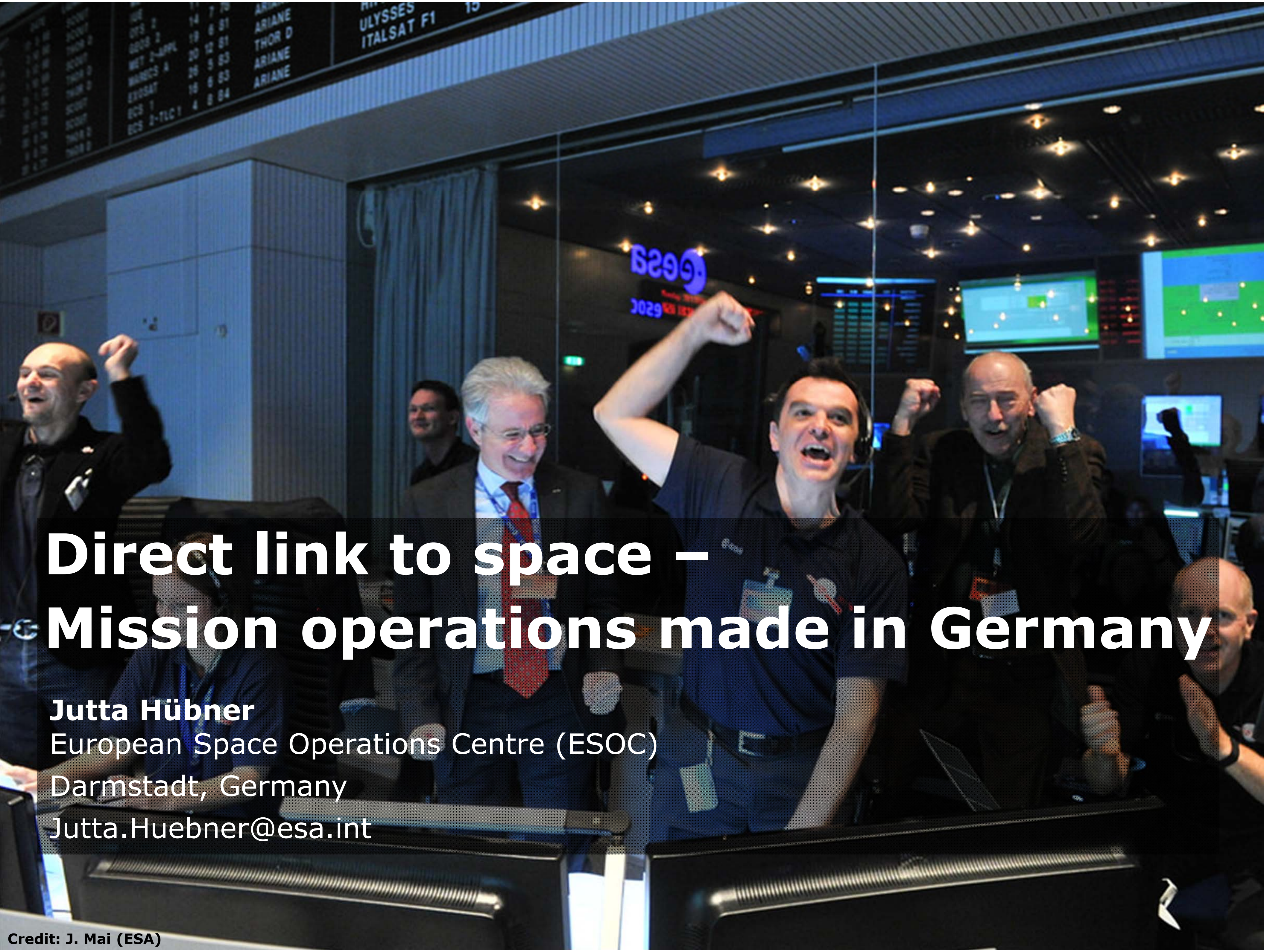


Direct link to space – Mission operations made in Germany

Jutta Hübner
European Space Operations Centre (ESOC)
Darmstadt, Germany
Jutta.Huebner@esa.int

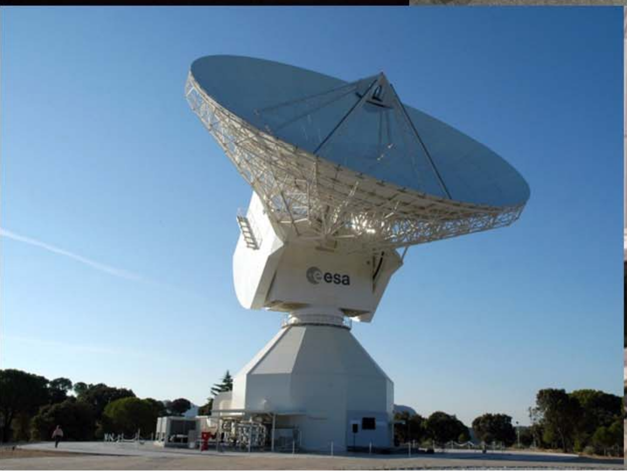
Credit: J. Mai (ESA)

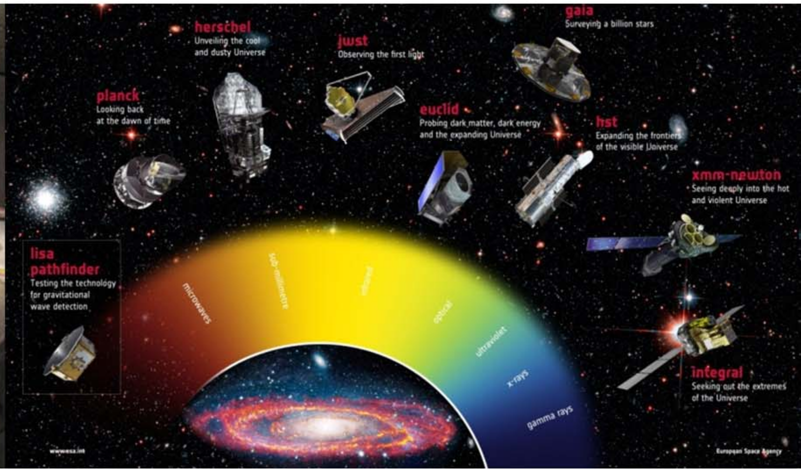
Outline

- Short intro of ESOC
- How to operate a satellite
- Teams involved in mission operations
- Examples
  - Complex mission operation scenarios
  - Special, critical operations
  - In-flight anomalies

ESOC in Darmstadt

- **History**
  - Since 1967
  - 65 ESA missions
  - more than 57 other missions supported
  - 8 missions rescued after in-orbit failure
- **Today**
  - ~ 800 staff
  - 9 missions (14 s/c) in routine operations from ESOC, 3 from REDU, and 4 from GSOC
  - >20 missions in preparation/assessment phase





