Herschel mission: status and observing opportunities

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ABSTRACT

Herschel is the fourth cornerstone mission in the European Space Agency (ESA) science programme. It will perform imaging photometry and spectroscopy in the far infrared and submillimetre part of the spectrum, covering approximately the 57-670 μm range and thus bridging the 'traditional' space infrared range with the groundbased capabilities.

The key science objectives emphasize current questions connected to the formation and evolution of galaxies and stars and stellar systems, however, having unique capabilities in several ways, *Herschel* will be a facility available to the entire astronomical community.

Herschel will be equipped with a passively cooled 3.5 metre diameter classical Cassegrain telescope. The science payload complement - two cameras/medium resolution spectrometers (PACS and SPIRE) and a very high resolution heterodyne spectrometer (HIFI) - will be housed in a superfluid helium cryostat. The ground segment will be jointly developed by the ESA, the three instrument consortia, and NASA/IPAC.

Herschel is scheduled to be launched into a transfer trajectory towards its operational orbit around the Earth-Sun L2 point by an Ariane 5 ECA (shared with the ESA cosmic background mapping mission *Planck*) in 2008. Once operational about half a year after launch *Herschel* will offer 3 years of routine observations; roughly 2/3 of the available observing time is open to the general astronomical community through a standard competitive proposal procedure.

Keywords: Space vehicles: instrumentation, cryostat; Stars: early-type, formation, late-type, pre-main sequence, winds, outflows; ISM: jets and outflows, molecules; Galaxies: evolution, formation, ISM; Infrared: galaxies, stars; Submillimetre

1. INTRODUCTION

The *Herschel Space Observatory* (or simply *Herschel*) is an astronomy observatory mission that targets approximately the 57-670 μm wavelength range in the far infrared and submillimetre part of the electromagnetic spectrum, providing observation opportunities for the entire scientific community. *Herschel* (Fig. 1) was the fourth of the 'cornerstone' ('flagship') missions in the ESA science 'Horizon 2000' plan, and is now being implemented as the next astronomy observatory mission prior to the 'Cosmic Vision' - the new ESA Horizons Programme[1].

Herschel is the only space facility dedicated to this part of the submillimetre and far infrared range. Its vantage point in space provides several decisive advantages. The telescope will be passively cooled, enabling a significantly larger aperture than for previous infrared missions. A stable thermal environment and low telescope emissivity together with the total absence of atmospheric emission offers a stable background enabling very sensitive photometric observations. Furthermore, the absence of even residual atmospheric absorption gives full access to the entire range of this elusive part of the spectrum, which offers the capability to perform completely uninterrupted spectral surveys.

2. SCIENCE OBJECTIVES - THE 'COOL UNIVERSE'

Herschel is designed to observe the 'cool universe'; it has the potential of discovering the earliest epoch proto-galaxies, revealing the cosmologically evolving AGN-starburst symbiosis, and unravelling the mechanisms involved in the formation of stars and planetary system bodies.

The continuum emission from bodies with temperatures between 5 and 50 K peak in the *Herschel* wavelength range, and gases with temperatures between 10 and a few hundred K emit their brightest molecular and atomic emission lines here. Broadband thermal radiation from small dust grains - typically re-radiating absorbed shorter wavelength radiation - is the most common continuum emission process in this band; this is the situation e.g. at 'stellar' level in starforming molecular clouds, and at 'galactic' levels for active (star forming or AGN 'powered') galaxies.

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Several major symposia have been held to discuss the scientific objectives and the resulting requirements on the observatory, its instrumentation and observing programmes, see for instance[2,3]. The key science objectives emphasize specifically the formation and evolution of stars and stellar systems, of and galaxies, and the interrelation between the two.

