Science Operations

of the

Herschel Space Observatory

SCIOPS-2013:
Leo Metcalfe
Herschel SCOM/MM

10-September-2013

Principal Characteristics

of the

Observatory

HERSCHEL

1. **Launched 14 May 2009**
   - 25 years since conception

2. **Large telescope** (for space)
   - 3.5 m diameter Silicon Carbide

3. **Opened new spectral window**
   - 55-672 μm – bridging the far infrared & submillimetre – the 'cool' universe

4. **Instruments**
   - 3 camera/spectrometer instruments: PACS, SPIRE and HIFI mounted on a superfluid helium cryostat
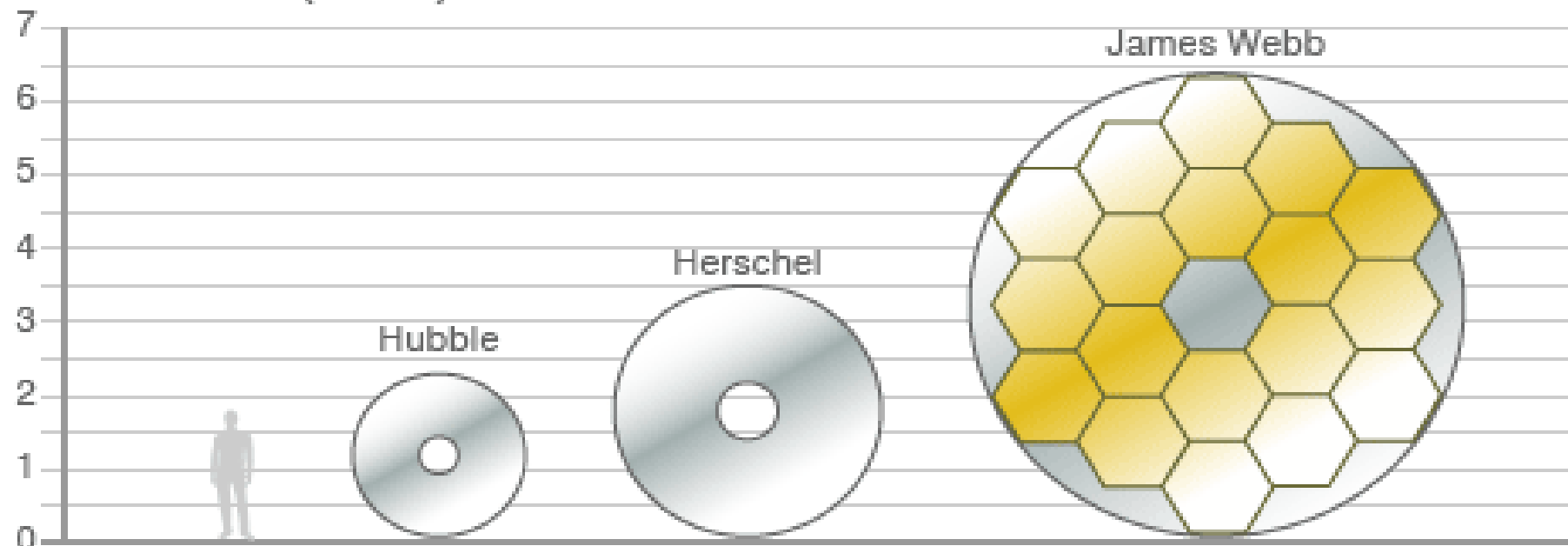
5. **Orbit**
   - orbited Earth-Sun Lagrange 2 point

6. **Objectives**
   - targets ranging from Solar System out to most distant & primordial galaxies
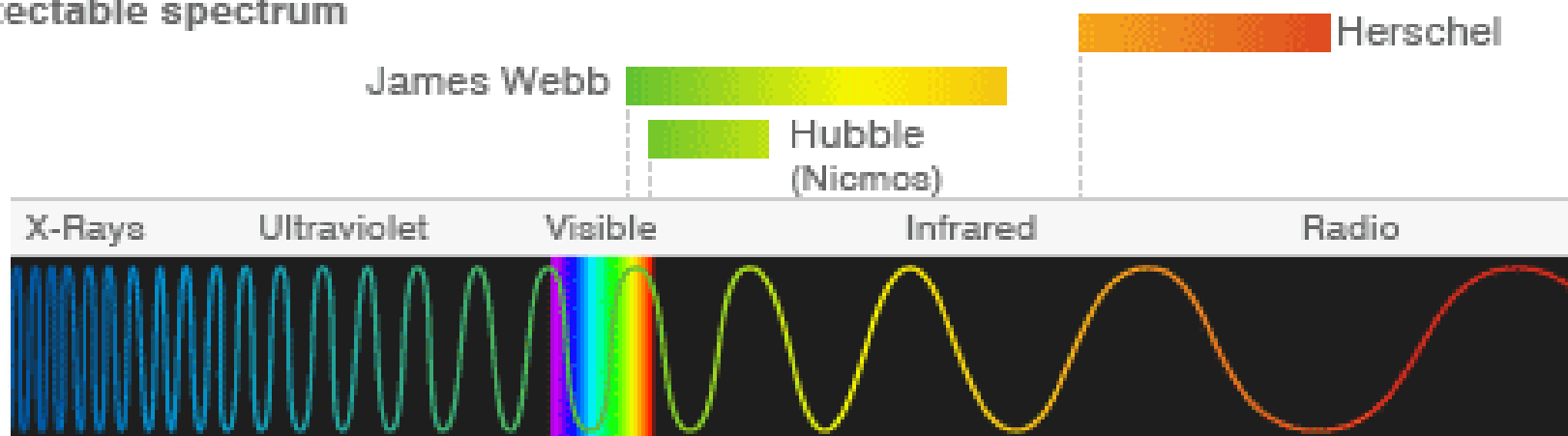
SPACE TELESCOPE COMPARISON

Mirror diameter (metres)

James Webb

Herschel

Hubble

Detectable spectrum

Herschel

James Webb

Hubble
(Nicmos)

X-Rays | Ultraviolet | Visible | Infrared | Radio

HERSCHEL

- Herschel was(is) an observatory open to everyone

- Scientific leadership through Project Scientist/Science Team

- Independent time allocation committee (HOTAC)

- (later) User Group (HUG)

