The view from space, which engineering skills are needed for the growing Norwegian Space industry?

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Let us define Engineering:

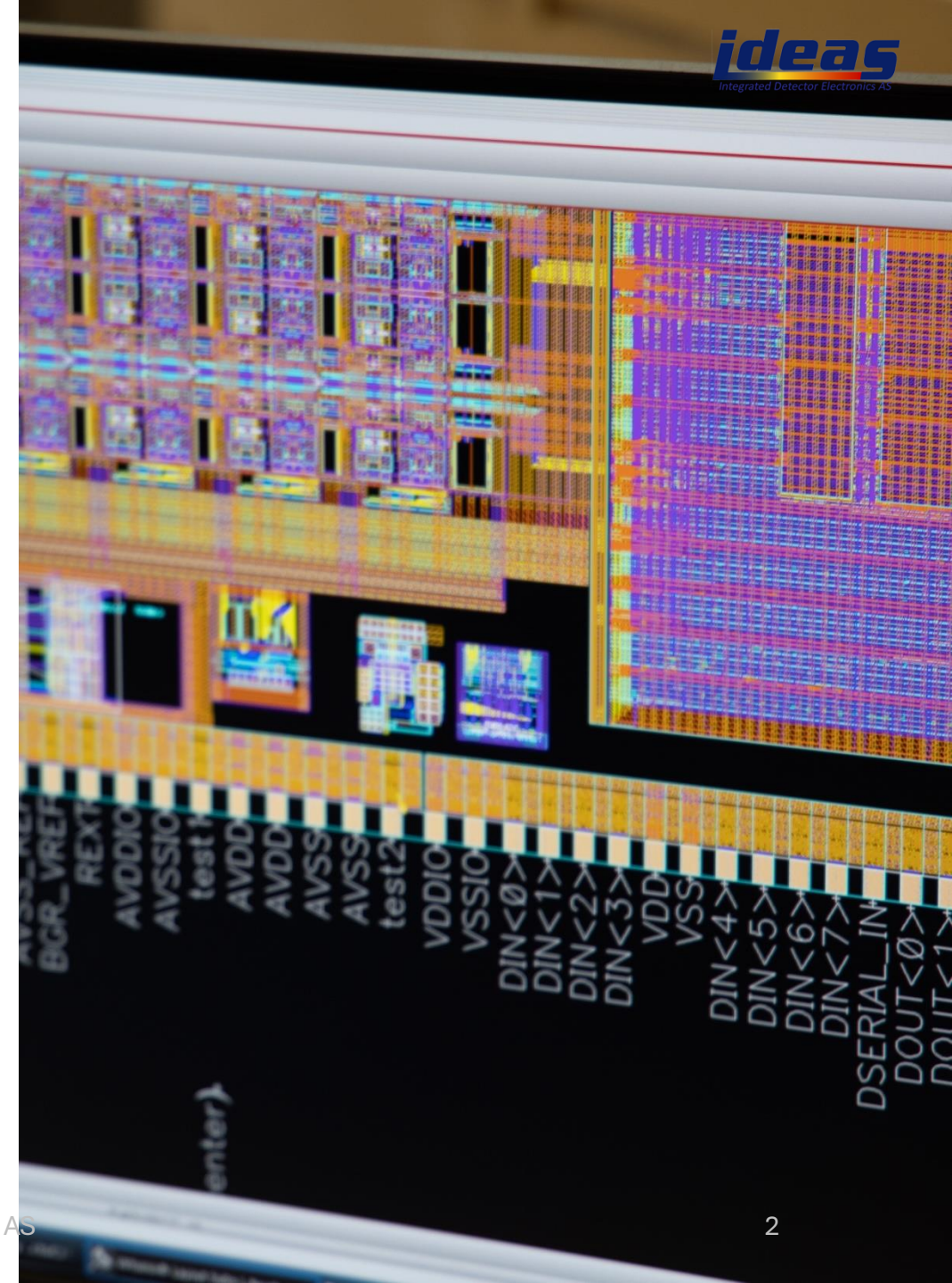
From *IDEAS Engineering Handbook*:

The engineering process is using established knowledge and procedures to create or refine products. Products may be physical or non-physical in the form of software.

