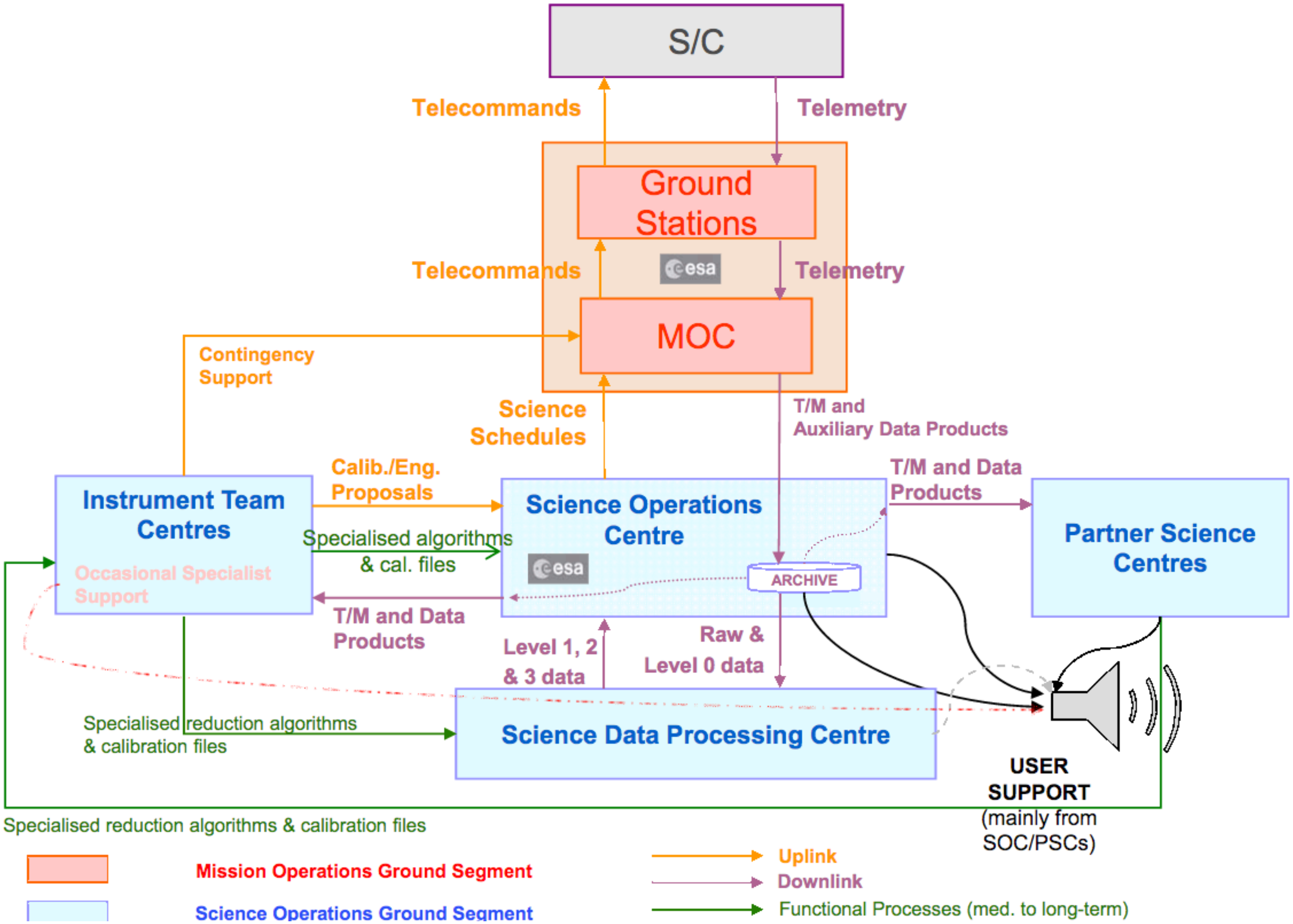
Distributed Science Operations: The Herschel Experience