Sun, Earth, and Moon in the 'same direction' in the sky

a. Thermally favourable and stable environment

b. Good access to the sky for observations

c. Avoid Earth's radiation belts
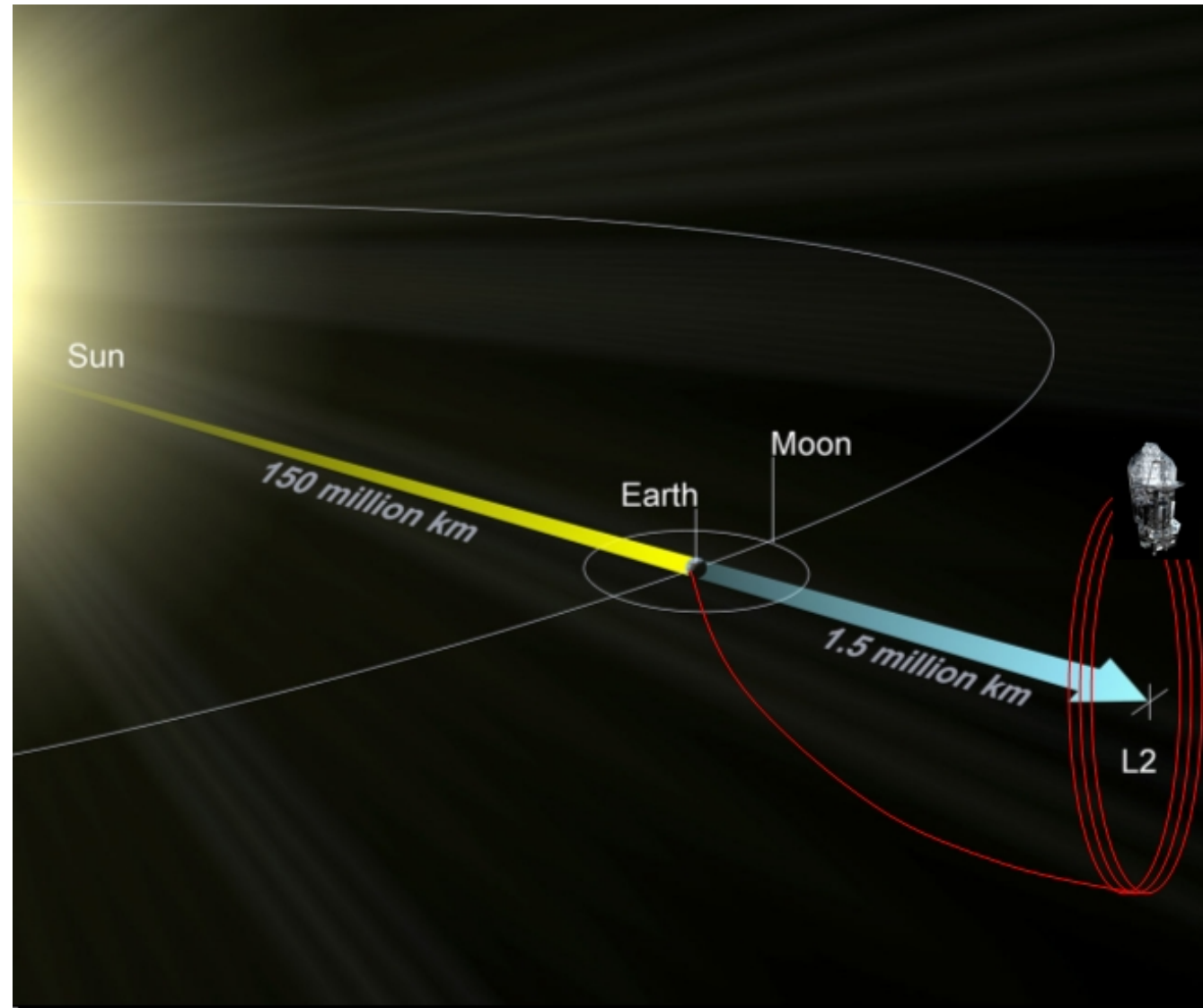
MAIN MISSION PHASES
(approximate, as the various phases were in fact interleaved)

esa

❑ *Pre-launch / Development* : Including, crucially, pre-flight sims./rehearsals

❑ *Launch 14 May 2009*

❑ *mid-May   to mid-July 2009* : LEOP & CoP

❑ *mid-July   to Nov.2009* : Performance Verification (PV) Phase

❑ *Nov.2009 to Jan.2010* : Science Demonstration Phase (SDP) *

❑ *Jan.2010   to Apr.29 2013* : Routine Phase ending with end-LHe

❑ *May 2013 to Dec.2017* : Post-operations Phase

* Initial Results Workshop held December 2009

- **Design philosophy of "Smooth Transition" means the same system used for:**
  - o pre-flight instrument ILT tests
  - o pre-flight simulations & end-to-end (SVT/SOVT) tests
 - **… is used throughout:**
  - o Commissioning / PV / Routine / & Post-operations Phases

- **Therefore for e.g. the Herschel Common Science System (HCSS) in use, and existing Management/Interface structures, from Operations transition smoothly into post-operations.**