This contrasts with **research** which is the process of gathering **new knowledge.**

From Wikipedia: *The key difference between the engineering process and the scientific process is that the engineering process focuses on design, creativity and innovation while the scientific process emphasizes explanation, prediction and discovery (observation).*

The engineering process shall always start with a set of **requirements**. These requirements are then translated into a product physical or non-physical. Any product shall be tested before being released for sale or transfer to a third party. The procedures to be used during test shall be developed or at least described in the requirements.



Technology become obsolete, science evolves

- three trivial statements:
  1. Today's cutting-edge technology, is tomorrows obsolete.
  2. Yesterday's physics is a subset of todays research frontier.
  3. The math of the 17th century is highly relevant in today's technology.

Thomas A. Edison

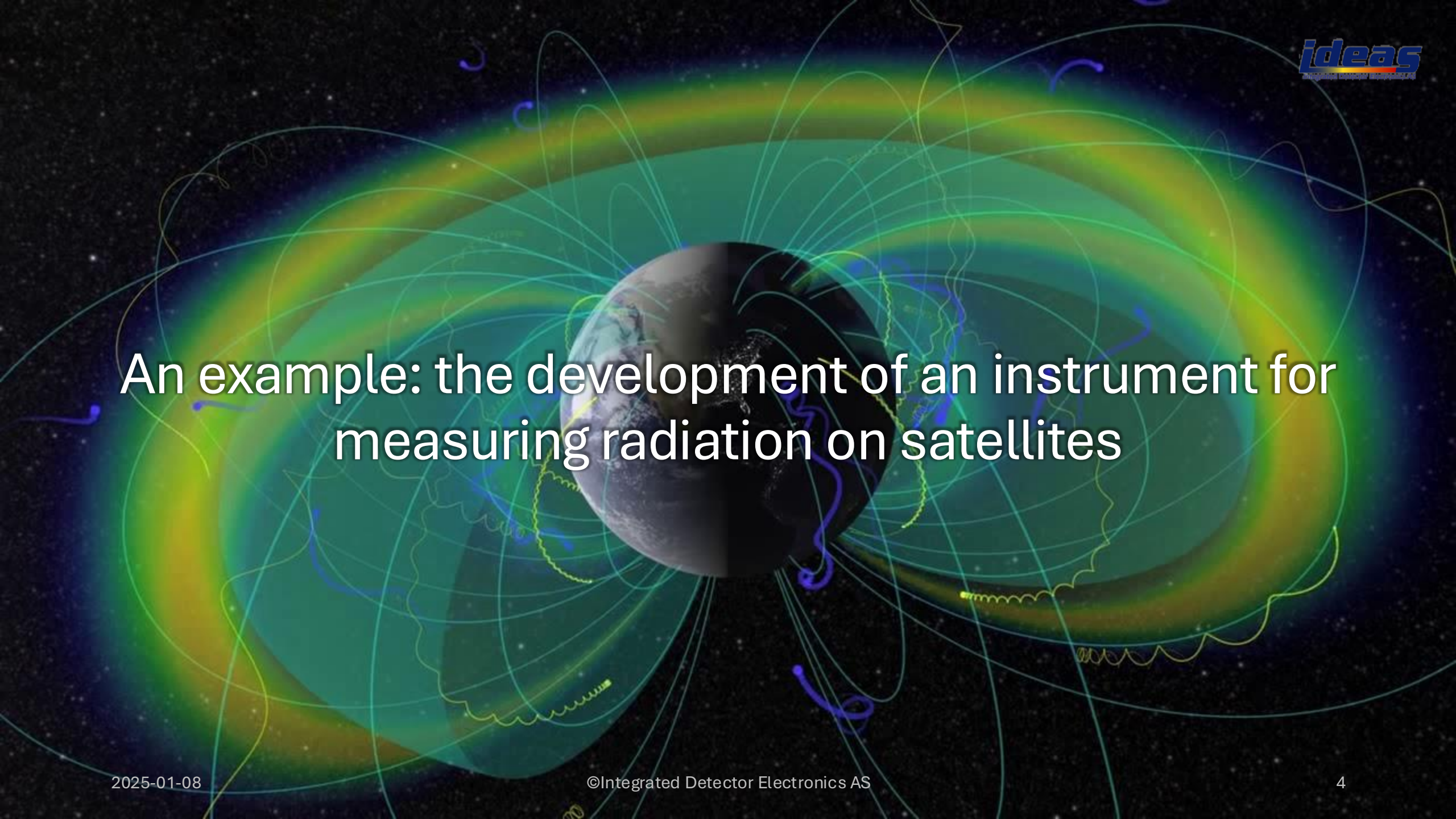
Michael Faraday

Joseph Fourier

Some technologies even become illegal to sell such as the once ubiqous incandescent light bulb

Anyone remember this?

Or this?



An example: the development of an instrument for measuring radiation on satellites

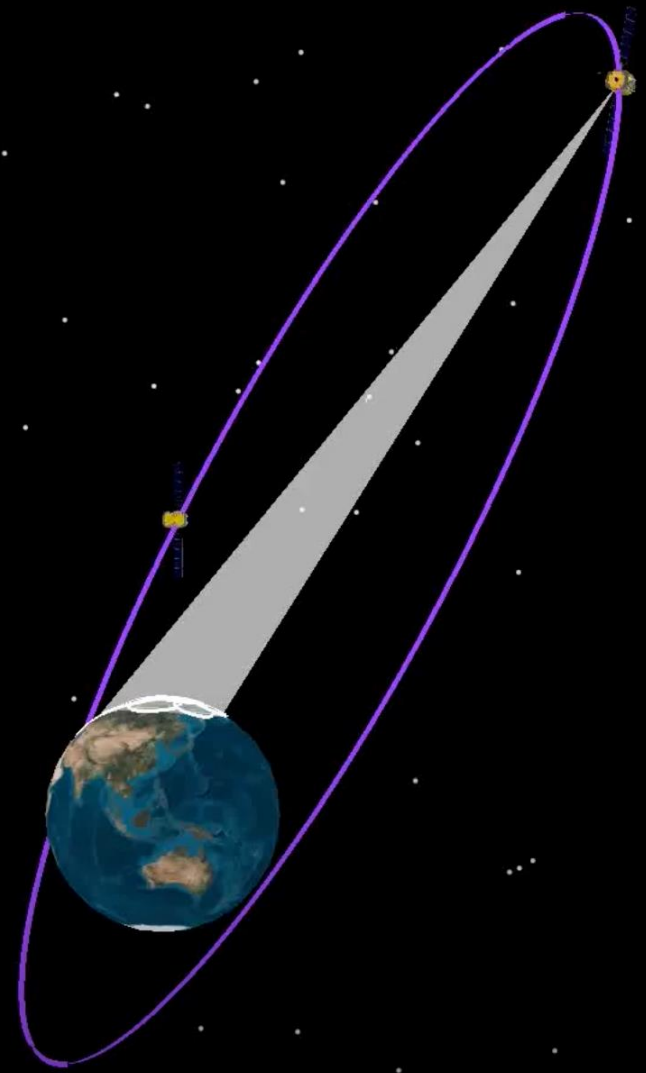
Requirements & deliverables

- **Purpose**: Measure electron and proton spectra and abundancies in situ around a satellite.
- **High level requirements:**
  - Tolerate at least 100kRAD total ionizing dose.
  - Lifetime at least 5 years, preferably 15
  - 36V power supply, <3kg, <5W, -40 to +85C operating temperature.
  - Launch on SpaceX Falcon 9.
  - No interference to other systems on the spacecraft.

