Herschel Science/Instrument Planning and Scheduling

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**Herschel Space Observatory**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Far infrared &amp; sub-mm</td>
<td>57-672 μm</td>
</tr>
<tr>
<td>Telescope diameter</td>
<td>3.5 m</td>
</tr>
<tr>
<td>Instruments</td>
<td>HIFI, PACS, SPIRE</td>
</tr>
<tr>
<td>Launch date</td>
<td>14-05-2009</td>
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<tr>
<td>End of liquid helium</td>
<td>29-04-2013</td>
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<tr>
<td>Orbit</td>
<td>L2 lissajous</td>
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<tr>
<td>Downlink</td>
<td>1.5 Mb/s</td>
</tr>
<tr>
<td>Max. slew rate</td>
<td>7° /min</td>
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</table>
Herschel Space Observatory

Complex commanding
- About 30 science observations/day
- Up to 22000 instr. commands/day (mean 5000)
- Up to 3800 ACMS commands/day (mean 600)
- Complex pointing modes

Operational day
- ~ 24 hours between ground-station passes
- 3 hour communications period (DTCP)
- Autonomous operation
Smooth Transition Concept

Objectives

• Use the same software for all mission phases
• Test the software and instruments together

Benefits

• Early testing of operational software with the real instruments
• Early testing of instruments with the real software
• Robust well-tested system at launch
• Less special instrument test software had to be developed
• Avoided need to build instrument simulators
Smooth Transition

CUS
→ EGSE-ILT → Instrument
→ EGSE-IST → CCS
→ MOC → G/Stn

MPS

Devel ILT
2002-2007

RMS SOVT
2007-2008

PV Ops
2009-2013

Mission phases
Uplink Chain

Proposer -> HILTS

Mission Planner -> CUS

CUS -> MPS

MPS -> MOC

MIB -> Pointing
Common Uplink System (CUS)

A key component of Herschel instrument commanding

The CUS consists of:

- A special language for instrument commanding
- An engine for generating telecommands
- An IDE for developing and testing CUS scripts

Used for:

- Definition of standard observing modes
- Definition of one-off engineering observations
- Definition of test observations during ILT / IST
- The CUS is a key part of the Herschel smooth transition concept
CUS Features

Manages command timing

- Microscheduling of commands within an observation
- Interleaves and synchronizes spacecraft pointing commands
- Models spacecraft bus scheduling

Command generation

- Conversion of command parameters from engineering to raw values
- Pluggable command formatters for ILT, IST, operations, testing
- Building block identifiers link downlink with uplink

Execution modes

- Generate sequence of telecommands
- Calculate duration, noise level, data rate, type, print, #TCs
Pointing Modes

e.g. Nodding raster

- Chop-nod at each raster point
- Calibration hold at fixed pointing after every M points
- Load-slew on every N'th slew
- OFF position, SSO tracking, etc
- Accurately synchronize instrument commanding with spacecraft pointing
Scientific Mission Planning

Herschel Inspector & Long-Term Scheduler (HILTS)

- Plan 14-day cycles
- Identify critical observations

Scientific Mission Planning System (SMPS)

- Schedule each operational day (science, calibration & engineering)
- Generate telecommand sequences (Instrument & ACMS)
- Used for commissioning, PV, operations & post-He tests (smooth transition)
  - Minimal use of manual commanding

Common framework

- Reusable Java libraries
Planning cycles (14 days)

- Days allocated to specific instruments
  - Cooler recycling takes 3 hours, 48-hour hold time
- One instrument at a time: SPIRE+PACS as a “Parallel” instrument
- PACS PHOT & SPEC, SPIRE PHOT & SPEC, Parallel, 14 HIFI bands

Factors

- HIFI band switching takes 10-60 minutes to stabilize
  - Trade-off against slew-time
- Some SSOs required special OD assignments
### Scientific Mission Planning System (SMPS)

#### Table

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<thead>
<tr>
<th>Id</th>
<th>Title</th>
<th>Inst.</th>
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<th>Duration</th>
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#### Diagram

[Image of the Herschel SMPS interface]
Interactive scheduler

- Emphasises good visualisation (linked spatial, temporal & list views)
- Simulated Annealing optimizer (but manual in practice)
- Enforces standard constraints during scheduling
- Validation integrated into scheduler
Scientific Mission Planning System

Basic constraints

- Attitude: Sun, Earth, Moon, bright planets
  - boresight, solar panel, star tracker, antenna
  - orientation (roll) -> time windows
- Temporal: visibility, fixed-time, concatenations, etc

Special constraints

- Instrument interactions: HIFI not for 12 hours after SPIRE
- Thermal effects at high Solar Aspect Angles
- Special concatenations, follow-on
- Override bright-planet constraint
- Stray light
Scientific Mission Planning System

Flexibility

• Spacecraft operations are complex
• Must be able to cope with non-nominal situations
  – instrument anomalies (e.g. SEUs)
  – spacecraft anomalies (e.g. star-tracking problem early in mission)
  – late TOOs
  – etc (ground-station test, leap-second, ...)
  – Observations with special constraints (e.g. SSOs)
• Software evolution in response to new requirements (e.g. stray light)
Solar System Objects

- Changing ephemerides required late replans (e.g. comets 45P & 103P)
- Special OD assignments in planning cycle
- Sometimes exceeded maximum tracking rate (10" / min)
- Observation time chosen for low background
Summary

One system for all mission phases

- CUS for instrument development, test & operations
- MPS for SOVT, commissioning, PV, operations & post-He tests

One system for all instruments

- CUS is a Common Uplink System

Flexibility to cope with non-nominal situations

- CUS allows one-off observing modes for on-ground or in-flight tests
- Special mission planning constraints
- Recovery from problems (e.g. SEUs)