Science Operations

Organisation & Management

Generic mission operations organisation
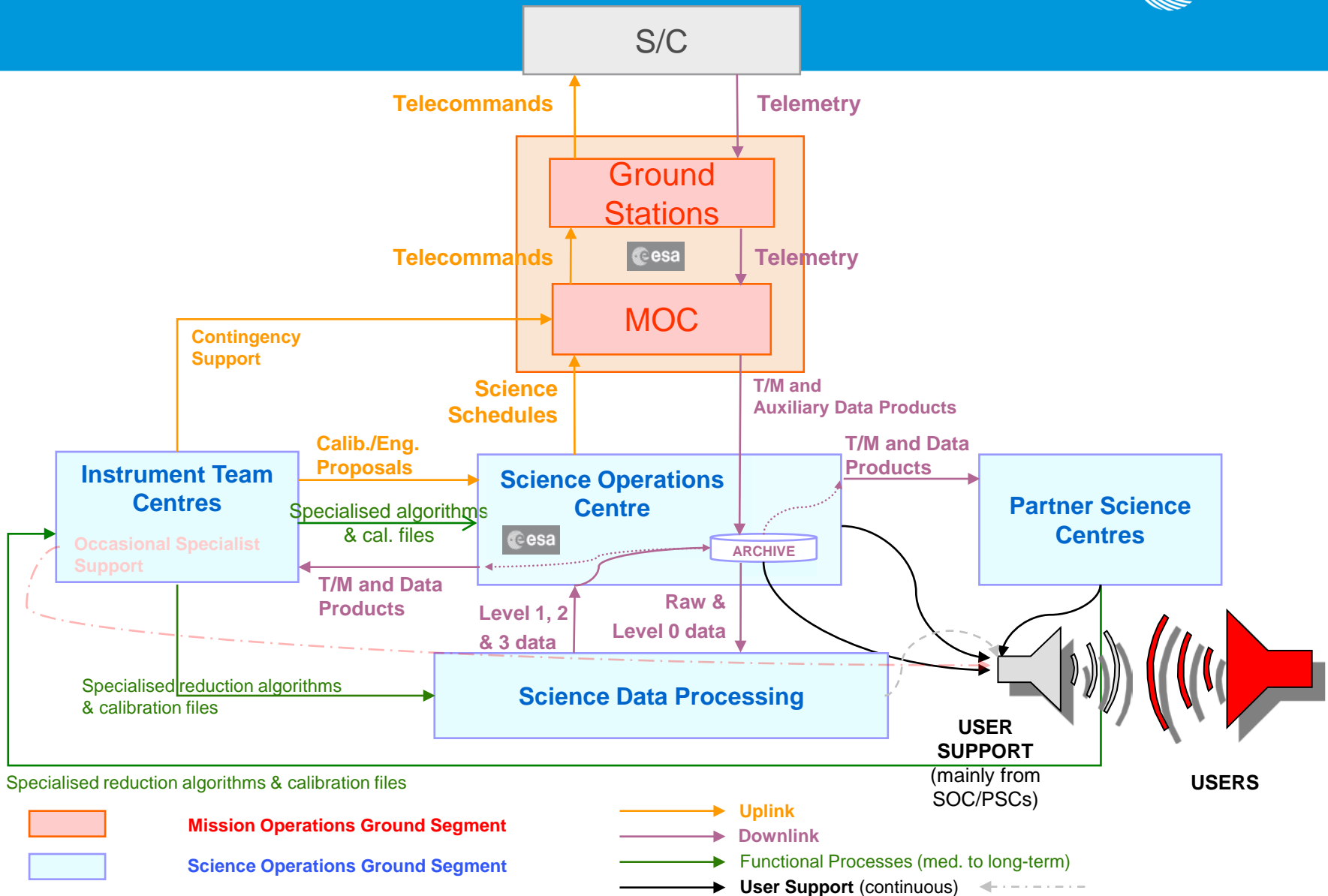
Herschel Operations Workflow
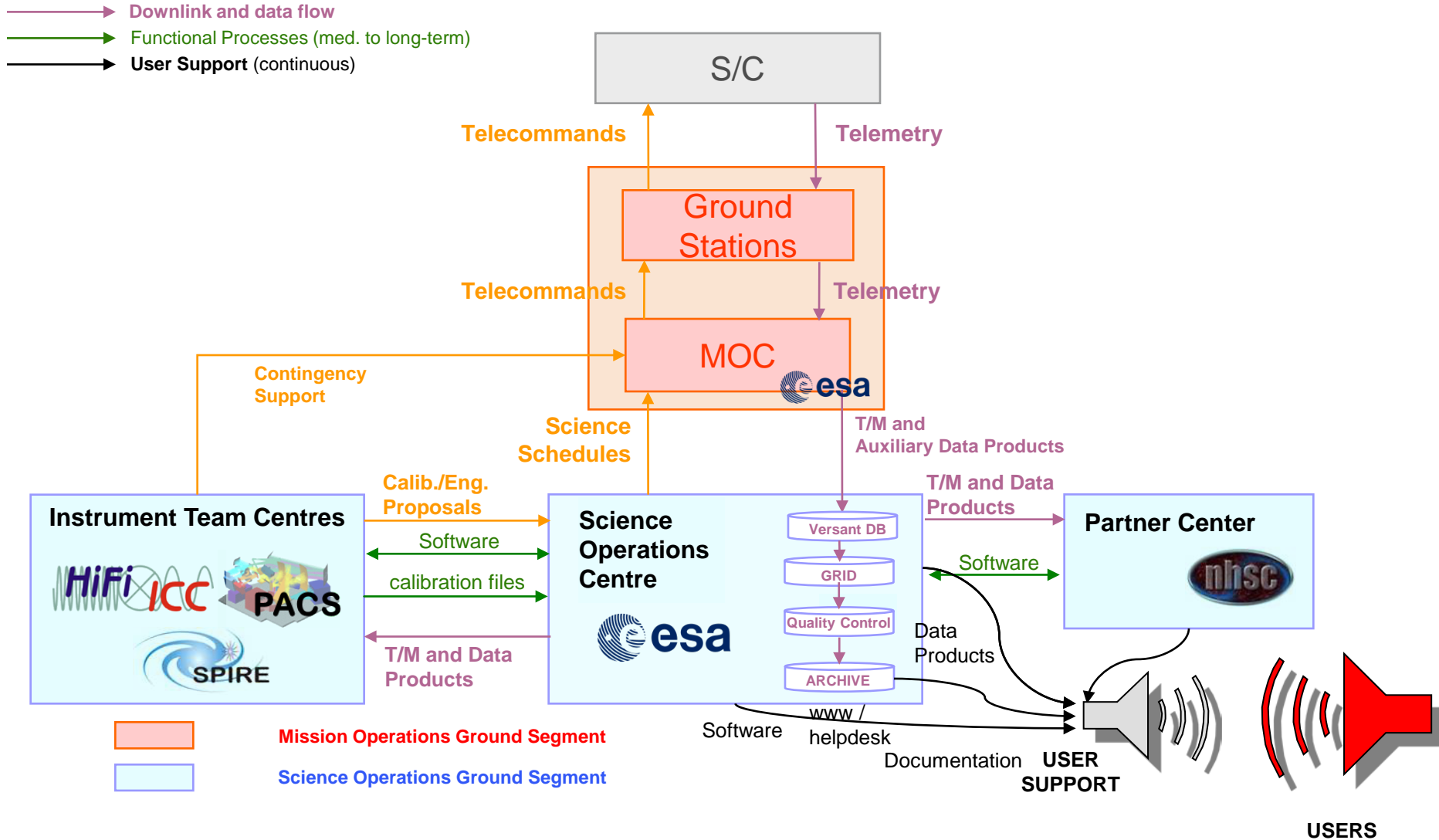
