Herschel Science / Instrument Planning and Scheduling

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Herschel Space Observatory

Far infrared & sub-mm	57-672 μm
Telescope diameter	3.5 m
Instruments	HIFI, PACS, SPIRE
Launch date	14-05-2009
End of liquid helium	29-04-2013
Orbit	L2 lissajous
Downlink	1.5 Mb/s
Max. slew rate	7° /min

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

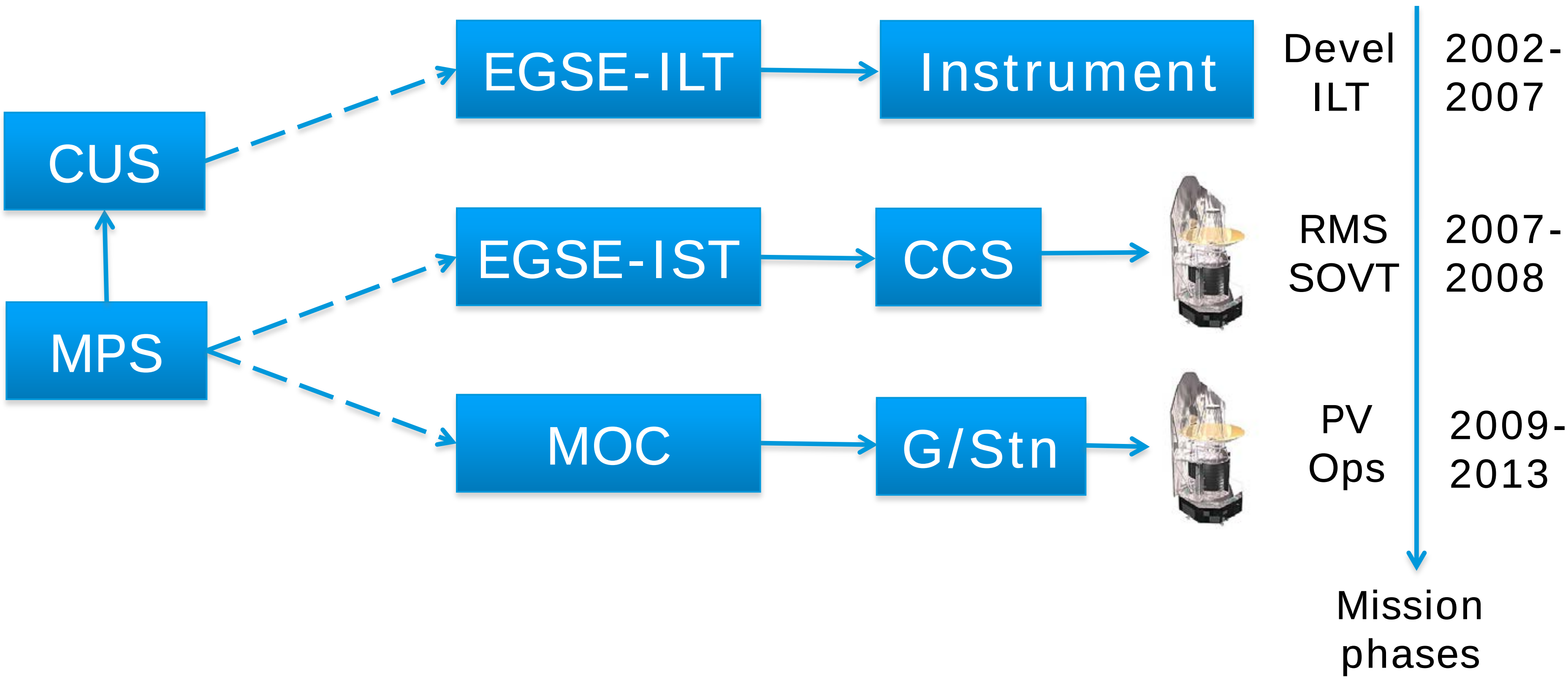
Objectives

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

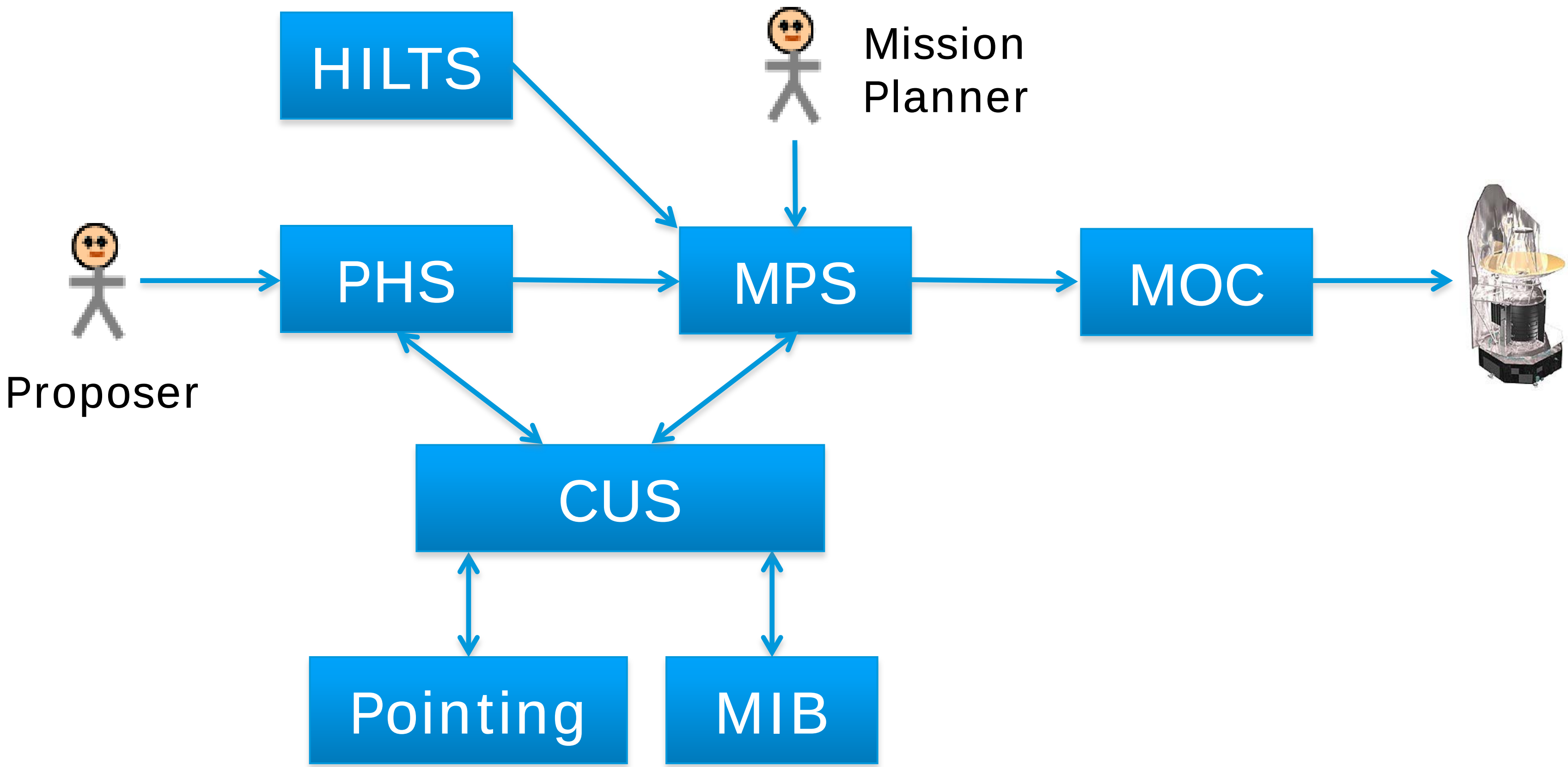
Benefits

- 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



Uplink Chain



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

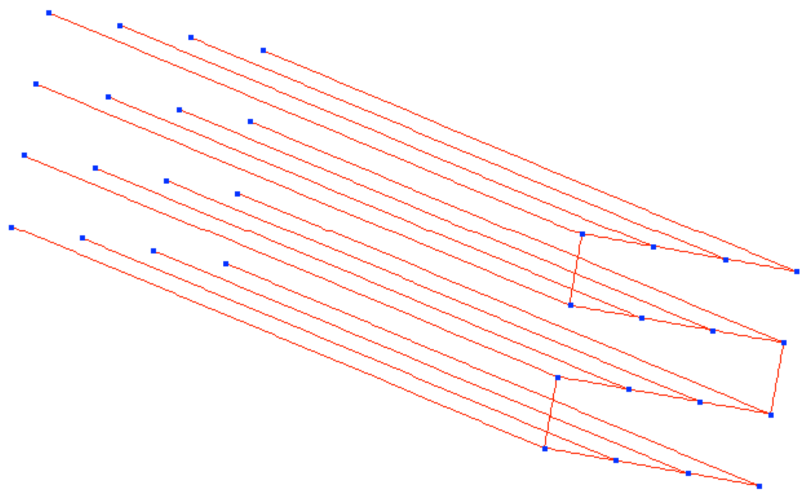
