Direct link to space – Mission operations made in Germany

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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





Short intro of ESOC

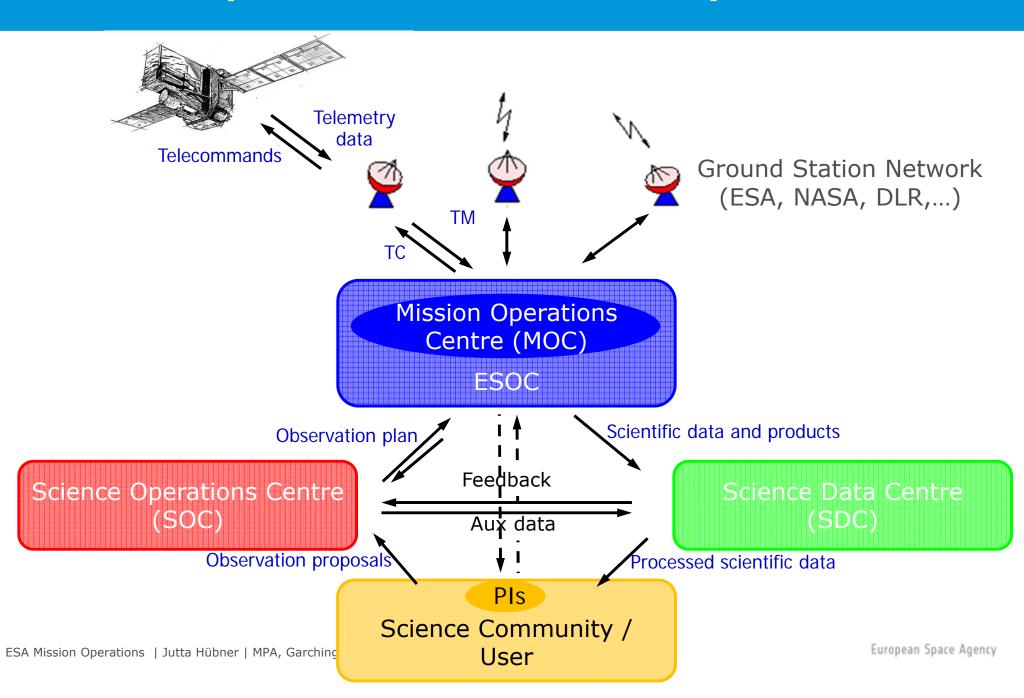
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ESA Tracking Station Network (ESTRACK) – CSA Global coverage