Herschel Post-Operations Workflow
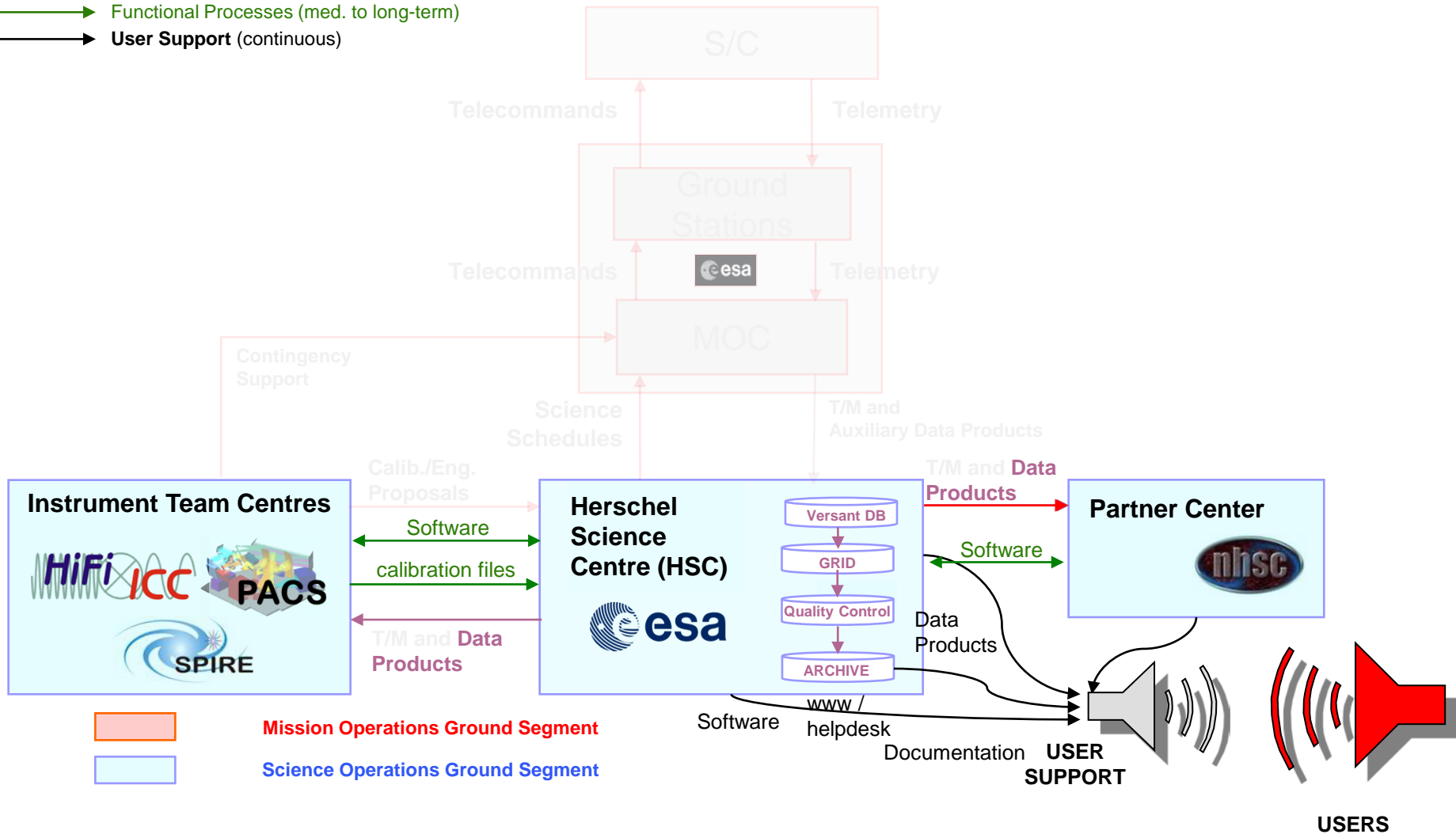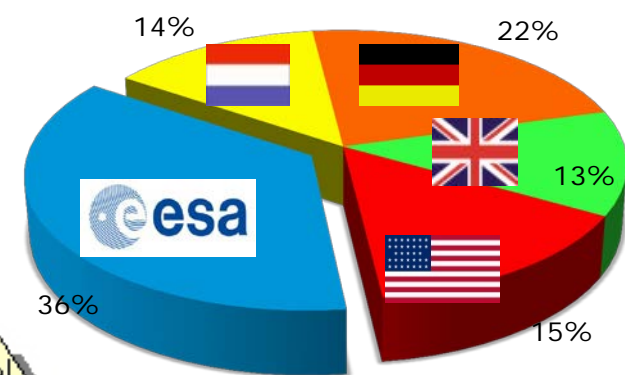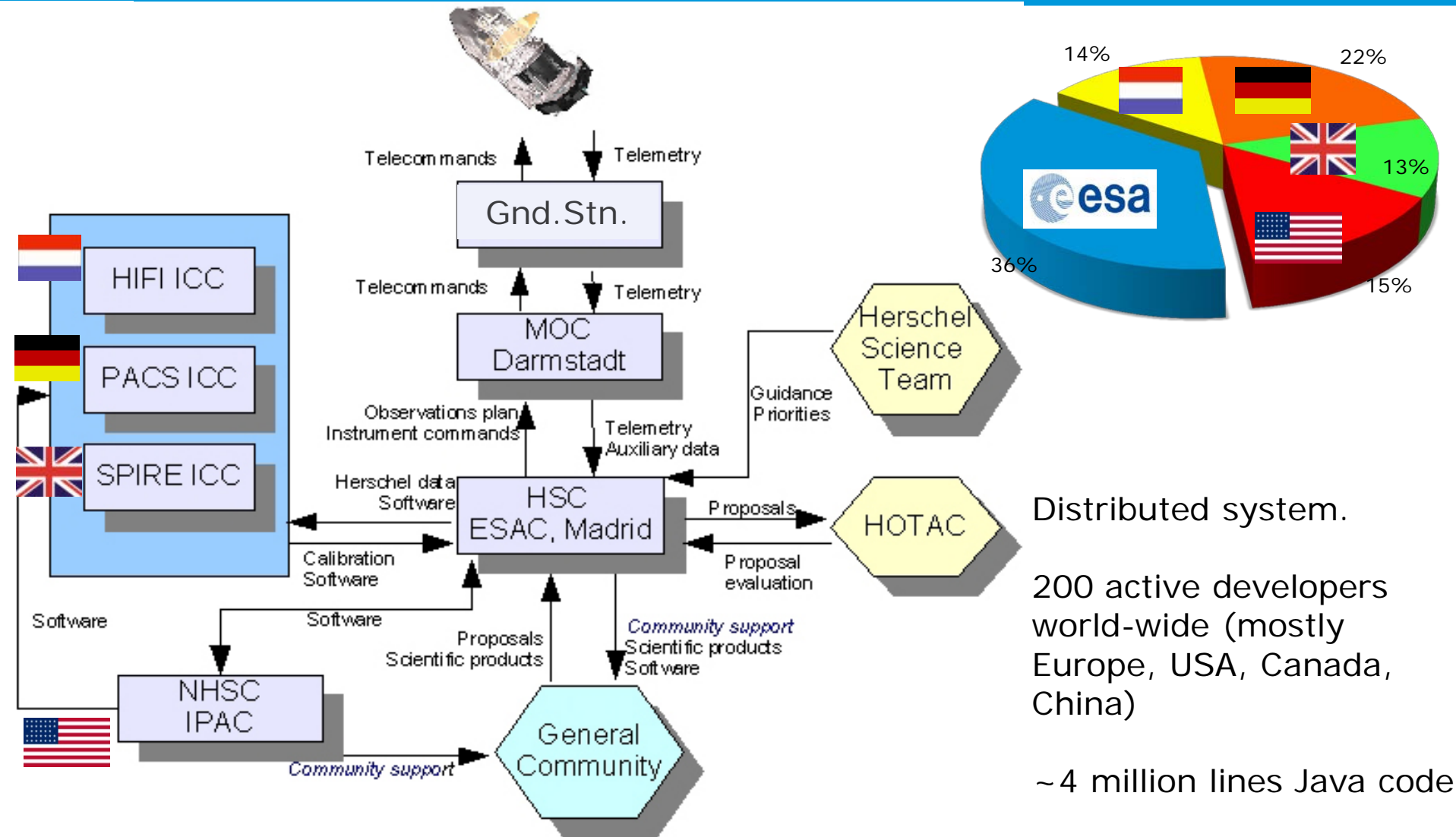
Distributed system.