Execution modes

- 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 & engineeering)
- 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

Scientific Mission Planning

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

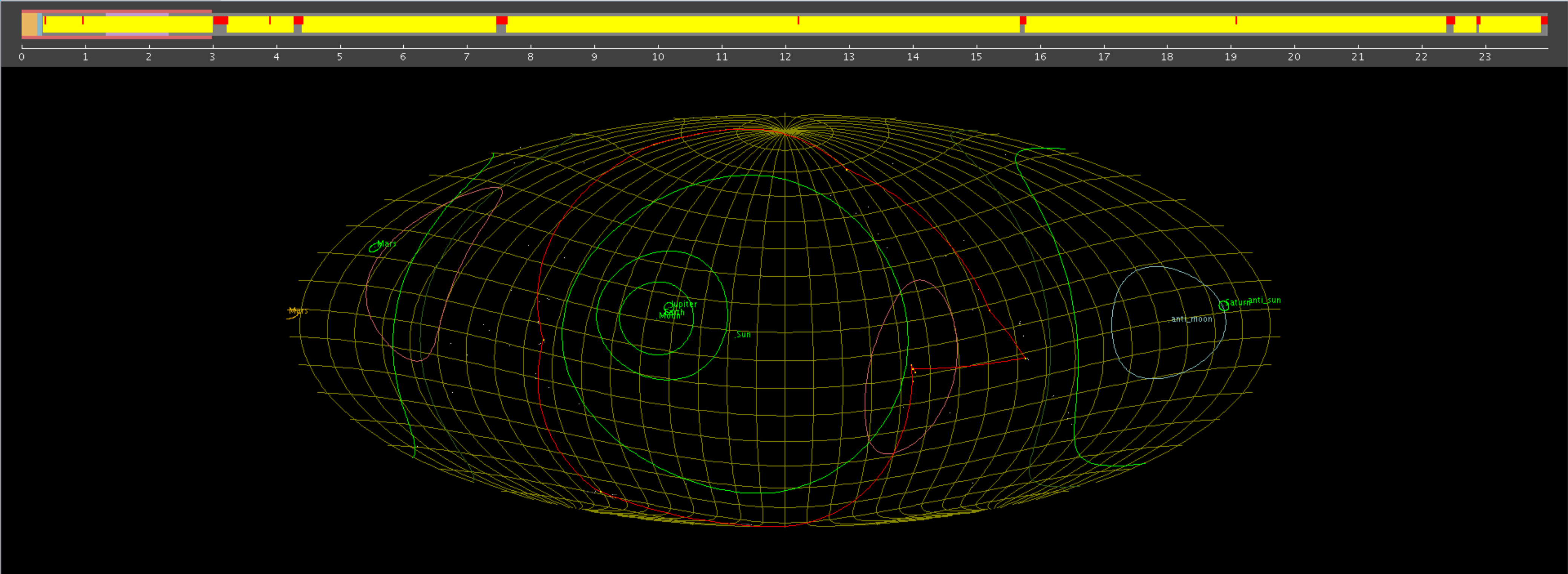
Factors

- 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)