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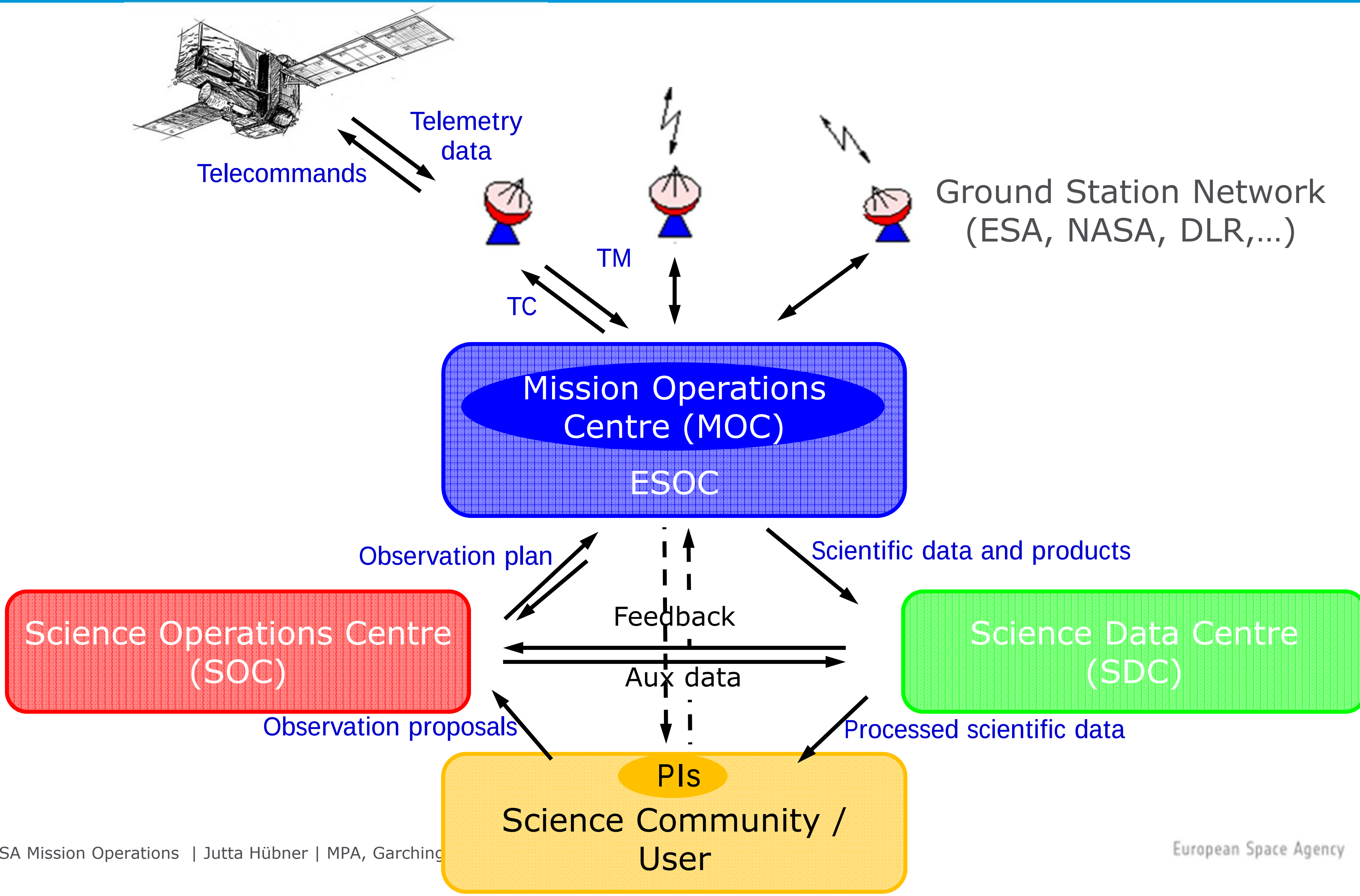
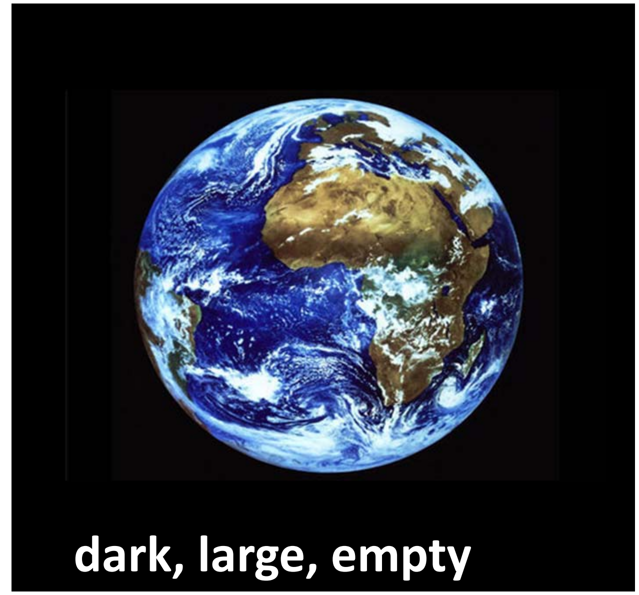
Direct link to space...
Mission operations made in Germany

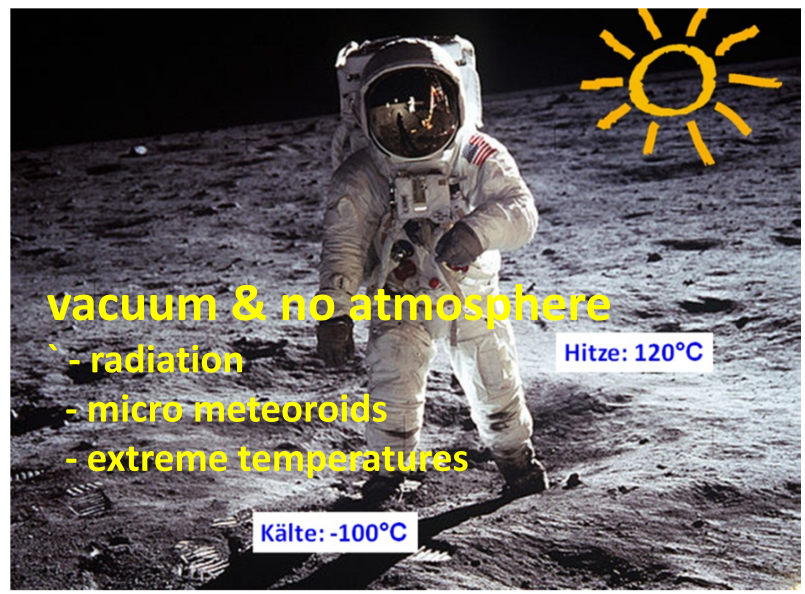


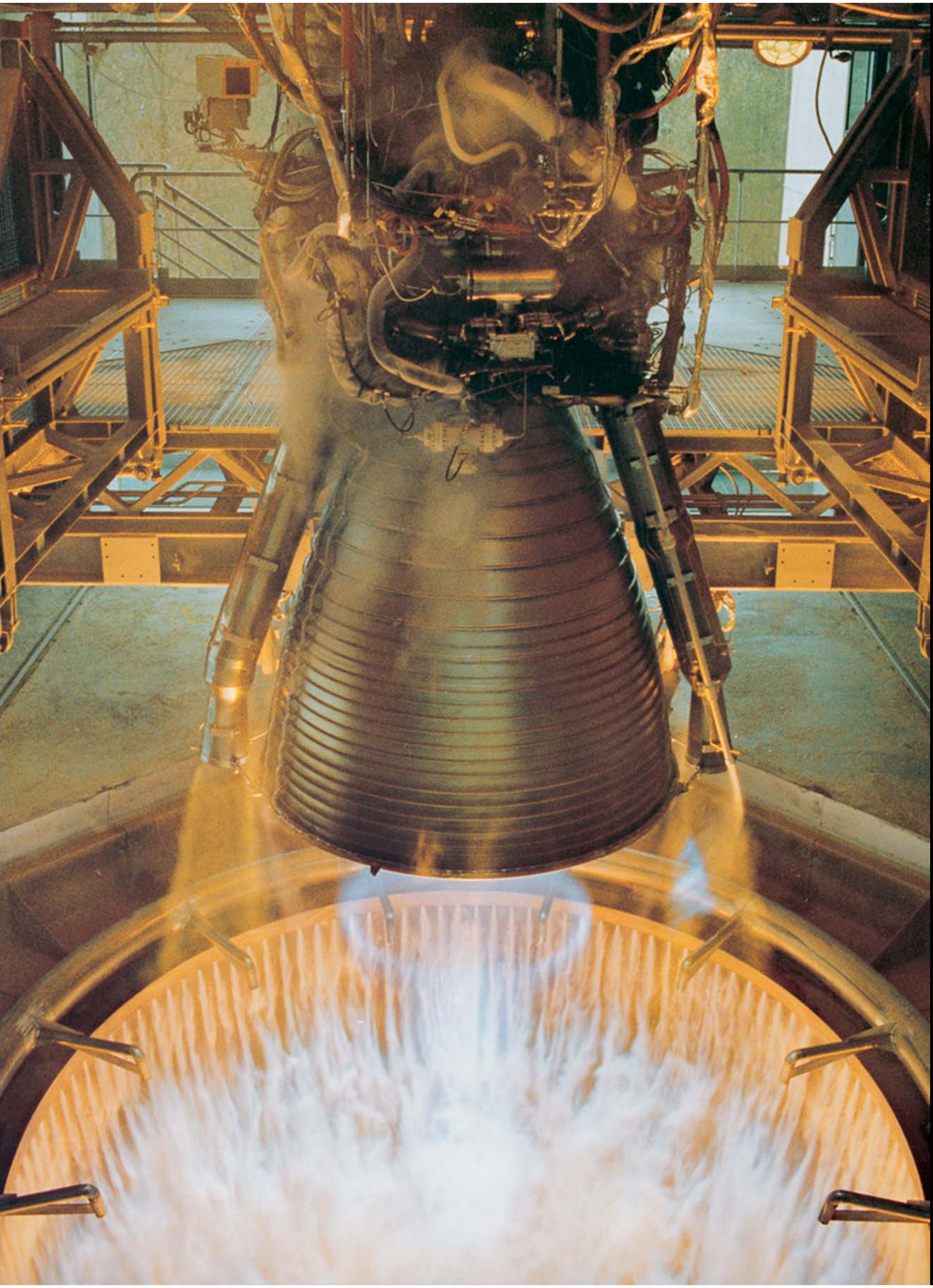
ESA Tracking Station Network (ESTRACK) – Global coverage