200 active developers world-wide (mostly Europe, USA, Canada, China)

~4 million lines Java code

Geographically distributed set of centres...

1. Herschel Science Centre @ ESAC, Spain

2. HIFI ICC @ SRON-Groningen, The Netherlands

3. PACS ICC @ MPE, Garching, Germany

4. SPIRE ICC @ RAL, United Kingdom

5. NHSC @ IPAC, Pasadena, United States

6. Mission Operations Centre (MOC) @ESOC, Germany

Cebreros 35m DSN Antenna

MOC responsibilities
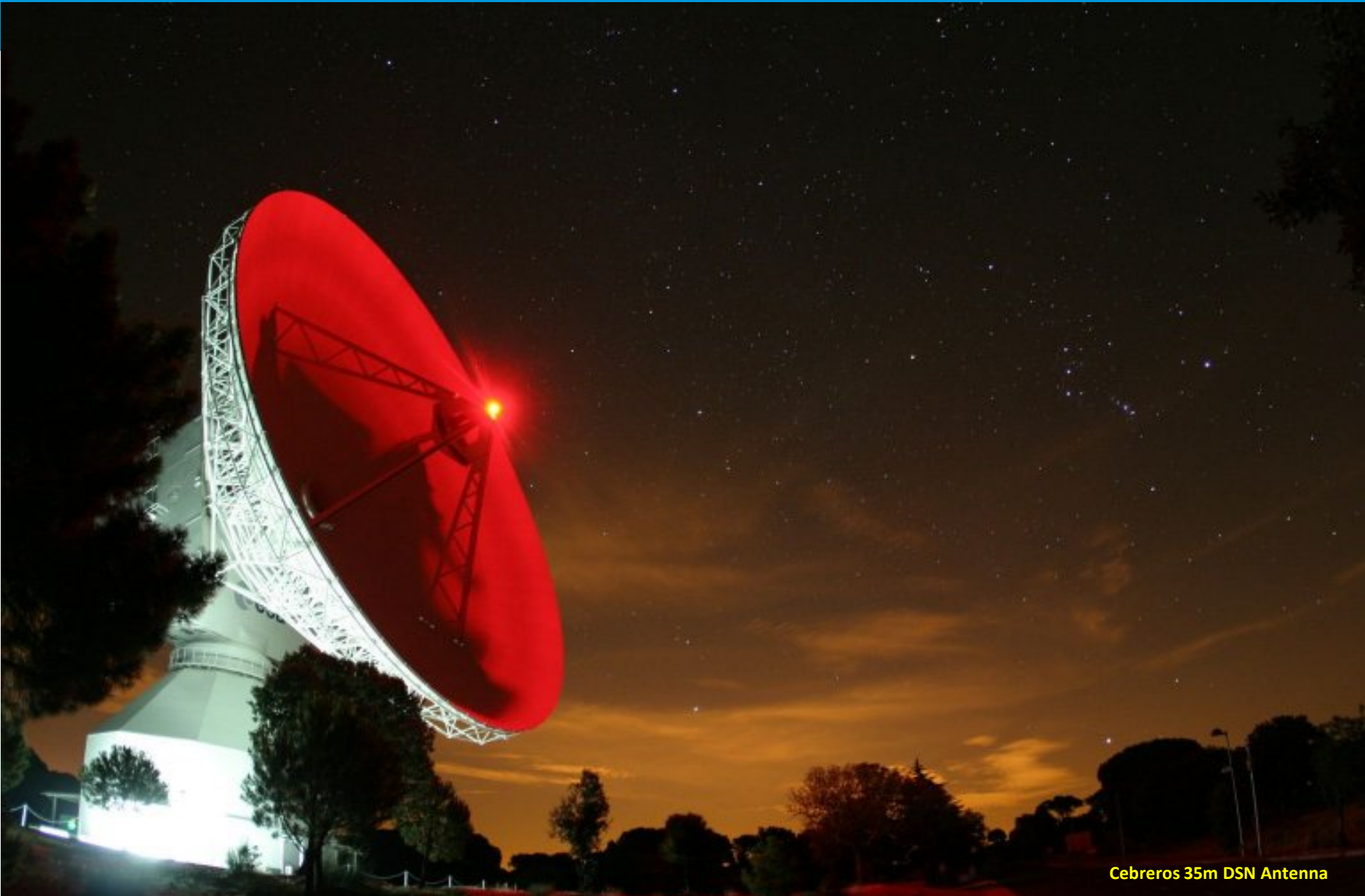
- Operates the S/C and manages the payload globally

  - ensures health and safety of S/C, its subsystems and payload

  - merges science timeline from SOC with S/C operational commands

  - commands are uplinked & stored onboard for offline execution

  - assigns Ground Stations & managing link budget

  - receives & makes available the T/M to Ground Segment via the SOC

Science Ground Segment responsibilities

Triggered star formation observed in HOBYS – P.I.: F. Motte

ESAC SOC (Herschel Science Centre – HSC) Responsibilities

HSC IS:

- the working interface between Mission & Scientific Community
    - anticipate community of ~5000 astronomers worldwide over life of mission
    - coordinates all the support functions across the Science Ground Segment

- acts as hub linking activities of itself, Instrument Centres & NHSC

- maximises scientific productivity of mission within the constraints

ESAC Role: Herschel Science Centre (HSC)

- Overall coordinaton of SGS activities

- Run Calls for Proposals
  - TAC support
  - proposal & observation management & maintenance

- Routine scheduling of Science observations

- Timeline calib. & eng. obs. from Instr. teams

- Level 1, 2, 3 DP products & QLA on all obs.