Examples of potential observing programmes with Herschel include:

- Galactic and extragalactic broadband photometric surveys in the 100-600 μm *Herschel* 'prime' wavelength band and related research. The main goals will be detailed investigations of the formation and evolution of galaxy bulges and elliptical galaxies in the first third of the present age of the Universe and star formation in the Galaxy.
- Follow-up spectroscopy of especially interesting objects discovered in the surveys. The far infrared/submillimetre band contains the brightest cooling lines of interstellar gas, which give very important information on the physical processes and energy production mechanisms (e.g. AGN vs. star formation) in galaxies.
- Detailed studies of the physics and chemistry of the interstellar medium, both locally in our own Galaxy as well as in external galaxies, by means of photometric and spectroscopic surveys and detailed observations. This includes implicitly the important question of how stars form out of molecular clouds in various environments
- Observational astrochemistry (of gas and dust) as a quantitative tool for understanding the stellar/interstellar lifecycle and investigating the physical and chemical processes involved in star formation and early stellar evolution in our own Galaxy. *Herschel* will provide unique information on most phases of this lifecycle.

Figure 1. The *Herschel* spacecraft in the ESTEC Test Centre on 1 Feb 2006. Although in structural/thermal test configuration, it contains significant flight hardware, notably the flight cryostat and parts of the service module and sunshade.

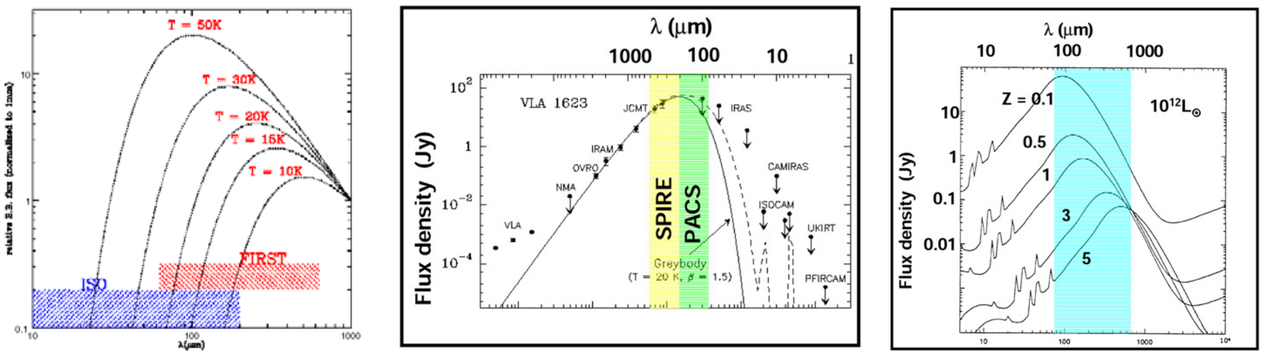

Figure 2. From left to right: *Herschel* will observe cool black (grey) bodies and line radiation from colish gases. The *Herschel* spectral coverage is perfectly adapted to observing the spectral energy densities (SEDs) of young protostars and those of 'typical' infrared dominated star forming galaxies at redshifts from the local universe out to about z~5.