Pedro García-Lario
Herschel Mission Manager

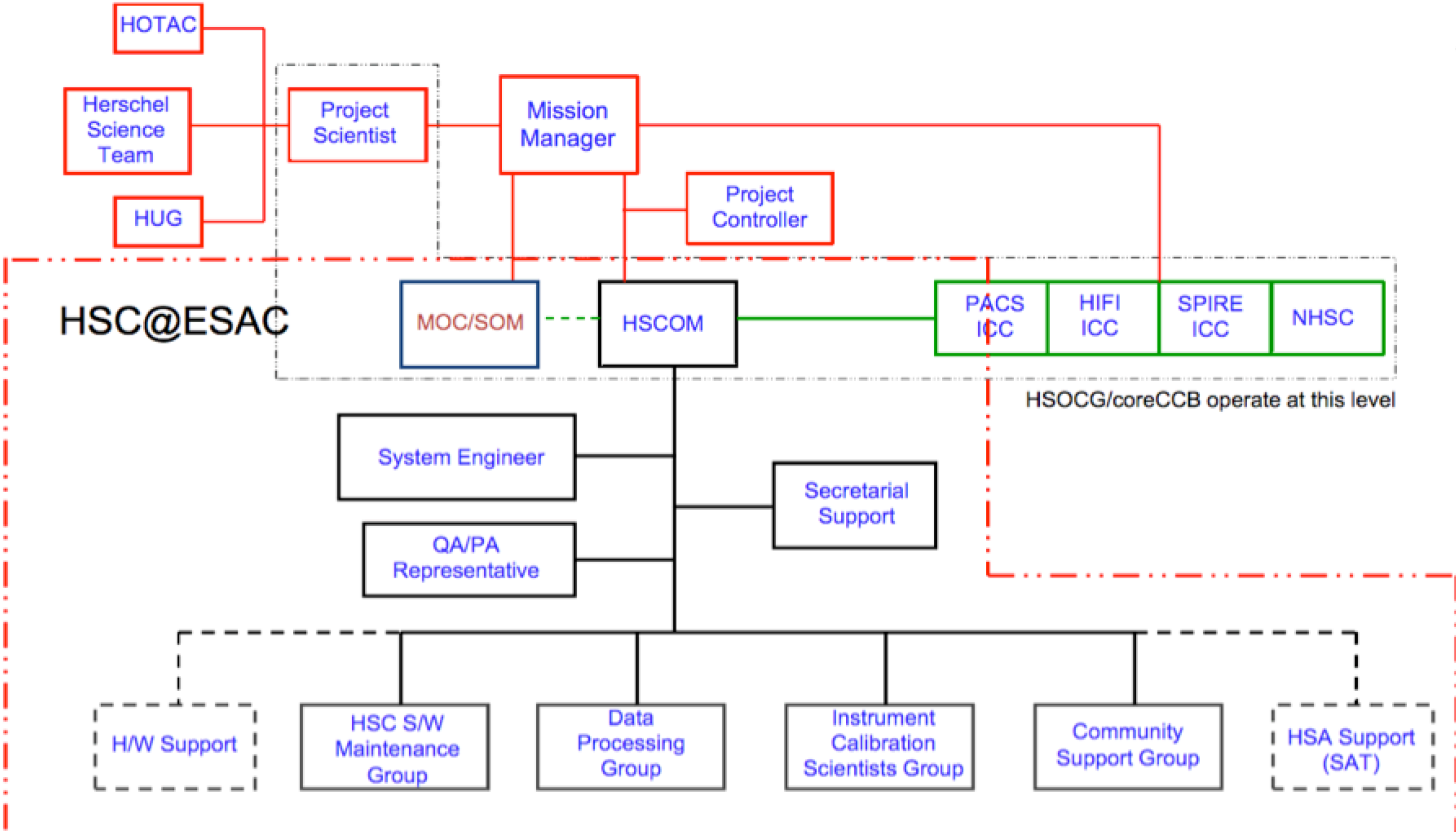
Science Operations 2017 – ESAC
17-20 October 2017