- **Deliverable from IDEAS**: Engineering Model, Engineering Qualification Model and Flight Model. On-board software. Ground support equipment for test and validation. Documentation
- **Additional deliverables:** Ground processing software and distribution of level 1 data.
- **Allocated time:** maximum 3 years.
- **Heritage**: Existing ASIC developed for ESAs JUICE mission to Jupiter.

Space Norway ASBM/HEOsat, TAP orbit

- Two (approx. 2500kg) telecom satellites built by Northrop Grumman launched to HEO TAP orbit by SpaceX.
- 15-year mission,
- Three payloads:
  - The Norwegian defense
  - US Space force
  - Inmarsat
  - Radiation detector from IDEAS



Detector Unit DGU / Sensor	Electronics Unit DHU + PSU
Detector Diodes + 7085 FrontEnd Board	SAMV71-Evalboard + ASIC shield + Lab-PSU, SAMV71RH Eng. Board + 1553 Test HW
EM Detector stack + Readout PCB (ASIC) + EM housing	SAMV71RH, PSU, 1553 Bus on Design PCB, Eng. Components, Housing to Flight Design
FM Detector stack + FM housing	EM with FM footprint RH components, non-certified, FM housing
FM Detector stack + FM housing	As EQM with certified components, FM housing

Refurbished EQM parts possible

Model	Test and Verification	
PM	Development on Breadboard Prototypes	Phase B
EM	Electronics Testing, MIL-STD-1553-BUS Testing Sensor Functional Test Mechanics (Vibration/Shock) and Noise-Testing Calibration (“Beam-Test”)	Phase C1
EQM	Thermal Vacuum, Vibration Testing, EMC/EMI Environment and Mechanics Design Verification Calibration (“Beam-Test”)	Phase C2
PFM	Flight Model Functional Testing Environment and Mechanics Acceptance Testing	Phase D

What skills were needed to deliver the instrument?

Electronic hardware skills:

- Radiation hard IC design skills:
  - Analogue low noise design.
  - Digital design, HDL, synthesis, place and route.
- Circuit board design with special considerations for use in space.
  - Electrostatic charging from radiation.
  - Requirements on soldering and mounting.
- Voltage converter design
  - high voltage source on transistor level.
  - Magnetics

- Selection of
  - radiation hard components.
  - power converter modules.
  - Connectors.
  - Internal and external cabling.
- Understanding of EMC test and design considerations at all levels.
- Electrical interface (MIL STD 1553)
- Mechanical interface of connectors and boards.
- Understanding of the use of standards.

Mechanical hardware skills:

- Mechanical engineering:
  - 3D CAD design.
  - Thermal analysis of assemblies in vacuum
  - Mechanical analysis of strength and effect of vibrations during launch
  - Emissivity of external surfaces.