esa

The challenge – Extreme conditions







Leight weight

Compact & small

Combination: stable & flexible

Extrem robust

Reliable

Long-lasting

Resistent against temperature, radiation & corrosion

Communication

Effect on design, analysis & verification

Reviews & endless tests

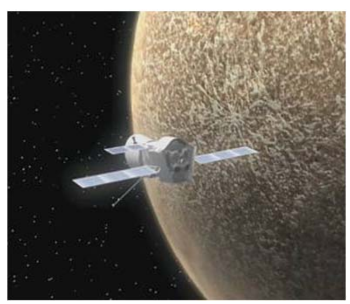
Expensive & time consuming

Mission operations –
A highly complex process

Telecommands: < 10
Telemetry Parameters = 0

Telecommands: ~ 25
Telemetry Parameters ~100

Telecommands: < 100
Telemetry Parameters ~1000

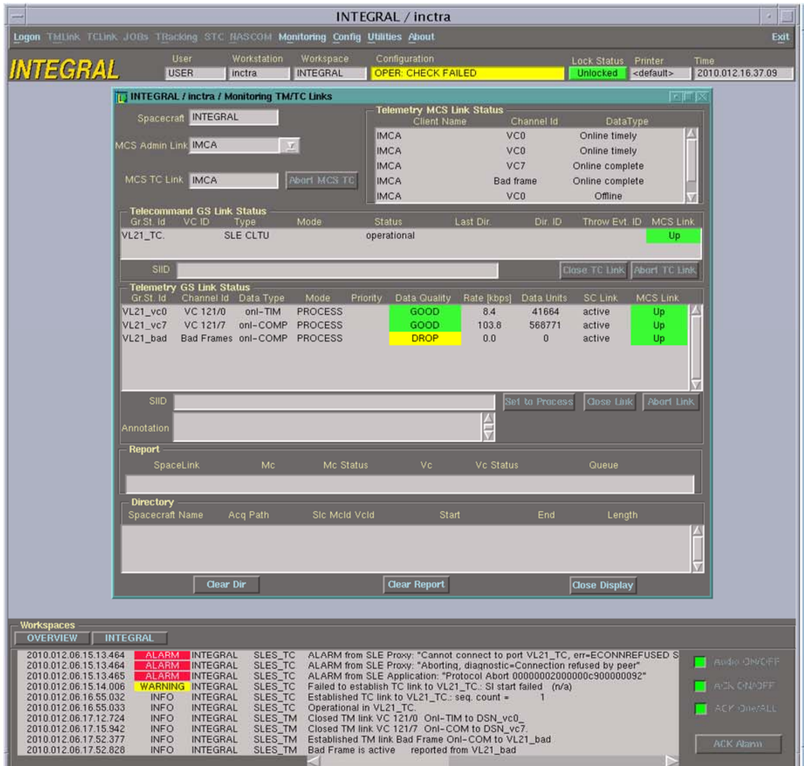


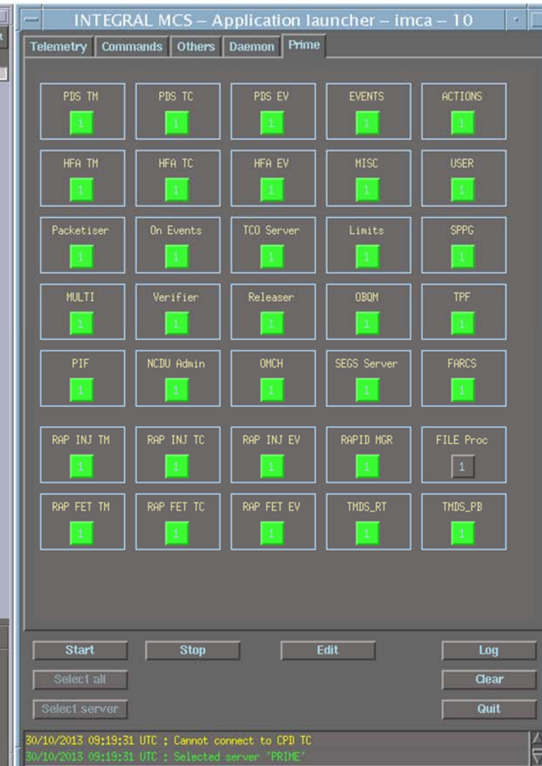
Telecommands: ~5000
Telemetry Parameters ~30.000

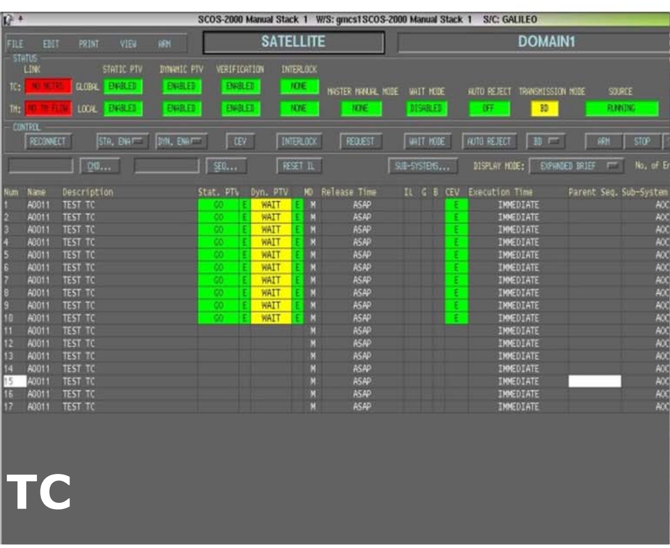
Satellites are very complex, but extremely reliable