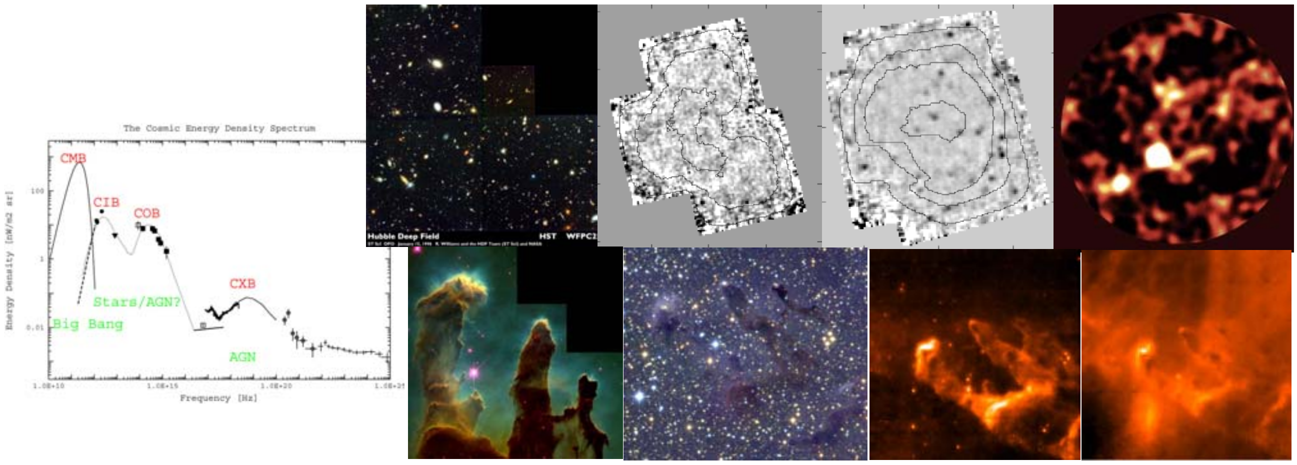

Figure 3. The infrared background energy density is approximately equal to the optical, however, the infrared sky is much less well observed than the optical. In particular observations in the far infrared and short submillimetre part of the spectrum are only now coming of age. Top row: The Hubble Deep Field (HDF) in optical[4], ISO LW2 7 µm[5] and LW3 15 µm[5], SCUBA 850 µm[6]. Lower row: The M16 'Eagle nebula' in optical[7], JHK[8], ISO LW2 7 µm[9] and LW3 15 µm[9]. *Herschel* will bridge the current lack of observational data between the optical/NIR and submillimetre, helping cross-identification of sources and elaborating on the physics of these sources.

- Detailed high resolution spectroscopy of a number of comets and the atmospheres of the cool outer planets and their satellites.

In order to provide concrete examples and to aid potential open time proposers some information is provided about the current planning of guaranteed time observing programmes on the internet at http://www.rssd.esa.int/Herschel/.

Herschel will complement other available facilities by offering space observatory capabilities in the far infrared and submillimetre for the first time, extending the wavelength coverage longwards from that of *IRAS*, *ISO*, *Spitzer*, and *Akari,* and shortwards of *SWAS* and *Odin*. A major strength of *Herschel* is its photometric mapping capability for performing unbiased surveys related to galaxy and star formation. Redshifted ultraluminous *IRAS* galaxies (with spectral energy distributions (SEDs) that 'peak' in the 50-100 µm range in their rest frames) as well as class 0 proto-star and pre-stellar object SEDs peak in the *Herschel* 'prime' band (Fig. 2). *Herschel* will extend current optical/NIR observations into the FIR/submm, bridging the gap (Fig. 3) helping not only cross-correlating observations of currently known sources, but will yield large numbers of 'new' sources in both galactic and extra-galactic surveys. *Herschel* is also well equipped to perform spectroscopic follow-up observations to further characterise particularly interesting individual objects.

From past experience, it is also clear that the 'discovery potential' is significant when a new capability is being implemented for the first time. Observations have never been performed in space in the 'prime band' of *Herschel*. The total absence of any detrimental atmospheric effects - enabling low background for photometry and full wavelength coverage for spectroscopy - and a cool low emissivity large telescope open up a new part of the phase-space of observations. Thus, a space facility is essential in this wavelength range and *Herschel* will be breaking new ground!

3. SPACECRAFT

The *Herschel* spacecraft (Fig. 4, see also[10]) has a modular design, consisting of the 'extended payload module' (EPLM) and the 'service module' (SVM). The EPLM consists of the PLM 'proper' with a superfluid helium cryostat - based on the proven successful *ISO* technology - housing the *Herschel* optical bench (HOB) with the instrument focal plane units (FPUs), and supporting the telescope, the sunshield/shade, and payload associated equipment. The SVM houses 'warm' payload electronics, and provides the necessary 'infrastructure' for the satellite such as power, attitude and orbit control, the onboard data handling and command execution, communications, and safety.

Although *Herschel* relies on the successful *ISO* cryostat technology (Fig. 5), a major difference compared to *ISO* is that since *Herschel* will be operating from an orbit around L2 (Sect. 6) both the Sun and the Earth will be in the same general direction making it possible to design the spacecraft to have a 'warm' and a 'cold' side, which has enabled optimisation of the thermal design. The 'cryostat vacuum vessel' (CVV) has been equipped with radiators on the 'cold' side signifi-