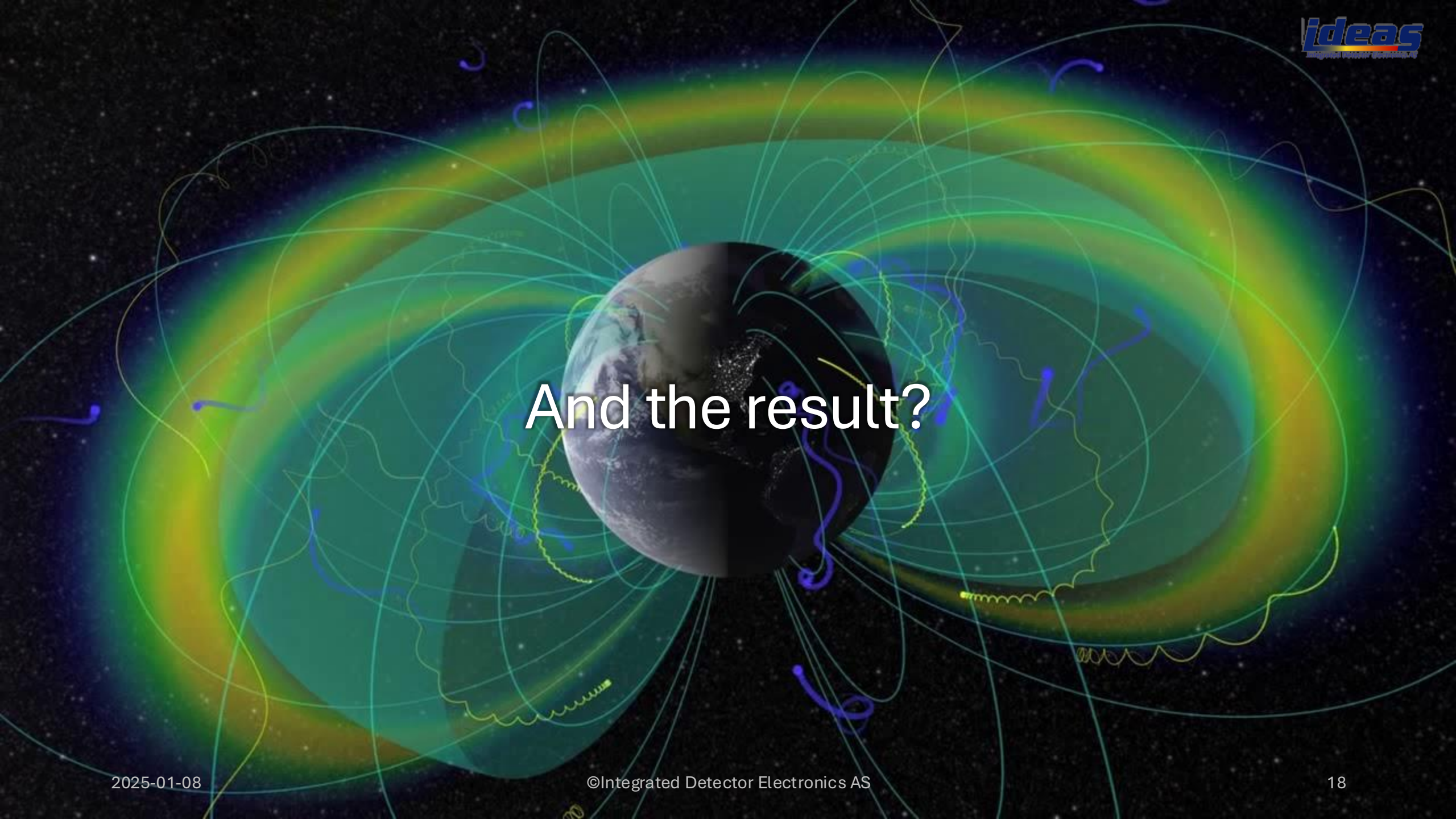
- Mechanical tests
  - Thermal vacuum.
  - Vibrations
  - Shock

Software engineering skills:

- Embedded Software
  - Translating requirements & standards to design.
  - Understanding of electronics and low-level layers.
  - Bare-metal: no operative system support.
  - Coding standards (for space).
  - Communication protocols (for space).
  - Typical languages: C/C++/Rust.
- Test and User Software
  - Understanding the scope of the application.
  - All code must be unit-testable.
  - Ensure compliance to requirements.
  - Typical languages: C/C++/C#.
- Data Analysis
  - The data scope matters as much as the data itself.
  - Typical languages: python/matlab.
- In general
  - git commit → git push!
  - Organization skills.
  - Think "System", "Module" and "Interface".
  - Documentation is part of your life, now.