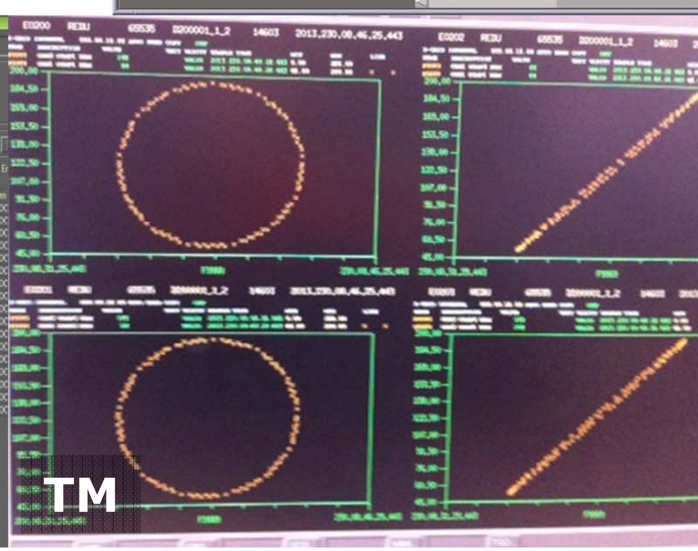
The Mission Control System (MCS) – VISUALISE the invisible

- TM
- TC
- Planning
- Data distribution & archiving
- User interfaces
- …









Mission success

Signal received from Rosetta Credits: J. Mai (ESA)

GAIA launch at ESOC Credits: J. Mai (ESA)

Basis for successful mission operations:

- Well designed & validated **ground segment** – where possible re-use of previous developments & infrastructure
- Nominal & contingency operations well prepared: **Validated procedures** for all operations of spacecraft & ground segment covering both nominal & contingency recovery operations
- **Fully trained** operations & support teams (build a team for the best, prepare for the worst) – size and composition depend on mission phase
- **Principles**
  - Failure avoidance rather than failure recovery: continuous monitoring, maintenance, adaptation of concepts and procedures,...
  - First planning, then execution
  - Always apply procedures
  - Never: "Trial-and-Error" approach
- **Experience !!** (>40 years @ ESOC)

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Teams involved in mission operations

Flight Control Team

CONTROL spacecraft & instruments via TM

Monitor and maintain the performance, plan the observations

Flight Dynamics Team

LOCALISE spacecraft

Compute position (orbit), orientation (attitude) & satellite manoeuvres

INTEGRAL Mission Control Team, 2002

Ground Stations Team

COMMUNICATE via Ground Stations

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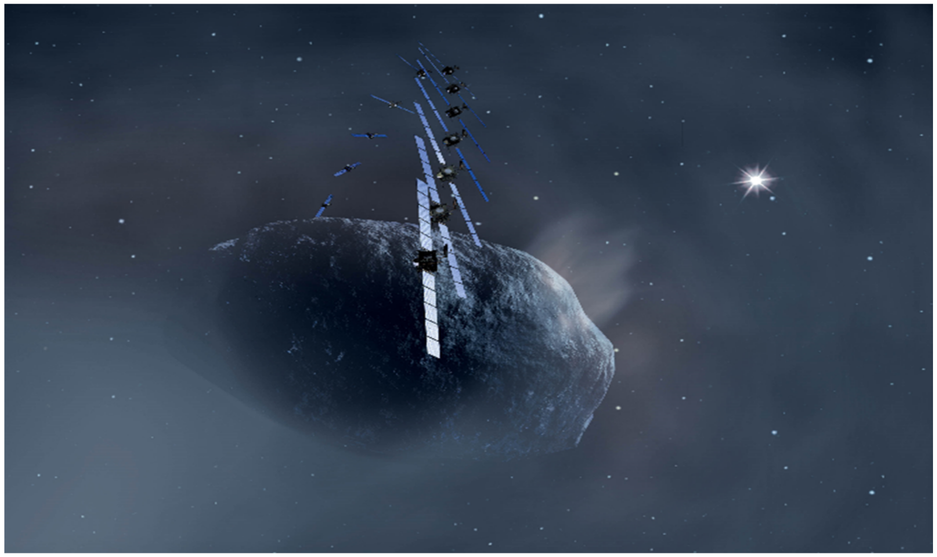
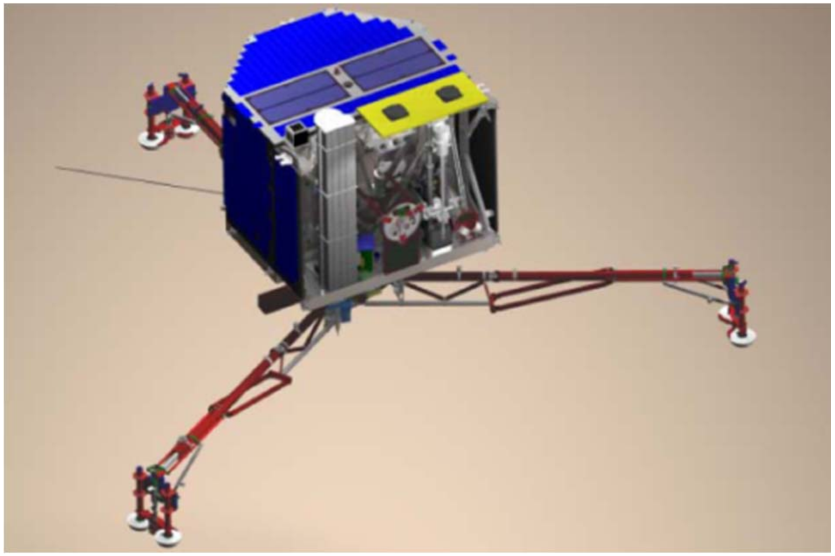
ROSETTA in a nutshell

- Leaving the Earth
- Long hibernation period driven by power budget, but also cost
- Reaching the target (comet)
- Getting into orbit
- Delivering a lander





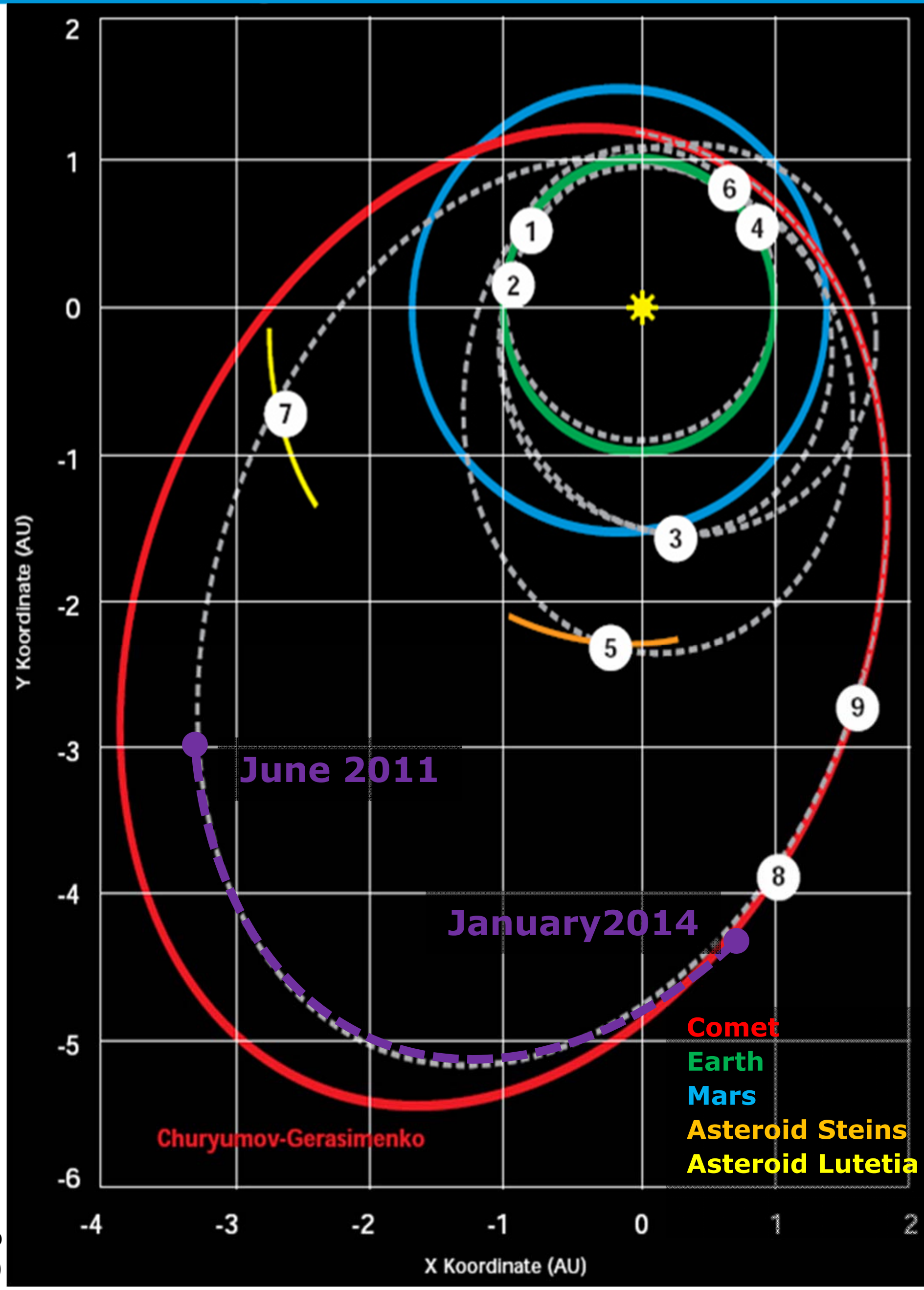
ROSETTA orbit transfer & navigation – A masterpiece of flight dynamics