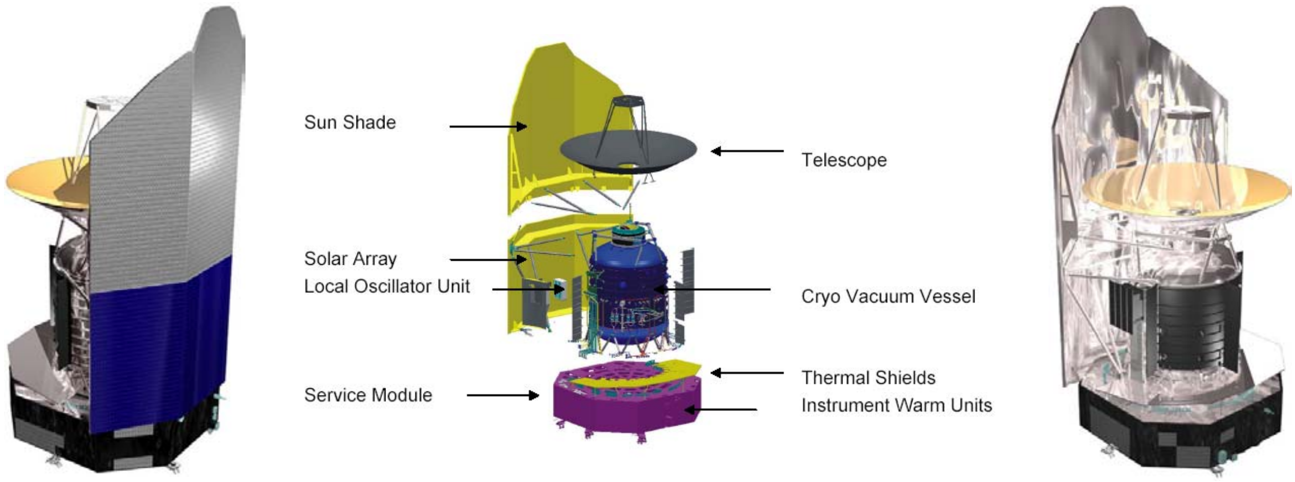

Figure 4. The *Herschel* spacecraft has a modular design. On the left facing the 'warm' side and on the right facing the 'cold' side of the spacecraf, the middle image names the major constituents. Approximate vital data include a launch mass of 3200 kg, height 7.5 m, width 4 m, and power 1500 W. It is designed to offer 3 years of routine science operations.

cantly lowering the outside temperature of the cryostat. The resulting helium boil-off rate for *Herschel*, just over 2 mg/s, is only approximately half that of *ISO*, while the fraction of the total heatload contributed by the science payload has doubled to ~20 %.

A large industrial consortium led by Alcatel Space Industries (Cannes) as prime contractor, with EADS Astrium (Friedrichshafen) being responsible for the EPLM and Alenia Spazio (Torino) for the SVM, and a host of subcontractors from all over Europe, are presently designing, building, and testing the spacecraft.

4. TELESCOPE

In order to fully exploit the favourable conditions offered by being in space *Herschel* will carry a precise, stable, low background telescope, and a complement of appropriately capable scientific instruments. In order to maximise its size the *Herschel* telescope will be passively cooled.

The *Herschel* telescope[11] must have a total wavefront error (WFE) of less than 6 μm - corresponding to 'diffraction-limited' operation at < 90 μm - during operations. It must also have a low emissivity to minimize the background signal, and the whole optical chain must be optimised for high straylight rejection. Protected by a fixed sunshade, in space the telescope will radiatively cool to an operational temperature in the vicinity of 80 K, with a uniform and very slowly changing temperature distribution.