Generic Mission Organisation



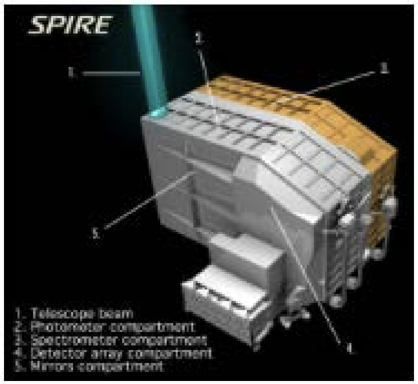
European Space Agency

Herschel Science Operations Organigram

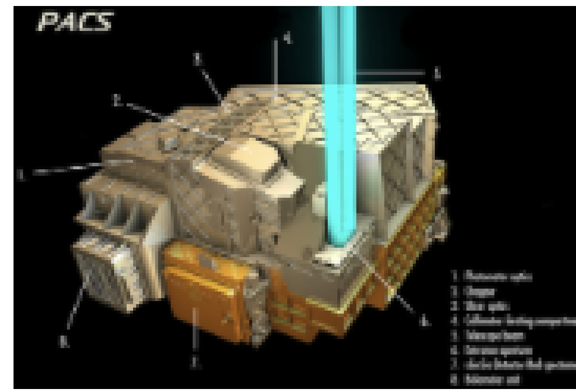


Instrument Control Centres

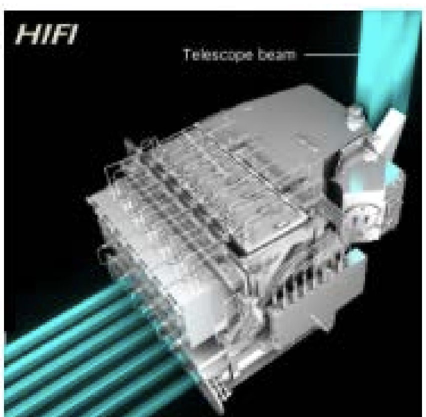
- Three instruments consortia: HIFI, PACS and SPIRE



Consortium Institutes: Univ. Lethbridge (Canada); NAOC (China); CEA, LAM (France); IFSI, Univ. Padua (Italy); IAC (Spain); Stockholm Observatory (Sweden); Cardiff University, Imperial College London, RAL, UCL-MSSL, UKATC, Univ. Sussex (UK); Caltech, JPL, NHSC, Univ. Colorado (USA).