Complex manouvres:

①	2004	Launch	
②	2005	1st Earth swing-by	5.9 km/s
③	2007	Mars swing-by	2.3 km/s
④	2007	2nd Earth swing-by	5.2 km/s
⑤	2008	Flyby asteroid Šteins	
⑥	2009	3rd Earth swing-by	6.35 km/s
⑦	2010	Flyby asteroid Lutetia	
	2011	Hibernation entry	
	Jan 2014	Hibernation exit	
⑧	Aug 2014	Orbit around comet (100-20 km)	
⑨	Nov 2014	Landing of Philae	
	2015 (TBC)	end of mission	

Gravity Assist via Planet Swing-Bys:

- total Δv-gain: 19.75 km/s
- 1700 kg fuel on-board: ~2.2 km/s !



Credits: A. Accomazzo (ESA)

ROSETTA and the challenges of interplanetary flight

Specifics of Interplanetary Flight

- Large radio signal propagation delays & minimisation of contact in cruise
- Long periods of low activity, followed by short, highly critical phases
- Long duration missions
- High spacecraft vulnerability (navigation, power, comms, thermal)
- Complex, variable navigation and attitude control operations
- Scarce knowledge of the target

⇨ Impact on Operations Concept

⇨ offline operations approach, on-board autonomy

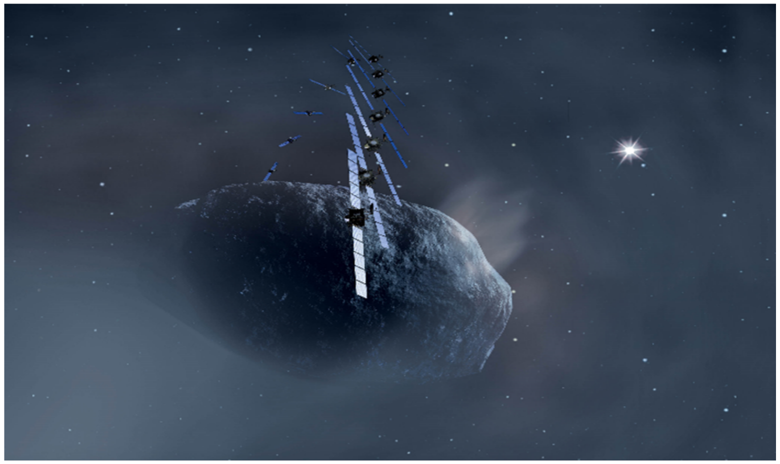
⇨ staff profile, training, on-ground pre-validation of critical one-off activities

⇨ knowledge management, training

⇨ on-board autonomy, extensive pre-validation of operations and procedures

⇨ intense coordination between Flight Dynamics and Flight Control

⇨ incremental, adaptive operations concept



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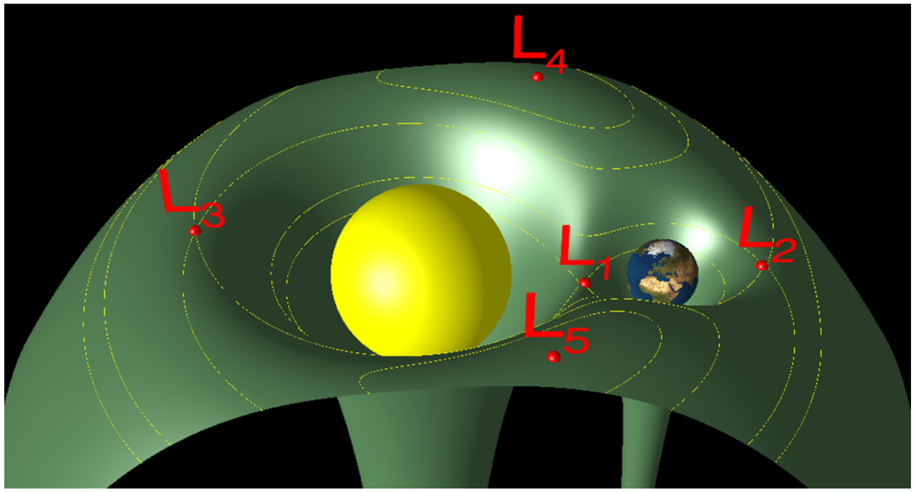
HERSCHEL
End-of-life

- **HERSCHEL** the largest infra-red telescope in space

- **At HERSCHEL end of Helium (End-of-Life)**
  - Still fully functioning platform
  - Still fuel for ~130 m/s available

- **Possible disposal scenarios**
  - Heliocentric orbit
  - Earth re-entry
  - Trailblazer Mission to Earth-Moon-Liberation points (L2)
  - Lunar impact
  - No-return disposal in the Solar System



Credits: M. Landgraf (ESA)

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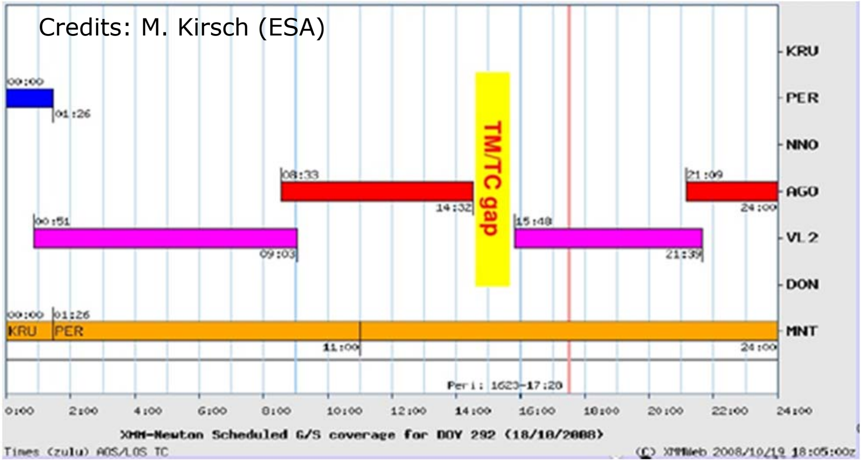
XMM
Loss of contact