- Provide the Herschel Science Archive (HSA)

- Support the worldwide scientific community

  - public web portal and user documentation

  - HelpDesk/Workshops etc.

  - expert support to users

ESAC, Spain

Three PI Instrument Centres:
Instrument Control Centres (ICCs)

- PACS: Max Planck Institute, D.

- SPIRE: Rutherford Appleton Laboratory, UK.

- HIFI: SRON Institute for Space Research, NL.

- Deep expertise in the payload

  - responsible for successful ops. of instruments

  - develop, test and support observing modes

  - monitor & optimise instrument performance

  - instrument calibration and trend monitoring

  - investigation of anomalies; OBSW maintenance

  - Instrument contributions to DP S/W

  - production of instrument & S/W user manuals

  - ESA Liaison Scis. co-located 50% pre-launch

NASA Herschel Science Center (NHSC)
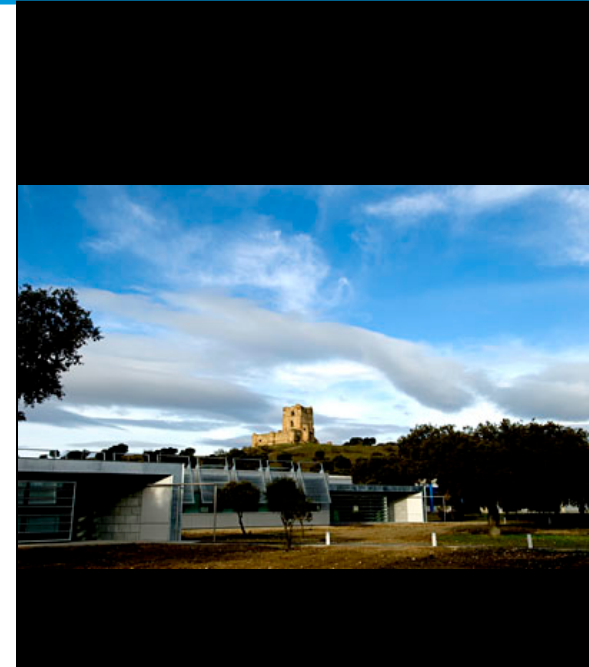
- Provides much the same support to the US community as HSC provides globally, but without the science scheduling aspects

- Collaborates with PI teams and HSC to provide support documentation, Data Processing S/W and calibration refinement

- One Liaison rep. at ESAC during Ops.
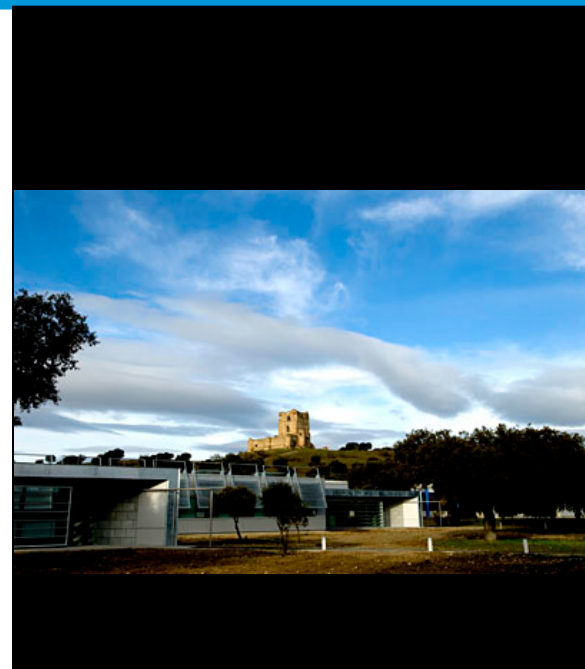
Interfaces with PI/Instrument teams, MOC, NHSC

Interfaces with PI/Instrument teams, MOC, NHSC

!!The various centres are one facility!!

!! The system doesn't know or care that it is distributed !!

!! We have shared responsibilities !!

!! We are in constant dialogue with our users !!

Science & Instrument Planning

Collecting the observation proposals

- 3 Calls in total
  - 1 pre-launch for key programmes (Guaranteed and Open Time)
    - 21 of each (coincidentally)
  - 2 post-launch about 1 year apart to
    - ~600 proposals received per Call, x3 oversubscription
  - Extensive effort to deconflict approved proposals
    - Especially for OT Call #1
  - Final completion percentages (OD#1446):
    - 100% of KPGT, KPOT, GT1, GT2, and OT2p1
    - 99.4% for OT1p1
    - 98.8%/42.5%/6.3% for OT1p2+OT2p2 top/middle/bottom third

Schedule Planning Considerations

- Efficient use of time (proposal ranking and completeness, visibility, slew length etc. – all much more critical near EOL)

- Interleaving of Calibrations (keep to budget, follow Inst.Team plan)

- Respect constraints (instr. Idiosyncrasies* and interactions*, thermal*, cooler recycles, straylight*, momentum dumps, passes, … * = learn as you go)

- Observation during communications pass (very restricted field)

- Contingency replanning (7-days on-call service)

Observing status ODs#963-1446

(1 January 2012 – 29 April 2013)

SEU

PACS H/W SPU-S Blue Channel (red OK)

1008	HIFI SEU
1029-1031	HIFI ICU SEU
1096/1097	PACS SPU-S Blue Channel anomaly (red OK)
1200	SPIRE memory corruption / SEU recovery in parallel
1223	SPIRE memory corruption / SEU recovery– PACS Obs. Lost
1232	HIFI LCU SEU
1371-1373	HIFI & SPIRE OBCP apparently independent switchoffs
1381-1383	PACS-S OBCP switchoffs
1419	Attempted recovery of PACS-P red array-9 from bias loss

Slew Time
Not used time
Failed // SPIRE part or other partial failure
Lost Time
Operations Windows
Observation Time

Operations Windows include orbit manoeuvres, reaction wheel biasing etc. and HIFI switch-on!
"Not used" time includes thermal stabilisation times and other operationally required inactive periods.
NOTE: Some slews include SPIRE data taking. This has not been included in the "green" time.