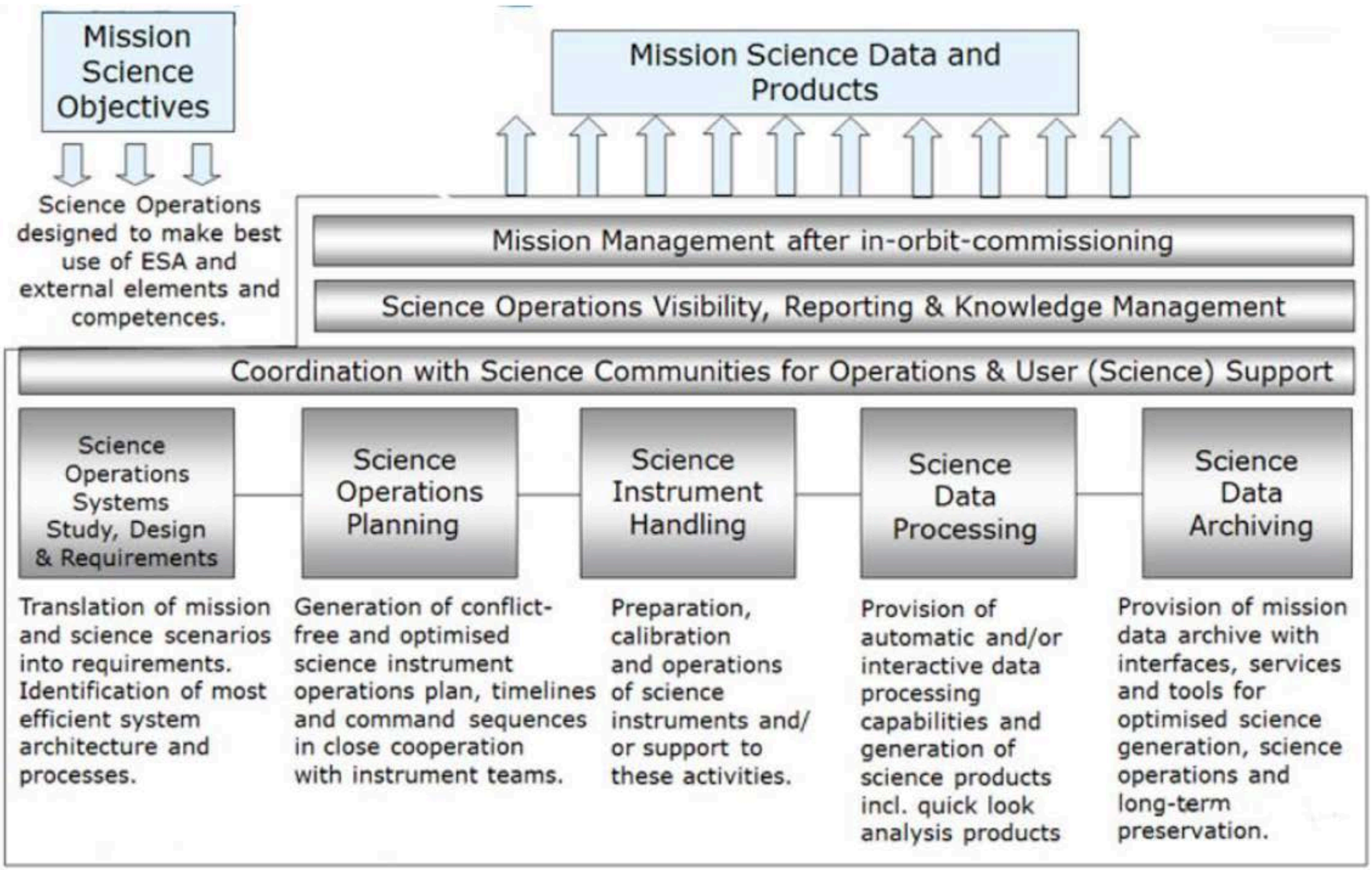


Consortium institutions: MPE (Germany); UVIE (Austria); KU Leuven, CSL, IMEC (Belgium); CEA, LAM (France); MPIA (Germany); INAFIFSI/OAA/OAP/OAT, LENS, SISSA (Italy); IAC (Spain).



Consortium institutions: CSA, U. Waterloo (Canada); CESR, LAB, LERMA, IRAM (France); KOSMA, MPIfR, MPS (Germany); NUI Maynooth (Ireland); ASI, IFSI-INAF, Osservatorio Astrofisico di Arcetri-INAF (Italy); SRON, TUD (The Netherlands); CAMK, CBK (Poland); Observatorio Astronómico Nacional (IGN), Centro de Astrobiología (CSIC-INTA) (Spain). Chalmers University of Technology – MC2, RSS & GARD, Onsala Space Observatory, Swedish National Space Board, Stockholm University – Stockholm Observatory (Sweden); ETH Zurich, FHNW (Switzerland); Caltech, JPL, NHSC (USA).

Science Operations for ESA Space Missions: Building Blocks



Ground Segment Organisation

- Co-location (‘a la ISO’) versus a novel concept of a **highly distributed ground segment: MOC, HSC (NHSC), and the three ICCs** all in different geographical locations
  - Distributed ground segment was a risk – eventually worked very well
  - Facilitated by development of new communication tools (internet, webex, videocons, twiki,..) during Herschel project lifetime
  - Important to get together in-person regularly (CSDT meetings) at least for a few days in every phase of the mission

- Large instrument consortia can be seen as undesirable in many ways: managerial discipline needed – importance of system engineering – artificial allocation of work packages among institutions may cause trouble

- The need for proper and early attention to the Ground Segment organisation was a lesson well-learned from ISO and XMM-Newton.

System Architecture

- **HCSS (Herschel Common Science System)**, a single system to cope with changes through all mission phases
- **‘Smooth transition’** concept: from ILT to post-operations was an excellent idea and a big success
- Good, sufficiently staffed and **centralised (at ESA) system engineering was vital**, particularly important in large collaborations is that authority needs to be recognised and accepted by everybody
- System Engineering costs a lot up-front but saves money later on, and it helps to create a real sense of order and discipline in a project
- **Pre-launch testing exercises** involving the whole Ground Segment were fundamental for running Herschel smoothly from the very early commissioning phase and performance verification phase through routine operations, including training for contingencies – running end-to-end simulations (interfaces are critical!) **involving the whole Science Ground Segment should be compulsory in all missions**

Software Development

- For Herschel there were **hundreds of developers distributed all around the world** – non-stop effort - 24 hours a day for years
- **Agile development**: iterative and incremental / good choice for a complex project with evolving requirements and large number of individual contributions
- **Java** – another good choice – remain valid for many years (still is)
- **Object oriented database: not so good** as seen a posteriori (Versant database was expensive - difficult for long-term preservation – had to be removed in the end involving significant effort)
- Module owners (instrument specific versus core / common data analysis tools); shared by HSC / NHSC / ICCs – **clear responsibilities** should be defined
- **Continuous Integration** Builds / several branches: development, integration, operational work very well
- **Nightly tester** for quick identification of problems
- **Strict configuration control** was essential
- **Open source** versus licensed software – right direction