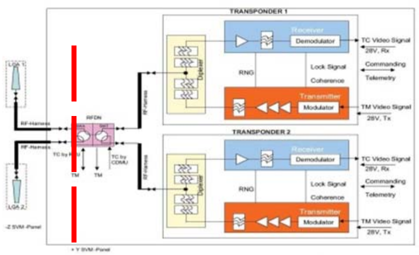
- **Contact lost** with XMM on Saturday 18th October 2008 following perigee passage (after Time-Tag command to switch on-board antenna)
- **Standard recovery procedures** did not re-establish contact
- First good news 20th October: **optical detection** of XMM by amateur astronomers (Starkenburg observatory) and follow up by other telescopes (German radar TIRA, ESA Space Debris Telescope) → satellite on predicted path & explosion or collision could be excluded
- **Radio contact** on 21st October: a very weak signal was picked-up by ESA's 35m antenna in New Norcia (West Australia)
  - ⇨ XMM was still alive!
  - ⇨ Likely failure: R/F switch used to select 1 of the 2 antennas assumed to be in intermediate position

XMM
Loss of contact

- **Final recovery** on 22nd October: Support from NASA's 35m Goldstone antenna (high uplink power & supported frequency)
    - Close to perigee (stronger signal as seen from XMM)
    - ESOC managed to send commands to move the switch back to last working position

⇨ nominal communications resumed after 4 days w/o contact

- **Reason for failure**
    - RF switch was stuck in a neutral position after Time-Tag command execution (imperfect switch command never achieved during pre-launch ground testing)



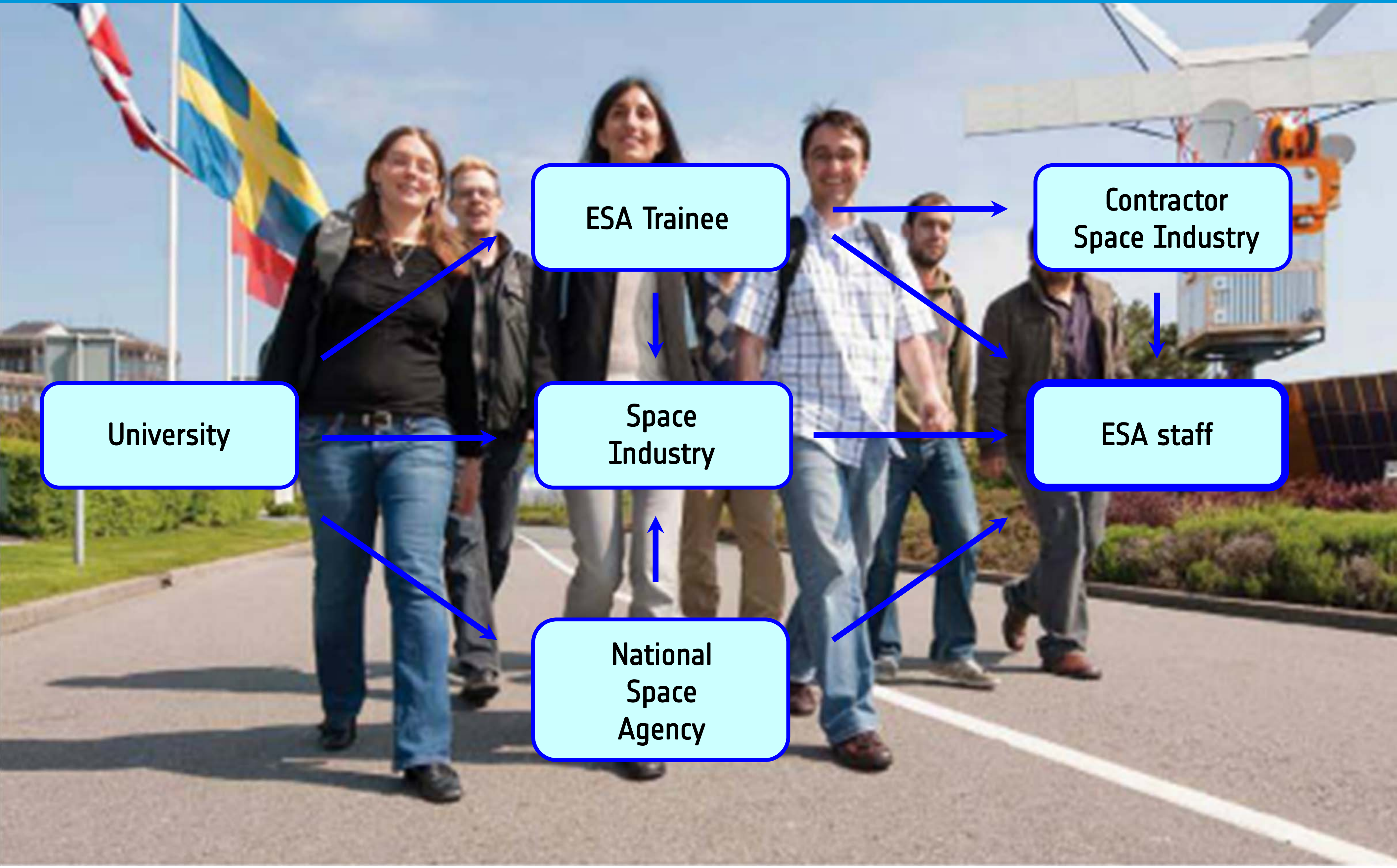
- **New operation strategy (Dec 2008)**
    - Without use of any R/F switch
    - Switching of transponders instead (antenna 1 connected to transponder 1 and antenna 2 connected to transponder 2)
    - Use only one transmitter (alternating the two transmitters)
    - Should one of the two transmitters fail, the RF switch needs to be used again


esa
Do you have the right stuff?
European Space Agency

So, do you have the right stuff?

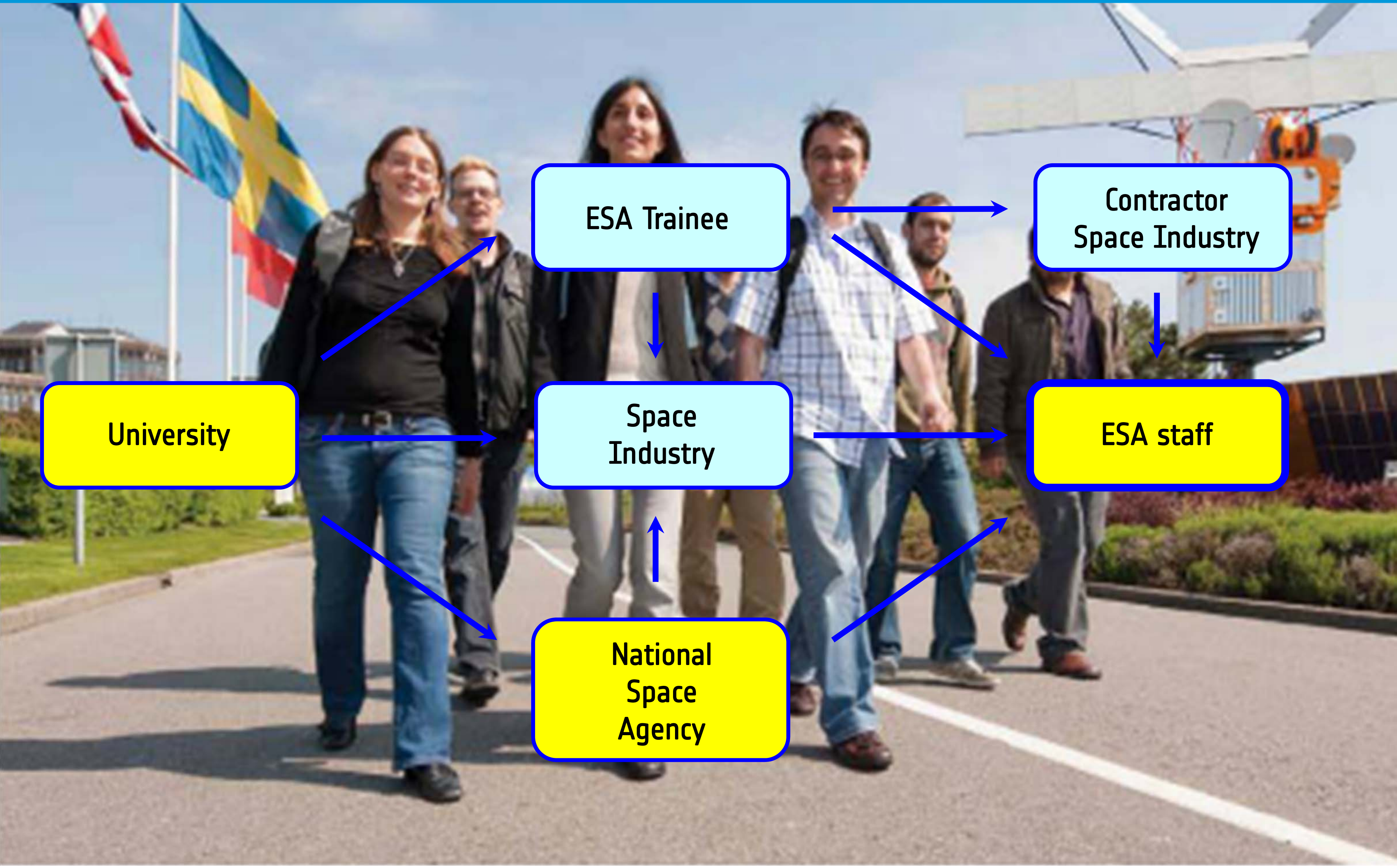
- ✓ Solid professional background
- ✓ Team spirit
- ✓ Results orientation
- ✓ Problem solving skills
- ✓ Interpersonal skills
- ✓ Communication skills
- ✓ Language skills