The challenge – Extreme conditions



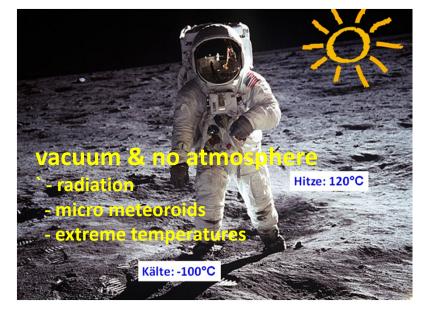


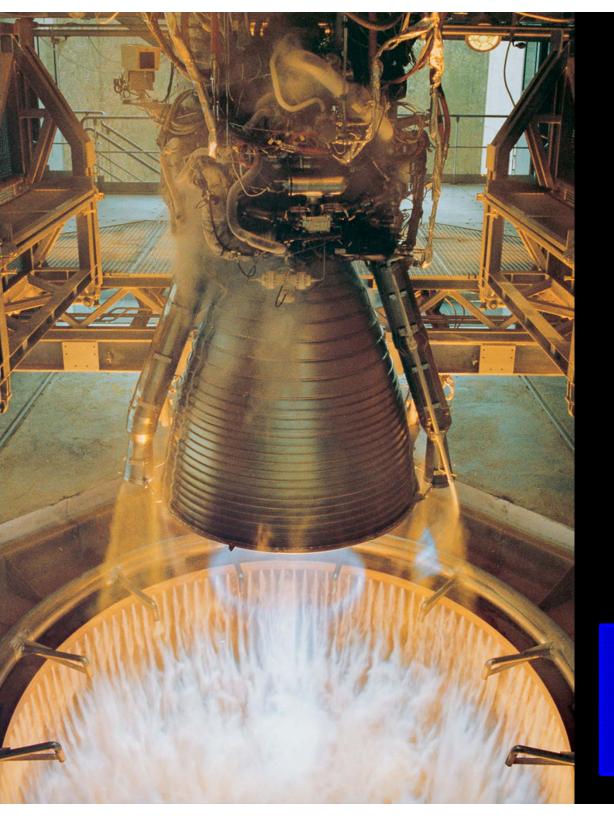






dark, large, empty





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





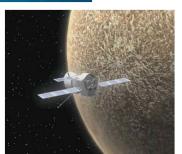
Telecommands: < 10 Telemetry Parameters = 0



Telecommands: ~ 25 Telemetry Parameters ~100



Telecommands: < 100 Telemetry Parameters ~1000



Telecommands: ~5000 Telemetry Parameters ~30.000

Satellites are very complex, but extremely reliable

ropean Space Agency

The Mission Control System (MCS) – VISUALISE the invisible



- TM
- TC

. . .

- Planning
- Data distribution & archiving

DOMAIN'

User interfaces

INTEGRAL / inctra	- INTEGR	AL MCS – A	pplication la	uncher – in	ica – 10
TMLInk TCLink JOBs TBacking STC BASCOM Monitoring Config Utilities About Bat User Workstation Workspace Configuration Lock Status Printer Time	Telemetry Comn	nands Others	Daemon Prime		
User Workstation Workspace Configuration Lock-Status Printer Time EGRAL USER Inctra INTEGRAL OPER CHECK FAILED Unlocked edefault> 2010.012.16.37.09					
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MCS TC Link IMCA Poert MCS TC IMCA Bad frame Online complete IMCA VC0 Offline Y					
Gr.St. Id VCID Type Mode Status Last Dir. Dir ID Throw Evt. D. MCS Link VL21_TC. SLE CLTU operational Up	Packetiser	On Events	TCO Server	Limits	SPPG
SIID Close TC Link Abort TC Link Telemetry GS Link Status Grst la Charmet Id Data Type Mode Priority Data Quality Ride (bor) Data Units SC Link MCS Link	HULTI	Verifier	Releaser	OBOM	TPF
VL21_vc0 VC121/0 onl-TMM PROCESS G000D 8.4 41664 active Up VL21_vc7 VC121/7 onl-COMP PROCESS 0600D 103.8 568771 active Up VL21_bad Bad Frames onl-COMP PROCESS DROP 0.0 0 active Up					
SID SID SID CONSTRUCTION	PIF	NCDU Admin	OMCH	SEGS Server	FARCS
	RAP INJ TH	RAP INJ TC	RAP INJ EV	RAPID MGR	FILE Pro
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Clear Dir Clear Report Clear Dirplay 1					
spaces					
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0.0126.0513.044 ALABAT INTEGRAL SLES, TC ALABM from SLE Proxy, "Aborting, diaprotic-Connection rotuged by peer 0.0126.0513.045 ALABAT INTEGRAL SLES, TC ALABM from SLE Proxy, "Aborting, diaprotic-Connection rotuged by peer 0.0126.0513.040 WARING INTEGRAL SLES, TC Failed to establish TC link to VL21_TC: SI tart failed (r/q) 0.0126.05153.020 INFO INTEGRAL SLES, TC Failed to establish TC link to VL21_TC: SI tart failed (r/q)	Select all				C
0.012.08.16.55.033 INFO INTEGRAL SLES_TC Operational in VL21_TC. O102.06.17.12.724 INFO INTEGRAL SLES_TM Closed TM link VC 121/0 OnI-TIM to DSN_vc0 O102.08.17.18.424 INFO INTEGRAL SLES_TM Closed TM link VC 127/2 OnI-COM to DSN_vc7	Select server				G
0.012.06.17.52.377 INFO INTEGRAL SLES_TM Etablished TM link Bad Frame Ori-COM to VL21_bad 0.012.06.17.52.828 INFO INTEGRAL SLES_TM Etablished TM link Bad Frame Is active reported from VL21_bad	30/10/2013 09:19:31 30/10/2013 09:19:31	1 UTC : Cannot o 1 UTC : Selected			
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Mission success