Herschel SMPS

File Schedule View Help



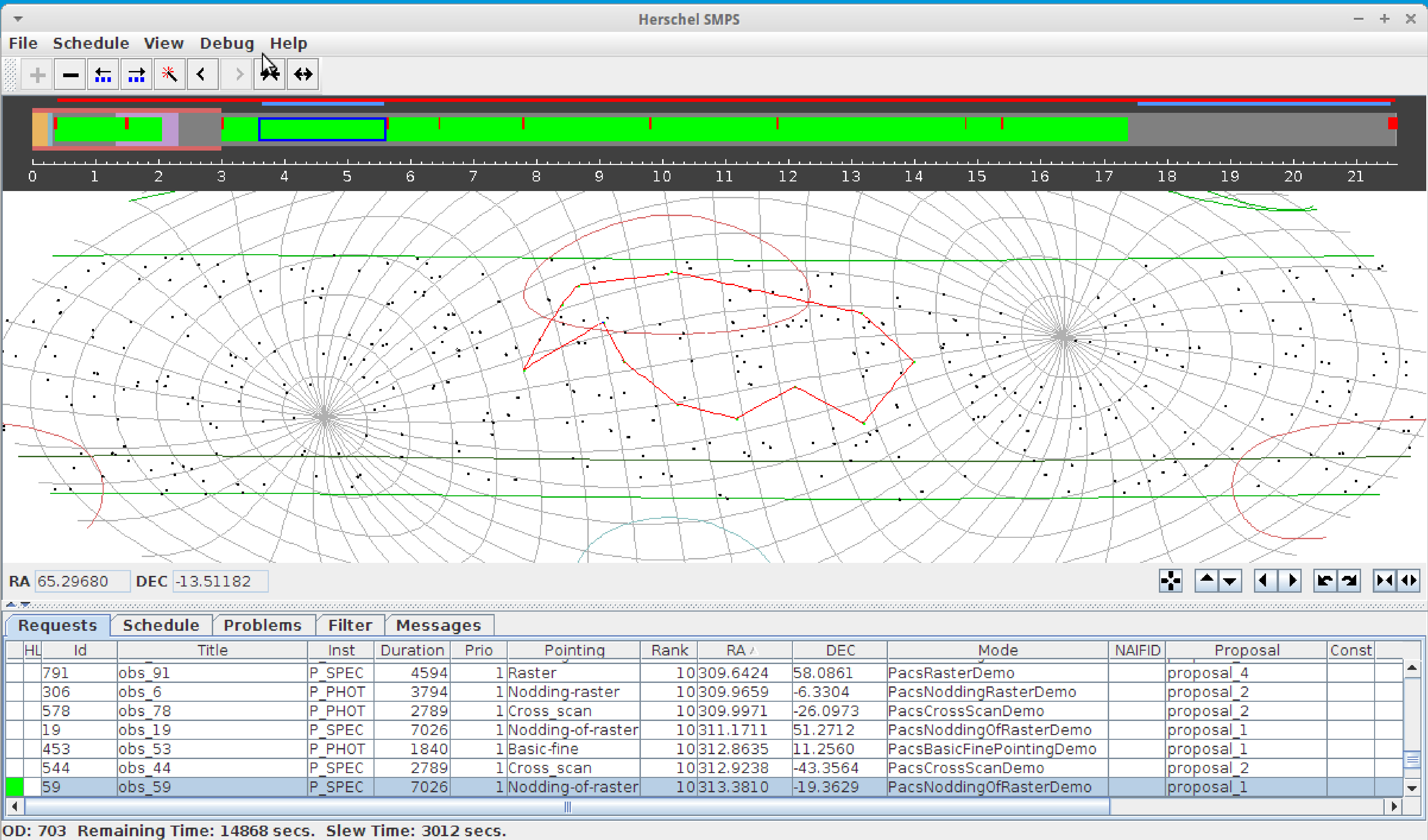
RA 47.42607 DEC 62.46380

Requests | Schedule | Problems | Filter | Messages

Id	Title	Inst	Slew	Start	Duration	Stop	NAIFID	RA	DEC	MC
2247668	SpireEngCheckPMGen-0232	S_ENG	0	2012-04-07T21:26:13Z	45	2012-04-07T21:26:58Z				MC_H98ASTR_P69ASTR_S66ASTR_RP
2718035	HifiEngOBS_SEU_check_DTCP – 0400	H_ENG	0	2012-04-07T21:27:02Z	26	2012-04-07T21:27:28Z				MC_H100ASTR_P69ASTR_S66ASTR_RP
2458481	637_584_52174 – PSpec [CII]	P_SPEC	123	2012-04-07T21:29:35Z	1988	2012-04-07T22:02:43Z		316.2861	-5.3998	MC_H98ASTR_P69ASTR_S66ASTR_RP
2115278	PSpecR-0000	P_SPEC	138	2012-04-07T22:05:05Z	7205	2012-04-08T00:05:10Z		316.0451	-11.3634	MC_H100ASTR_P69ASTR_S66ASTR_RP
1166558	DissIToDissII_6a – 003	H_ENG	0	2012-04-08T00:05:14Z	29	2012-04-08T00:05:43Z				MC_H100ASTR_P69ASTR_S66ASTR_RP
2443399	s052212_p1	P_SPEC	878	2012-04-08T00:21:55Z	2244	2012-04-08T00:59:19Z		80.5525	-67.9757	MC_H100ASTR_P69ASTR_S66ASTR_RP
2443401	s052212_p2	P_SPEC	126	2012-04-08T01:01:29Z	1254	2012-04-08T01:22:23Z		80.5525	-67.9757	MC_H100ASTR_P69ASTR_S66ASTR_RP
1956246 1956247 1956249	PSpecR-KHK-PAH-Range2-OriA-145-p1 PSpecR-KHK-PAH-Range2-OriA-145-OFFPOS 1-p1 PSpecR-KHK-PAH-Range2-OriA-145-p2	P_SPEC	606	2012-04-08T01:32:33Z	10813	2012-04-08T04:32:46Z		83.8472 83.0781 83.8472	-5.4695 -6.4076 -5.4695	MC_H100ASTR_P69ASTR_S66ASTR_RP
