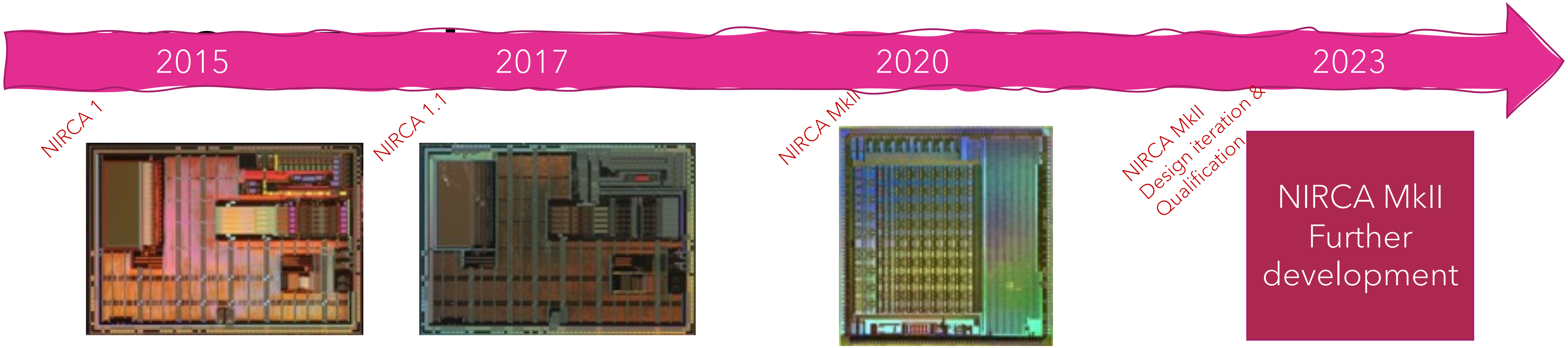
SEE

- SEL tolerance up to LET = 71.1 MeVcm^2/mg
- No SEU in configuration registers below LET < 16.1 MeVcm^2/mg, few SEUs above
- SECDED implementation of the RAM works

TID

- 27 krad (low dose rate) + 85 krad (high dose rate)
- No TID induced drift on DNL, INL, noise, offset/gain errors and max frequency
- Drift in voltage references/ODACs about -0.5 %





- NIRCA MkII is validated, radiation tested and packaged

  Samples are available

- Funding for further development is secured from ESA

NIRCA – Next steps

• Build qualification platform	Q4 2022
• NIRCA MkII design iteration available	Q2 2023
• Space qualified packaging	Q2 2023
• Procure engineering models	Q2 2023
Available for customers too	
• Radiation testing for qualification	Q3 2023
• Space qualification	Q1 2024
Flight models will be available	

Collaboration with users!

To take home

- The use of microelectronics in space have distinct challenges
  1. **Heat dissipation and cooling**
  2. **Radiation effects:**
     1. Single event effects
     2. Total ionizing dose
     3. Mitigation by desing and process

- Integrated Detector Electronics AS (IDEAS)
  1. **Develops systems and readout interated circuits circuits for sensors to be used in space and on ground.**
  2. **We work with companies or agencies that need to detect radiation in space and on ground in particular covering the above mentioned applications.**
  3. **We are open to explore new applications and innovations that can benefit from our technology.**

Contact: gunnar.maehlum@ideas.no