Access ESA



ESA Trainee
Contractor Space Industry
University
Space Industry
ESA staff
National Space Agency

Access ESA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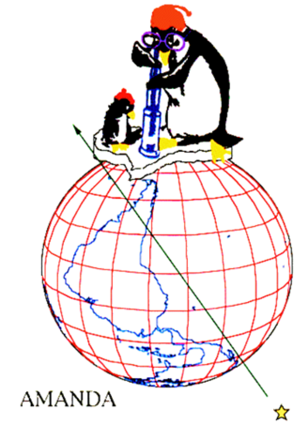
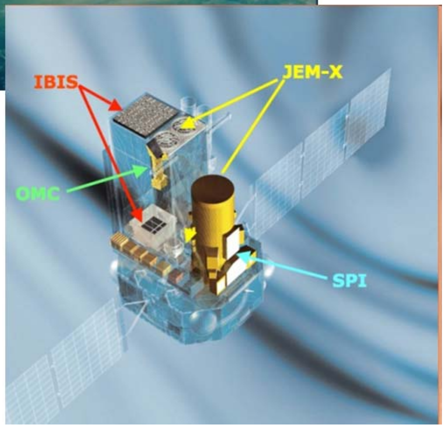
My journey to ESA

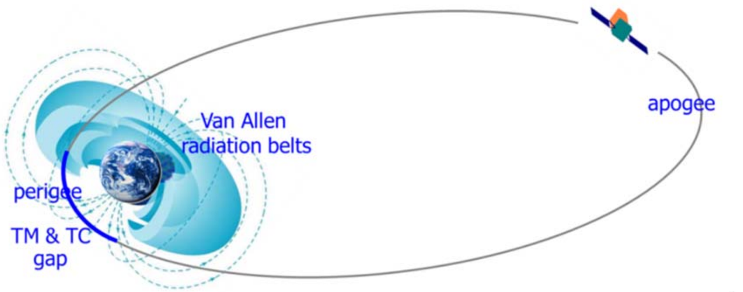


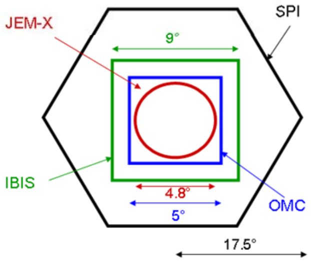
- Study of physics: University Mainz & University of Washington in Seattle
  - Worked in different groups throughout my studies
  - Diploma thesis at DESY Zeuthen (Berlin)
- PhD at MPIA in Heidelberg
- Project manager in the Program Directorate Space at DLR in Cologne
  - E.g., AsteroidFinder, CoRoT, DAWN, MEX, Rosetta, Mapheus, REXUS/BEXUS
- Deputy Spacecraft Operations Manager of INTEGRAL at ESA/ESOC
  - Support of the future satellite mission EChO as an expert
  - Member of the ESOC staff representatives committee

INTEGRAL Overview

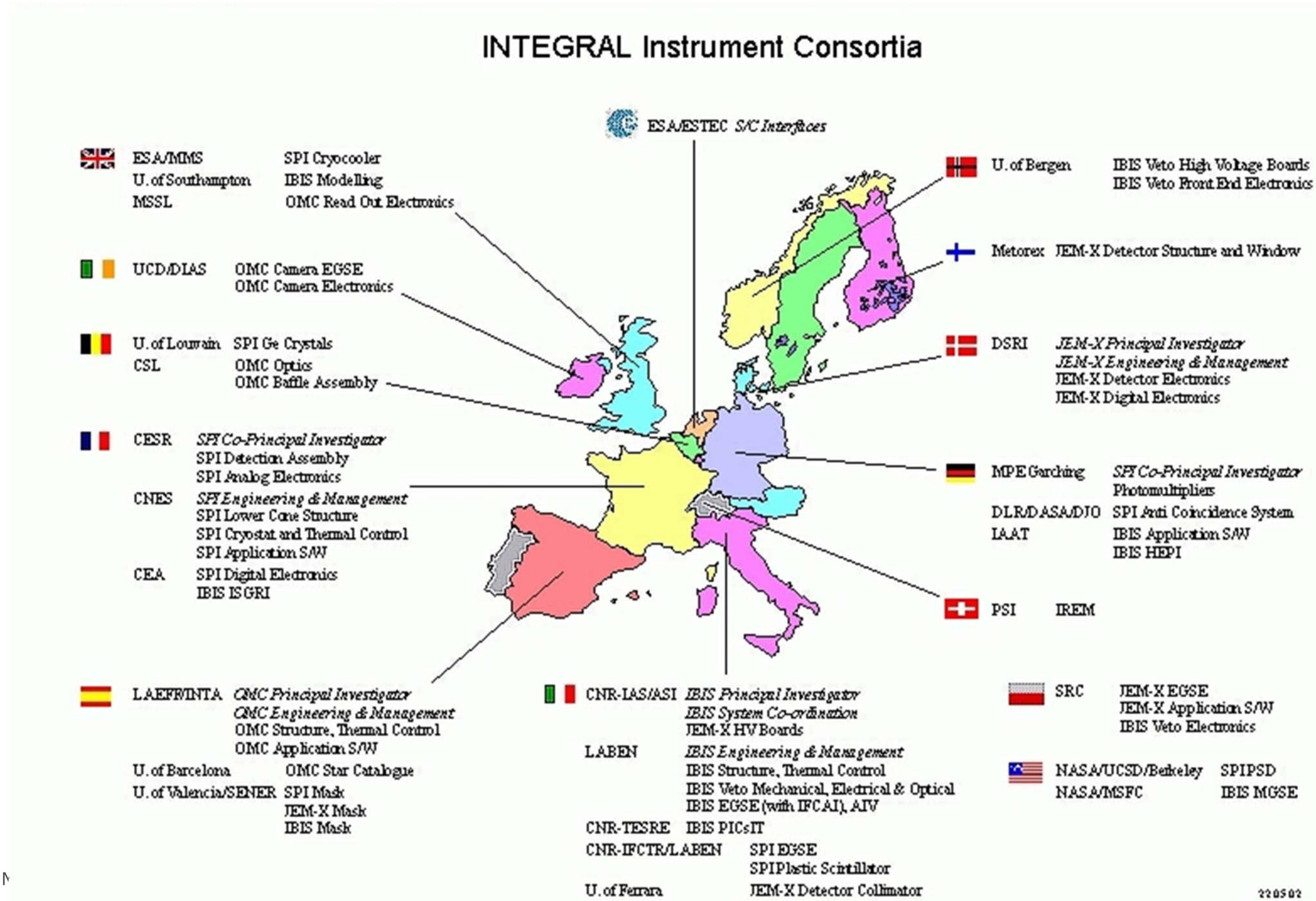
- INTernational Gamma Ray Astrophysics Laboratory
- ESA Science Mission: study most violent & exotic objects in the universe
- Most sensitive & accurate soft gamma ray observatory in space
- Launch: October 17th, 2002
- Nominal & extended lifetime of 2.5 years each far exceeded
- Multispectral observations: 4 scientific instruments
  - SPI: SPectrometer onboard Integral
  - IBIS: Imager onBoard Integral Spacecraft
  - JEM-X: Joint European Monitor X-rays
  - OMC: Optical Monitoring Camera
  - IREM: Integral Radiation Environment Monitor
- Real time mission: No on-board TM storage or TC schedule