2193169	07598 – A	P_SPEC	728	2012-04-08T04:44:58Z	16361	2012-04-08T09:17:39Z		121.1378	64.9968	MC_H98ASTR_P69ASTR_S66ASTR_RP
2193170	07598 – B	P_SPEC	124	2012-04-08T09:19:47Z	12419	2012-04-08T12:46:46Z		121.1378	64.9968	MC_H98ASTR_P69ASTR_S66ASTR_RP
1756543	PACS – L 1157 C	P_SPEC	478	2012-04-08T12:54:48Z	11753	2012-04-08T16:10:41Z		309.7758	68.0394	MC_H100ASTR_P69ASTR_S66ASTR_RP
1756548	PACS – L 1157 N	P_SPEC	123	2012-04-08T16:12:48Z	11753	2012-04-08T19:28:41Z		309.7388	68.0690	MC_H100ASTR_P69ASTR_S66ASTR_RP
2449468	R_Aql_B2A	P_SPEC	603	2012-04-08T19:38:48Z	1130	2012-04-08T19:57:38Z		286.5927	8.2300	MC_H98ASTR_P69ASTR_S66ASTR_RP
1765934	PacsSedB2A – MGE_3834	P_SPEC	268	2012-04-08T20:02:10Z	3347	2012-04-08T20:57:57Z		277.1390	-11.7788	MC_H98ASTR_P69ASTR_S66ASTR_RP
Slew			403	2012-04-08T21:04:42Z	0	2012-04-08T21:04:42Z		315.9993	-7.1258	

OD: 1060 Remaining Time: 64 secs. Slew Time: 4598 secs.

Scientific Mission Planning System



Scientific Mission Planning System

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

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)

Scientific Mission Planning System

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)