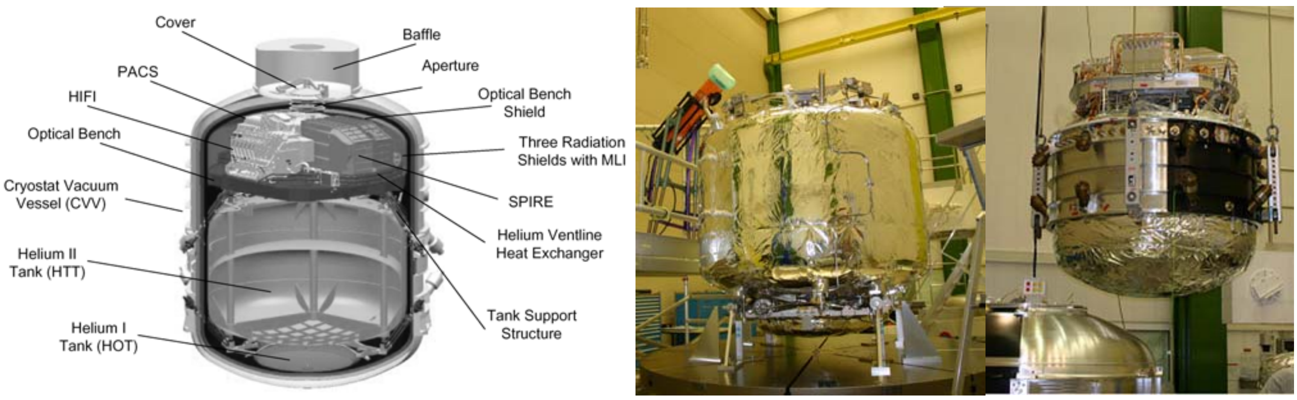

Figure 5. The *Herschel* cryostat technology builds on that flight proven by *ISO*. This enables the *Herschel* PLM to be built with a proto-flight model philosophy. From left to right: a schematic of the cryostat, the flight helium tanks, and with part of the outer vacuum vessel and the optical bench mounted.

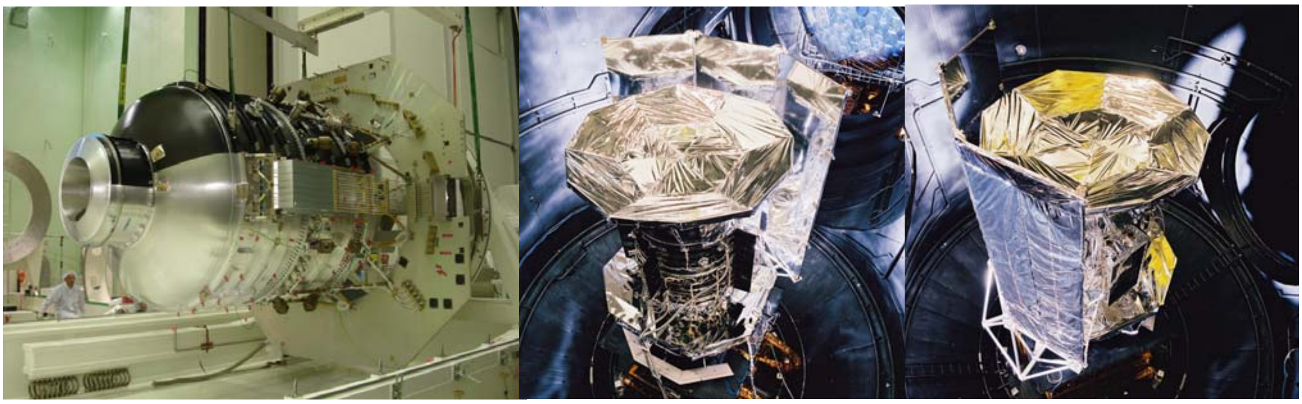

Figure 6. The *Herschel* flight cryostat arrived in ESTEC in August 2005 (left). In the pictures on the right two views on the cryostat in thermal balance/thermal vacuum configuration (TB/TV) under test in the Large Solar Simulator (LSS) in October/November 2005.

The chosen optical design is a classical Cassegrain with a 3.5 m diameter primary and an 'undersized' secondary. The telescope (Fig. 7) is provided by EADS Astrium (Toulouse) and has been constructed almost entirely of silicon carbide (SiC). The primary mirror has been made out of 12 segments (Fig. 6 in[12]). Each such segment was first pressed and then machined in its 'green body' state, then 'sintered' and prepared to be 'brazed' together to form a monolithic mirror which was machined and polished (much like a glass mirror) to the required thickness (~3 mm) and accuracy, providing positive control of the overall telescope WFE driver.

The secondary has been manufactured in a single piece, and machined with an integral 'scattercone' to suppress standing waves and the narcissus effect. It is being held in place by a 'barrel' and hexapod structure, which is connected to M1 in three points.

The proper telescope alignment and optical performance have been measured on ground in cold conditions. The measured wavefront performance in cold is in line with the requirements. The back focus position, however, has been found to deviate from the predicted position. The measured position has been found reproducible on a number of cooldown cycles and can be accommodated at spacecraft alignment level by adjusting the shimming, however, as there are no inflight adjustments, such as focusing, possibilities (which is similar to what was the case for *ISO*) the cause of the discrepancy between predictions and measurements is currently under intense study.