Total lost time from OD#170 to OD#1446 – all sources : ~804 hours (3.4%)
Total lost time from OD#963 to OD#1446 – all sources : ~257 hours (2.7%)

Community Support Services

(in addition to, or expanding on, services already mentioned)

Direct User Demand and Support

- **Helpdesk questions:**

  o total (as of 09 Sept.13) since helpdesk start (03 Feb.07) : 6553

  o avg. ~19 per week

 o 118 (1.8%) open, mainly tracking programmes with special support issues

- **Number of users**

  o 2645 registered users of the Herschel archive (25 new per month)

  o typically several hundred downloads per month

Direct User Demand and Support

- **Support documentation:**

  o Herschel www: http://herschel.esac.esa.int/

  o Instrument Manuals; Observers Manuals

  o Data Processing documentation

  o Technical notes

- **Regular User Support Workshops or**

- **Science Workshops/Conferences**
  - e.g. >350 participants registered for "The Universe Explored by Herschel", ESTEC, October 15-18 2013

Herschel Science Data Processing

Product Generation

&

Archiving

Herschel Computer Hardware

Herschel Common Science System (HCSS)
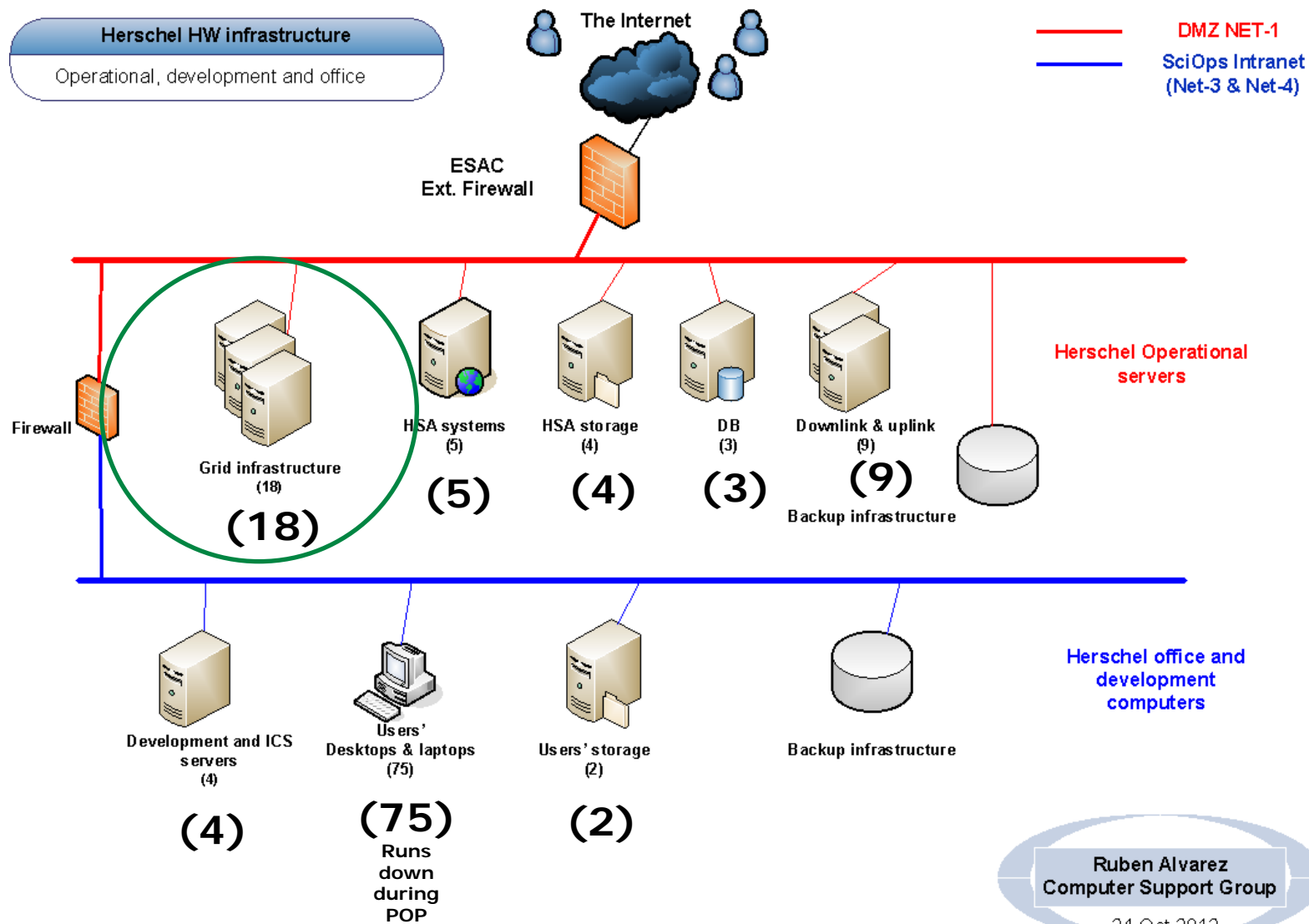
- Collaborative >10yr development by HSC, ICCs & NHSC

  a. Object Oriented

  b. Implemented in Java

  c. ~200 developers distributed in ~30 institutes worldwide

  d. Agile development; Continuous integration builds

- Java code

  a. of order 600 myr of effort invested

  b. ~4,300,000 lines of code

    - 100,000 Java methods
    - 13,000 Java classes
    - 800 Java packages
    - 260 deliverable modules
    - 12 build projects

Data Processing Software and Service:

- Collaborative development between HSC and ICCs

- Standard Product Generation pipeline special instance of I/A S/W

- SOC generated daily Level 1, 2 and higher level products

- Typically products from observation in HSA within 24 hours

- All products examined by human for quality

- Cyclical Bulk Reprocessings (BKRP) of all observations
  - Until now done every 6 months
  - In Post-operations going to 1 per year
  - Last week finished most recent: took 8 weeks

- Annual user training Workshop (1 at ESAC; 1 at NHSC)
  - ~20 participants typical, now with ~10 joining also online