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)

GAIA launch at ESOC

Credits: J. Mai (ESA)



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Teams involved in mission operations





Flight Control Team

<u>CONTROL</u> spacecraft & instruments via TM Monitor and maintain the performance, plan the observations



Flight Dynamics Team

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





Ground Stations Team

<u>COMMUNICATE</u> via Ground Stations

INTEGRAL Mission Control Team, 2002



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ROSETTA in a nutshell



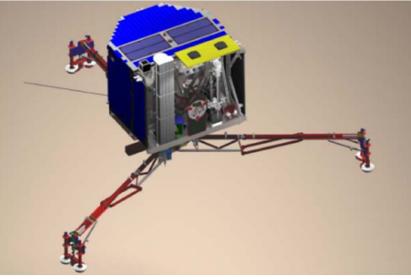
Leaving the Earth

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



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European Space Agency

ROSETTA orbit transfer & navigation – A masterpiece of flight dynamics

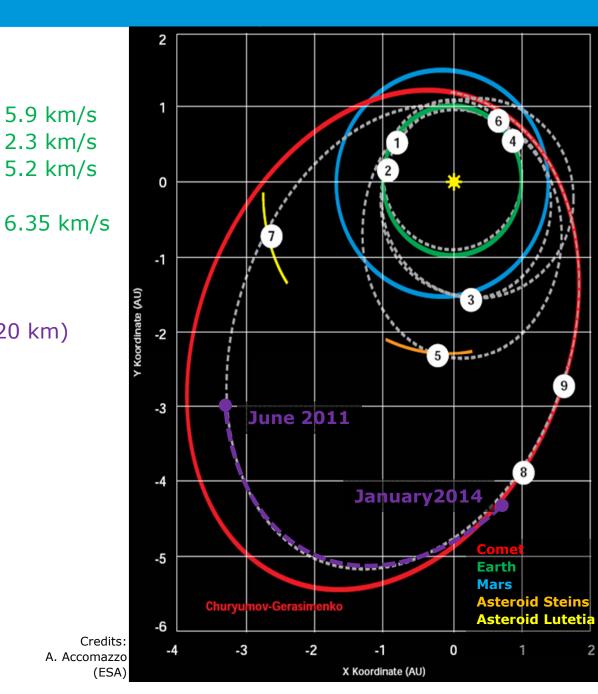


Complex manouvres:

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

Gravity Assist via Planet Swing-Bys:

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



ROSETTA and the challenges of interplanetary flight

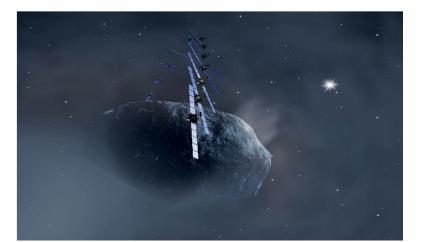


Specifics of Interplanetary Flight

- 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 prevalidation 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

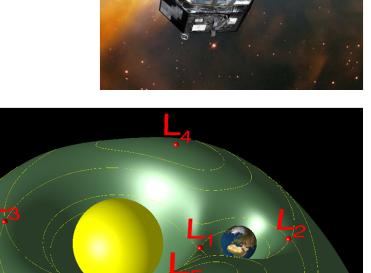
HERSCHEL the largest infra-red telescope in space

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









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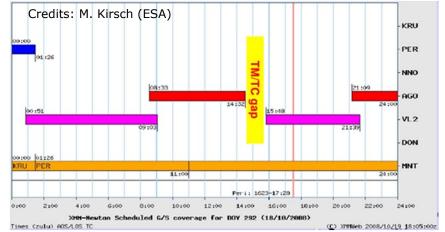
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XMM Loss of contact

- 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

Do you have the right stuff?