Physics

- The instrument was designed to measure energetic electrons and protons understanding of the interactions of radiation with matter.
- Detailed simulation of the electron and proton detector.
- Simulations of the radiation penetration into the enclosure during operations.
- Simulations of the radiation conditions in the orbit.
- Analysis of calibration data.
- Radiation tests on the component level.

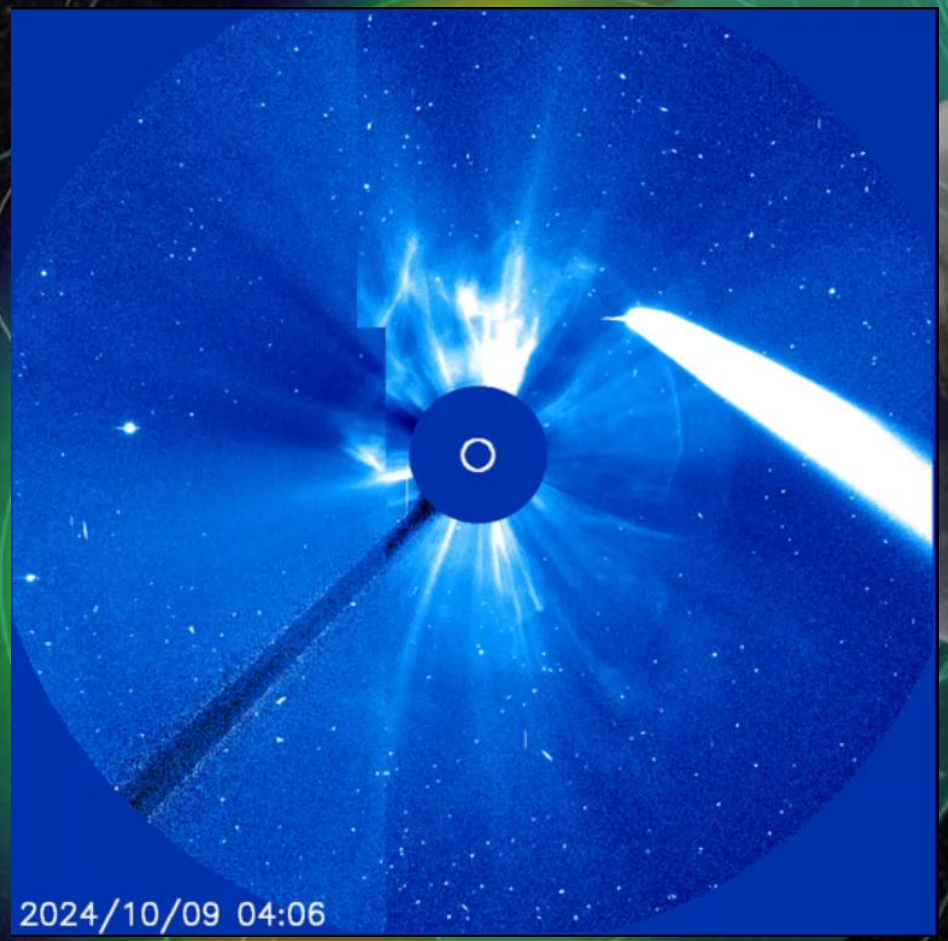


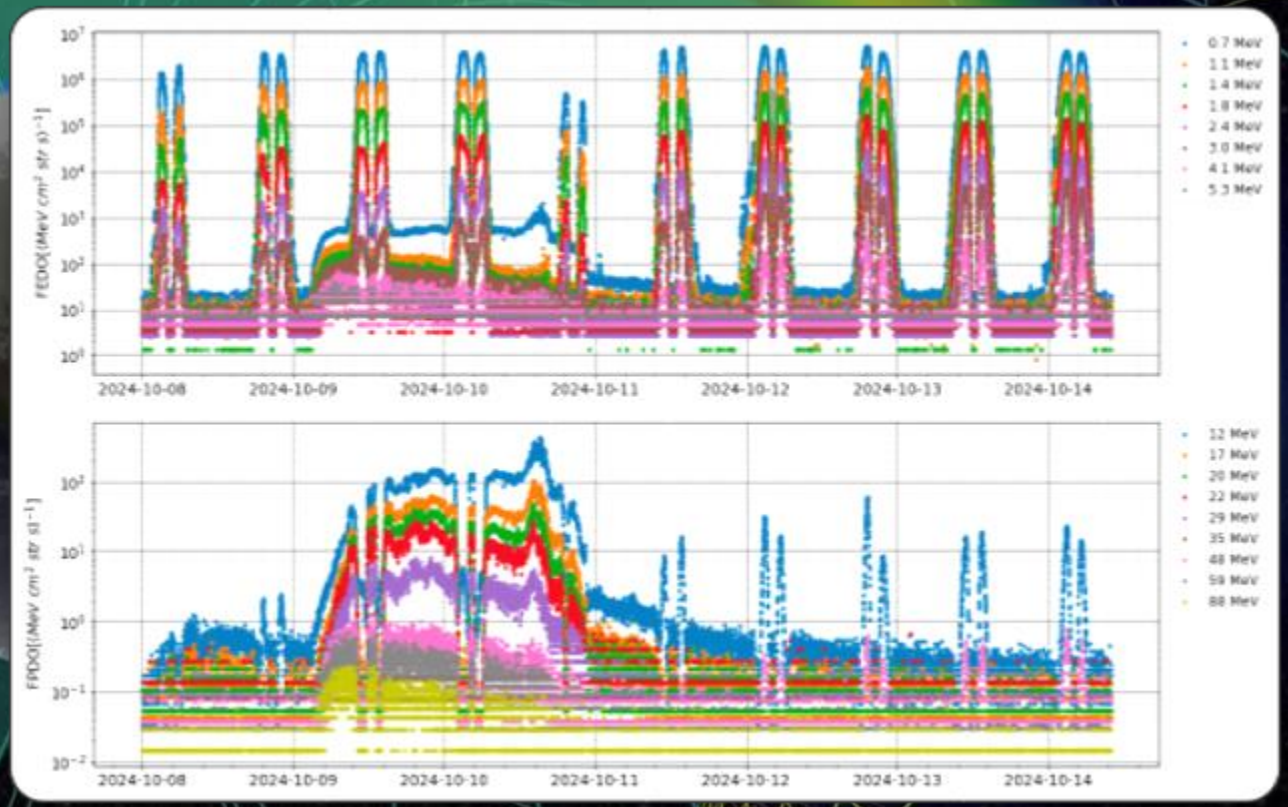
Norwegian Radiation Monitor on ASBM

- We built the instrument in < 3 years.
- Flight Model delivered to Northrop Grumman in April 2022
- Launched August 2024
- Fully operational shortly after launch

Cooperation with FFI and Space Norway

Images from SOHO and Radiation data from NORM





Electron,upper, and proton, lower graph flux seen by NORM on ASBM Oct 8 to 14 2024

We do of course not expect that new candidates have all these skills,but

- They must
  - Have solid training in math and physics
  - aquire an attitude of continous learning.
  - be trained in documenting their work
  - be trained to plan the work before starting any design, coding etc.
  - Be trained in delivery on time
  - Have engineering as a passion not a job

- Typical mistakes and errors observed
  - Design by trial and error.
  - Simulate without having a basic understand of what is simulated
  - Missing documentation at all levels.
  - Unstructured work.
  - Better is the enemy of good.
  - Late delivery.
  - No real passion for technology.

Contact: gunnar@ideas.no

To take home (message to students)

Follow

- Follow your interests.

Learn

- Learn the basics, math, physics, circuit theory. That never goes out of fashion

Work

- Work accurate, focus, document.

Respect

- Respect deadlines, timing is crucial in industry

Initiative

- Take initiative but ask for help when you are stuck

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