The M1 and M2 optical surfaces have been coated with a reflective aluminium layer, covered by a thin protective 'plasil'

Figure 7. The manufacture, alignment, and warm characterisation of the flight *Herschel* telescope was completed in August 2005 in the Astrium facilities in Toulouse. The left two pictures provide two views of the telescope immediately before tramsportation of the telescope to the intesapce facility of warm vibration. On the right the telescope in Centre Spatial de Liège (CSL) where the characterisation of the telescopoe under cold conditions started in October 2005.

The M1 and M2 optical surfaces have been coated with a reflective aluminium layer, covered by a thin protective ‘plasil’ (silicon oxide) coating. The telescope will initially be kept warm after launch into space to prevent it acting as a cold trap while the rest of the spacecraft is cooling down. Although the *Herschel* telescope sets a new standard when it comes to large, high accuracy, lightweight space telescopes it is still interesting to note that the reflective aluminium layer, which is the ‘working part’ of the telescope, accounts for only < 10 g of the total telescope mass of ~300 kg, or a fraction of only about 0.003 %.

5. SCIENCE PAYLOAD

The *Herschel* science payload complement has been conceived and optimised with the prime science goals in mind, but in addition it offers a wide range of capabilities for the ‘general’ observer. It was selected by the ESA Science Programme Committee (SPC) in May 1998 and approved in February 1999, based on the response to an Announcement of Opportunity (AO) issued in October 1997.

5.1 Payload instruments

The following three instruments which will be provided by consortia led by Principal Investigators (PIs):

- The Photodetector Array Camera and Spectrometer (PACS) instrument will be provided by an international consortium led by A. Poglitsch, MPE, Garching, Germany.
- The Spectral and Photometric Imaging REceiver (SPIRE) instrument will be provided by an international consortium led by M. Griffin, University of Wales, Cardiff, UK.
- The Heterodyne Instrument for the Far Infrared (HIFI) instrument will be provided by an international consortium led by Th. de Graauw, SRON, Groningen, The Netherlands.

The PI consortia provide the instruments to ESA under their own funding (from ESA member states, USA, Canada, and Poland), in return for guaranteed observing time. Taken together, the payload complement enables *Herschel* to offer its observers large-scale imaging photometric capability in six bands with centre wavelengths from 75 to 520 μm, medium resolution spectroscopy with limited imaging capability over the entire *Herschel* wavelength coverage, and high to very high resolution spectroscopy over much of the coverage.

The science payload is accommodated both in the ‘cold’ (Fig. 8) and ‘warm’ (Fig. 9) parts of the satellite (Fig. 4). The instrument FPUs are located in the ‘cold’ part, inside the CVV mounted on the HOB which is sitting on top of the superfluid helium tank. They are provided with a range of interface temperatures from about 1.7 K by direct connection to the liquid superfluid helium, and additionally to approximately 4 K and 10 K by connections to the helium gas produced by the boil-off of liquid helium gas whose enthalpy is used to efficiently providing the thermal environment necessary for their proper functioning. The ‘warm’ - mainly electronics - parts of the instruments are located in the SVM.