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European Space Agency

esa

So, do you have the right stuff?

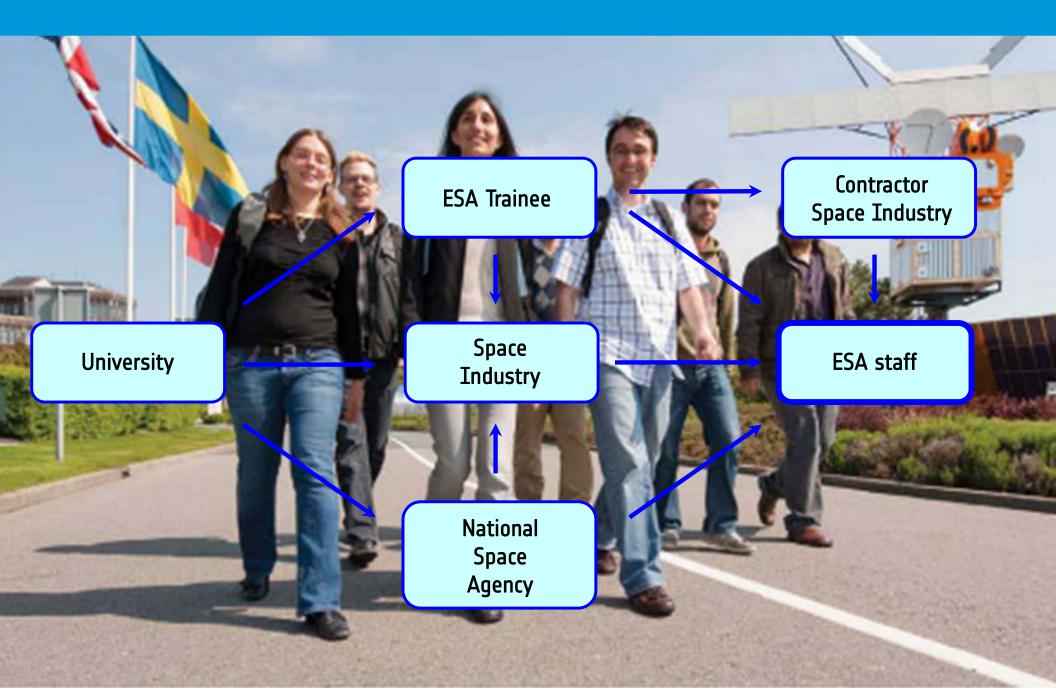


- ✓ Solid professional background
- ✓ Team spirit
- ✓ Results orientation
- ✓ Problem solving skills
- ✓ Interpersonal skills
- ✓ Communication skills
- ✓ Language skills