HIPE (Interactive Analysis S/W) Downloads
by supported platform

Operating System	Number of HIPE downloads
	20 June 2010 - 06 Sept.2013
Linux32	800
Linux64	2470
MacOSX	2735
Windows32	730
Windows64	720
All	**7455**

Scope of Herschel as a Software Project

- Herschel Science Archive (HSA):
    - Relational Database technology (open source PostgreSQL) in Java
    - ~160000 lines of code
    - ~30 man-years implementation effort

- HSA > than 50000 obs. + nx10^6 products (different SPG versions)
    - more than half of these observations are science obs
    - The rest engineering or calibration

- Of order 100 TB disks (+2 // test & integrn. archives +15 TB

- HSA major releases:
    - HSA v1.0 (1st. Major release) on Nov. 2008 well before launch
    - HSAv5.0 released yesterday

Herschel Science Archive (metrics)

- In POPS address final requirements on HSA
  - linking observations to published papers
  - High-level sci. products produced by users (UPDP, HPDG)

- On-demand reprocessing in HSA
  - users can request processing of observation in Archive using the very latest software version and calibration files

Herschel Science Archive – SPG, UPDP & HPDP

In our current philosophy, the Products are the Legacy!

- **Standard Pipeline Generated (SPG) Products**

  - o incl. combining several obs. to produce big maps of the sky)

- **User Provided Data products (UPDP)**

  - o refined with IA (HIPE) or other users tools
  - o collected on www from the 42 Key Programmes (at least)
    - ➔ http://herschel.esac.esa.int/UserProvidedDataProducts.shtml
  - o during POPS will link observations in HSA to final UPDP repository

- **Highly Processed Data Products (HPDPs)**

  - o UPDPs validated by Herschel Instrument experts

Potential or actual Technology Reuse:

- Mission Planning Tools (esp. Long-term Planner)

- Calibration Uplink System (instrument commanding)

- Herschel Interactive Processing Environment (HIPE)

- we reused Spitzer proposal capture system → (H)SPOT

- In some cases archive implementations cross missions

- ...

Now in Post-Operations Phase

1. high quality community support for ongoing data exploitation

2. create, advertise, and deliver, the Herschel legacy for posterity

3. derive lessons learned & identify items for future re-use

4. enable personnel to perform their own data exploitation

5. Beyond end-POP – the Legacy Science Phase:

   o Herschel legacy archive maintained indefinitely by ESAC SAT

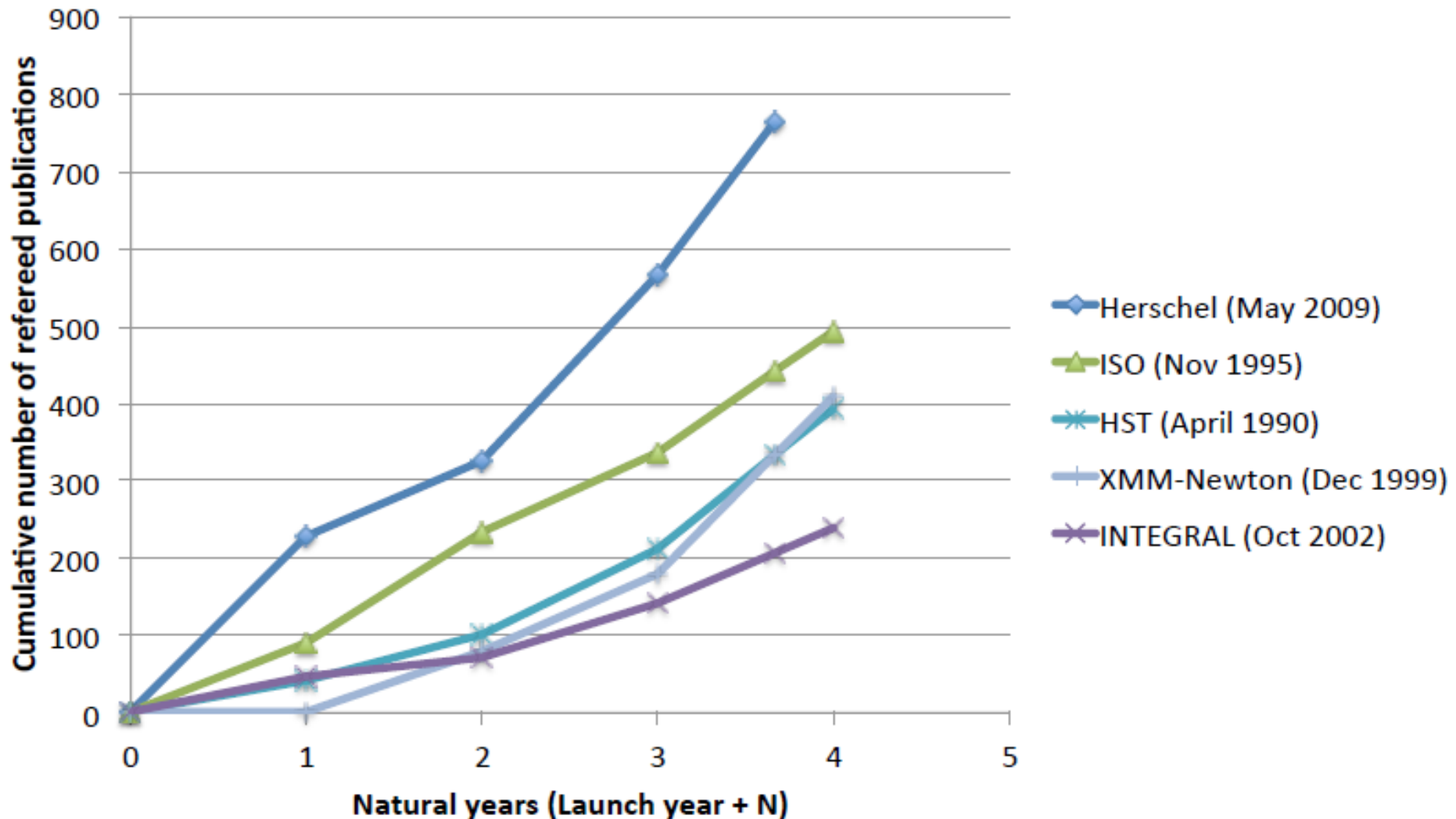   o no 'Herschel-specific' activities funded

END

BEYOND HERE RESERVE VGs ONLY

Science papers in early years after launch (updated 29 Aug. 2013)

Science papers in early years after launch (updated 29 Aug. 2013)