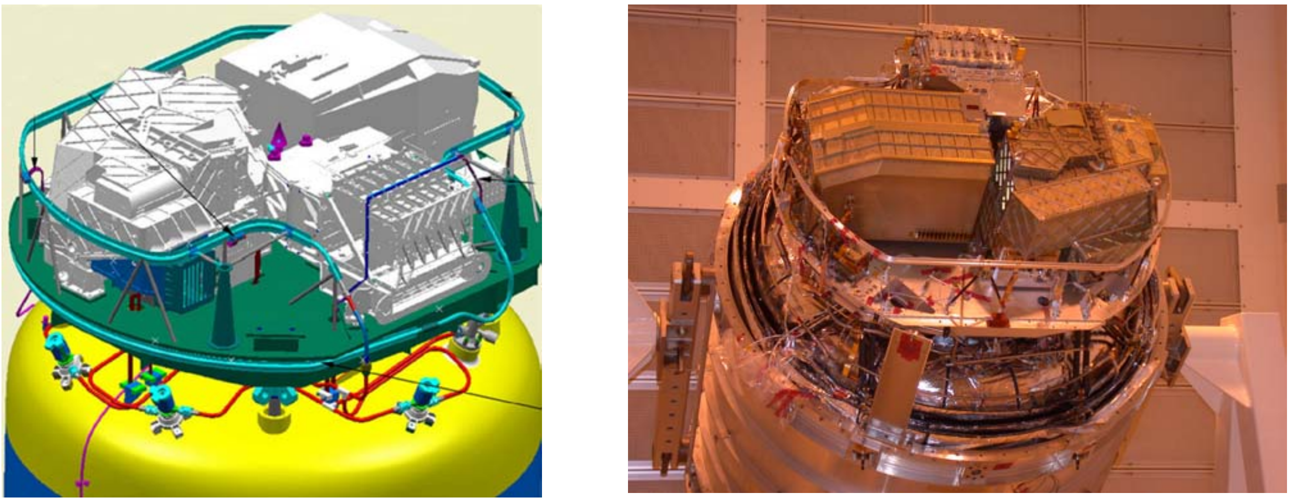

Figure 8. The *Herschel* instrument focal plane unit (FPU) accomodation on the optical bench (OB). Left picture shows a drawing, while the right picture depicts the FPU cryogenic qualification models (CQMs) mounted in preparation for the engineering qualification model (EQM - built using refurbished *ISO* hardware to provide a *Herschel* ‘OB simulator’) that took place in second half of 2005.

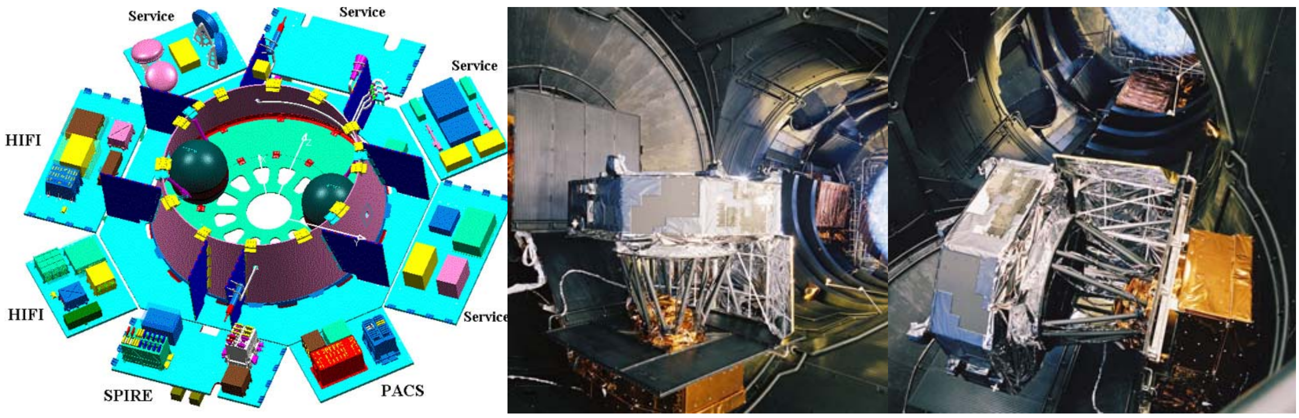

Figure 9. Most of the *Herschel* spacecraft service module (SVM) panels accomodate science payload warm electronics (WE) units (left). Some WE units have very strict thermal requirements, in particular the two spectrometers for the HIFI instrument. The SVM structural/thermal model (STM) was tested in the Large Solar Simulator (LSS) in the ESTEC Test Centre in May 2005 as shown in the middle and the right pictures.

5.2 PACS - the short wavelength camera and spectrometer

PACS (Figs. 8, 9, 10, for a full description[13]) is a camera and low to medium resolution spectrometer for wavelengths up to ~210 μm. It employs four detector arrays, two bolometer arrays and two Ge:Ga photoconductor arrays. The bolometer arrays are dedicated for photometry, while the photoconductor arrays are to be employed exclusively for spectroscopy. PACS can be operated either as an imaging photometer, or as an integral field line spectrometer.