Data Processing

- **Pipeline processing was centralized at HSC** in the case of Herschel (although instrument pipelines were provided by the instrument consortia)
- Absolute guarantee that there is a control on the population of the archive / bulk reprocessing exercises / timely delivery of products to the community
- **Validation / acceptance testing was, however, a distributed task** across the whole Ground Segment
- Originally (1997) the intention was that observers were to be provided with the 'raw' data (level 0) plus 'software tools' to reduce their observations themselves
- **Data processing plans were radically changed** in 2005; not only level 0 to be provided to the community but also level 1 and level 2 – this 'late' change in the SMP **brought quite a number of issues** with it (see next viewgraph), especially on the archive development area

Data Archive

- **Centralised at HSC** – important!
- **Novelty: integral part of the data processing system – final repository of pipeline data products**
- Data products available for retrieval by proposal PIs (and co-users) immediately after pipeline data processing
- But **initial assumptions were incorrect**, as it was conceived to contain originally only level 0 data products – SAT infrastructure not ready to cope with object oriented database concept and requirements
- **Late addition** of level 1, 2 (and more recently, level 2.5 and 3) was an **important source of conflicts / inadequate data model / poor performance** / only solved close to the end of the operational phase

Mission Planning

- SW shared with ICCs – some training needed pre-launch
    - **HSC providing science inputs**
    - **ICCs providing calibration inputs**
- Strict control of deliveries from ICCs to HSC
- HSC single interface with MOC
- **Regular coordination / planning meetings** involving ICCs/HSC/MOC especially useful in early operations and to discuss special operations

Configuration Control

- **Fundamental** in a distributed organization with contributions coming from such a large number of individuals
- **Core CCB fed by a complex system of subsidiary / lower level CCBs** (per instrument / per task)
- Approval of new versions of the software required pre-approval by all other subsidiary CCBs
- **Each CCB had members coming from all stakeholders, including PA/QA** for securing best practices
- System CCB – taking care of the acceptance/validation of every new operational version of the DP software

Instrument Calibration

- ICCs were responsible throughout the mission for safety, operation and the data reduction software for their respective instruments
- Long co-location periods of ESA's instrument calibration scientists with ICCs pre-launch
- **Early involvement of ESA scientists working with the ICCs** provided the necessary flow of information for development of operations / it also allowed running QC on data products by the HSC with support from ICCs if needed / technical assessment of received proposals / operate helpdesk for questions addressing instrument-specific issues
- Need to have scientists recruited at an early stage of the mission that understand the science and the operational payloads, particularly in observatory missions.

Community Support

- **HSC : main interface with the community**
  - Web pages (NHSC web site for US users)
  - Latest News
  - Documentation
  - Call for proposals
  - Mission Planning
  - Proposal Handling
- HSC was the gateway to the Data Archive / Data Reduction Software *
- HSC Newsletters *
- **HSC Helpdesk ***
  - Operated by HSC with the support of instrument teams when necessary

(* provided as well by NHSC)

The role of NHSC

- NASA-provided *NHSC* came later but the cooperation with *NASA* was also good for both sides.
  - For *NASA*: big return for a small investment (visibility in US)
  - For ESA: strong help e.g. for round-the-clock support provision close to AO-1 proposal submission deadline - cope with contingencies experienced on that date
- *Herschel* experience with *NHSC* suggests that a similar structure intended to provide support to the European community could be equally successful for NASA-led collaborative missions

Conclusions and lessons learned

Experience gained from Herschel could be very useful for future space and ground-based facilities in all areas of science operations

- ORGANISATION: science operations can work very well in a distributed ground segment environment even for a complex mission like Herschel!
- SYSTEM ARCHITECTURE: Must be defined early-on; agreed/accepted by all parties
- SOFTWARE DEVELOPMENT: Flexible to cope with changes - but under strict configuration control
- DATA PROCESSING: Better operated by a central SOC – SW can be contributed effort provided by instrument teams
- DATA ARCHIVE: Role must be clearly defined from the very beginning - important to define the right data model an ensure smooth system integration
- COMMUNITY SUPPORT: Some aspects (like Helpdesk) can be shared effort, but centralised contact point for the community is desirable; distributed community support may be useful if oriented to different communities