International consortium



Commonality & shared resources – ESA's high energy astrophysical missions

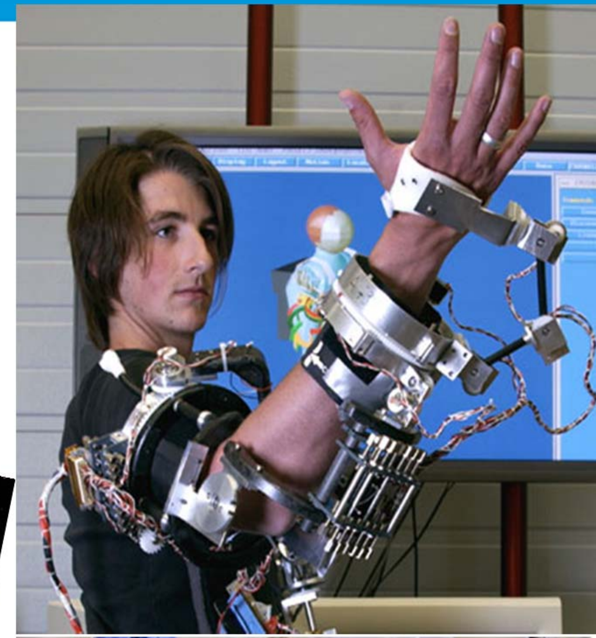
Synergy of INTEGRAL & XMM operations

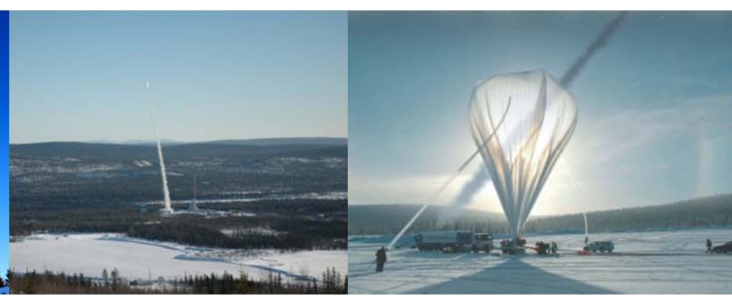
- Designed lifetime & even extended lifetime have passed
- XMM & INTEGARL have very similar platforms
- Shared resources:
  - Flight Control Teams merged in 2008 → Combined XMM & INTEGARL FCT
    - 1 Spacecraft Controller controls both satellites
    - 1 Spacecraft Operations Engineer is on-call for both missions
    - Shared team members
  - 1 dedicated control room
  - Knowledge pool

ESA for you?

Nationality requirement: ESA member state

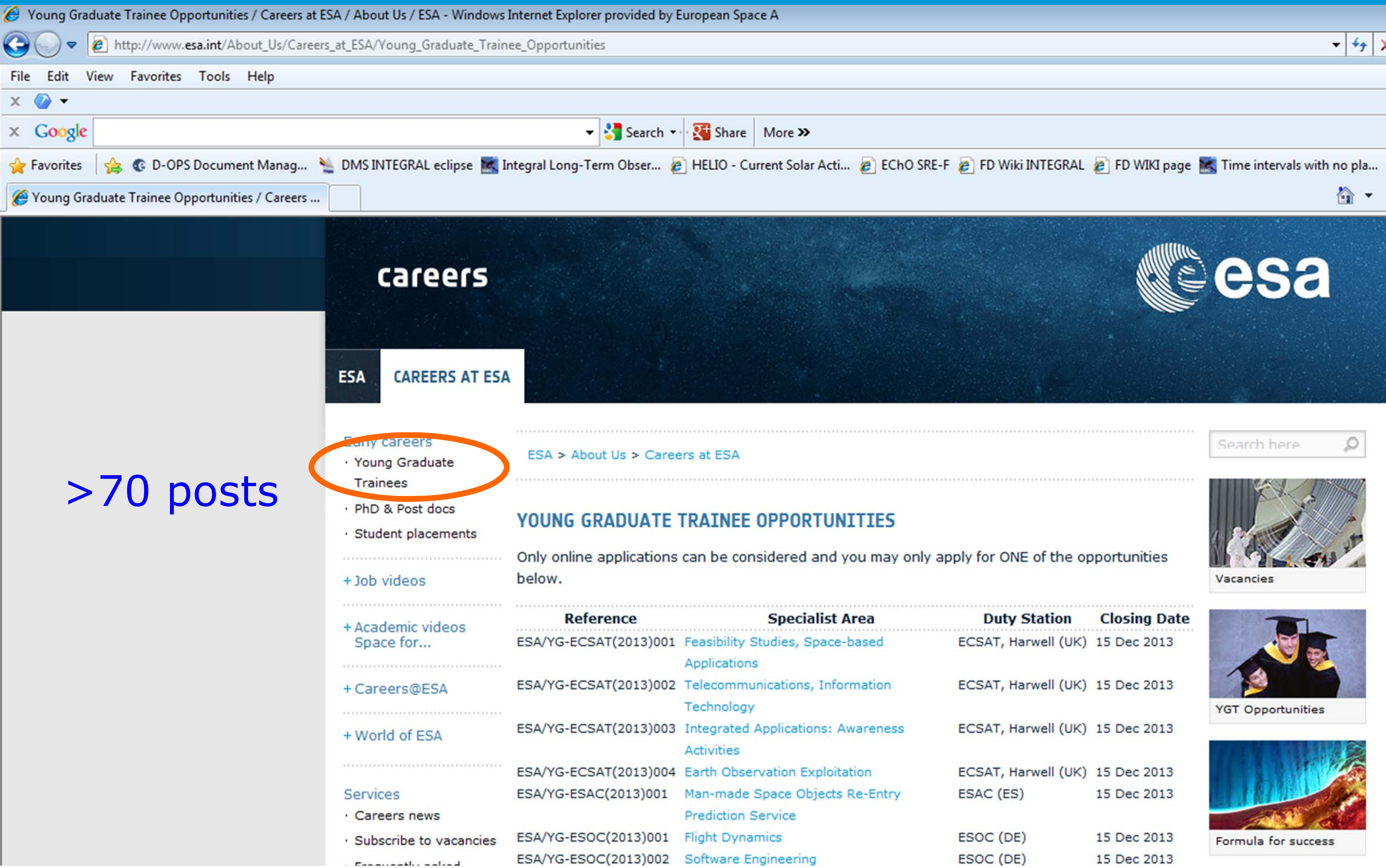
- Young Graduate Trainee Program - YGT (1 year)
  - Application deadline: end of November
  - Application within one year after end of studies
- German Trainee program (e.g., DLR/ESA)
- PhD Network Partnering Initiative (NPI)
- Postdoc Research Fellowship (2 years)
  - Application deadline: October





Space Careers
http://www.esa.int/careers

YGT posts



>70 posts

Thanks for your interest!