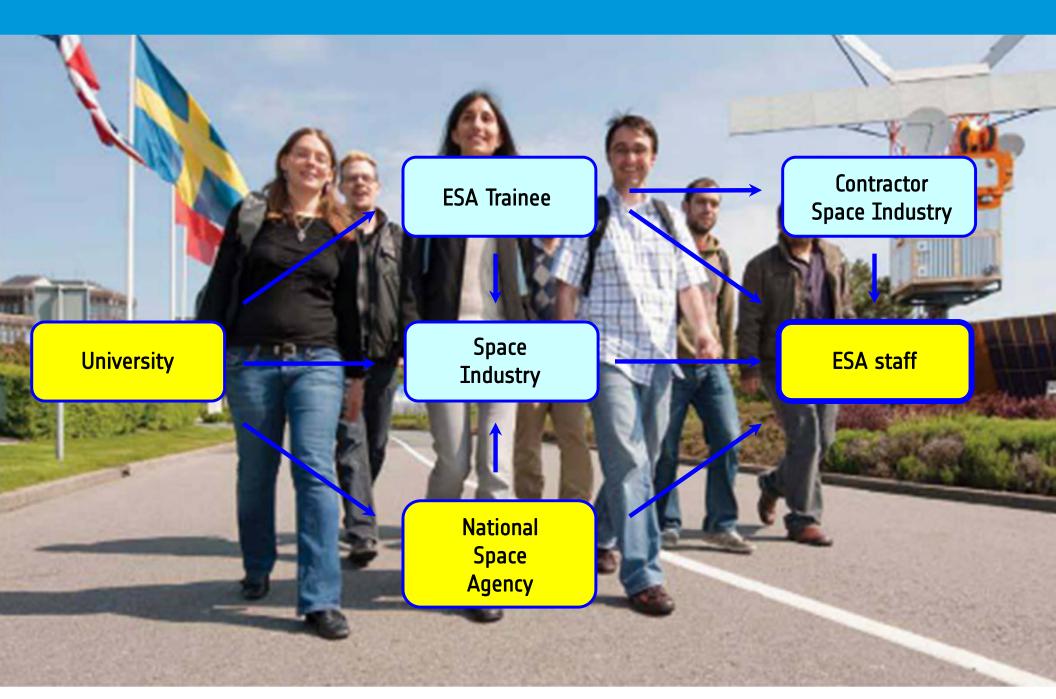












My journey to ESA

- 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

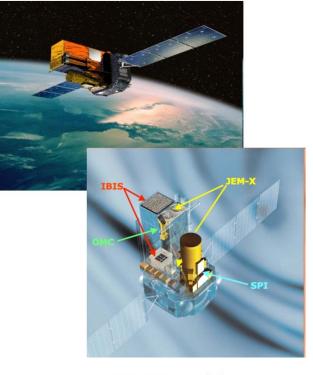


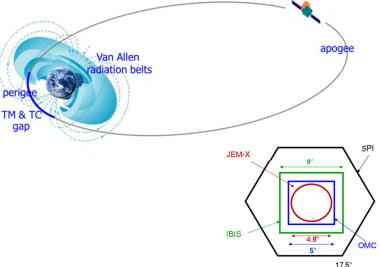


INTEGRAL Overview



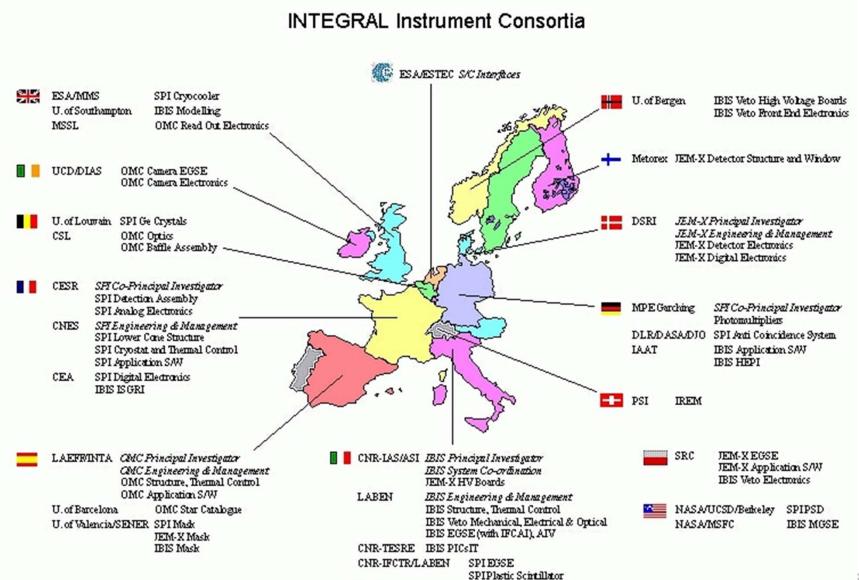
- INTernational Gamma Ray Astrophysics Laboratory
- ESA Science Mission: study most violent & exotic objects in the universe
- Most sensitive & accurate soft gamma ray observatory in space
- Launch: October 17th, 2002
- Nominal & extended lifetime of 2.5 years each far exceeded
- Multispectral observations: 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





U. of Ferrara

JEM-X Detector Collimator

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 \rightarrow 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



careers

→ LOOKING FOR BRIGHT MINDS

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