PACS offers three broadband (R~2) photometric bands. The short wavelength 'blue' array covers the 60-85 and 85-130 μm bands, while the long wavelength 'red' array covers the 130-210 μm band. In photometric mode one of the 'blue' bands and the 'red' band are observed simultaneously. The two bolometer arrays both fully sample (0.5Fλ) the same 1.75x3.5 arcmin field of view on the sky, and provide a predicted point source detection limit of ~3 mJy (5σ, 1 hr) in all three bands. An internal ^{3}He sorption cooler will provide the 300 mK environment needed by the bolometers.

For spectroscopy PACS covers 57-210 μm in three contiguous bands, using different grating orders, providing a resolution R~1000-4000 corresponding to a velocity resolution in the range 75-300 km/s and an instantaneous coverage of ~1500 km/s. The two Ge:Ga arrays are appropriately stressed and operated at slightly different temperatures - cooled by being 'strapped' to the liquid helium - in order to optimise sensitivity for their respective wavelength coverage. The predicted point source detection limit is ~4-5x10^{-18} W/m^2 (5σ, 1 hr) over most of the band, rising to ~8-10x10^{-18} W/m^2 (5σ, 1 hr) for the shortest wavelengths.

5.3 SPIRE - the long wavelength camera and spectrometer

SPIRE (Figs. 8, 9, 10, for a full description[14]) is a camera and low to medium resolution spectrometer for wavelengths above 200 μm. It comprises an imaging photometer and a Fourier Transform Spectrometer (FTS), both of which use bolometer detector arrays. There are a total of five arrays, three dedicated for photometry and two for spectroscopy. All employ 'spider-web' bolometers with NTD Ge temperature sensors, with each pixel being fed by a single-mode 2Fλ feedhorn, and JFET readout electronics. The bolometers are cooled to a working temperature of ~300 mK by an internal ^{3}He sorption cooler similar to the PACS one.

SPIRE has been designed to maximise mapping speed. In its broadband (R~3) photometry mode it simultaneously images a 4x8 arcmin field on the sky in three colours centred on 250, 360, and 520 μm. Since the telescope beam is not instantaneously fully sampled, it will be required either to scan along a preferred angle, or to 'fill in' by 'jiggling' with the internal beam steering mirror. The SPIRE point source sensitivity for scan mapping is predicted to be in the range 8-11 mJy (5σ, 1 hr). Since the confusion limit for extragalactic surveys is estimated to lie in the range 10-20 mJy, SPIRE will be able to map somewhere in the range 0.25-0.5 square degrees on the sky per day to its confusion limit.

The SPIRE spectrometer is based on a Mach-Zender configuration with novel broad-band beam dividers. Both input ports are used at all times, the signal port accepts the beam from the telescope while the second port accepts a signal from

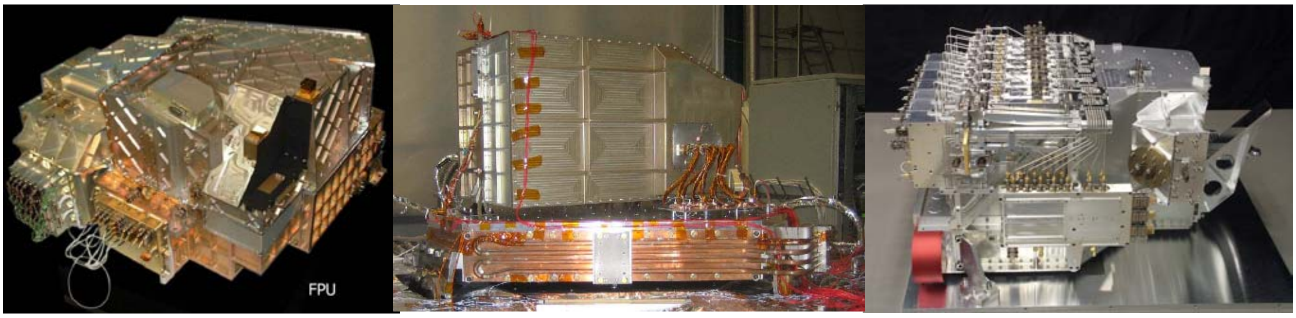

Figure 10. The *Herschel* science payload instrument focal plane units (FPUs). From left to right: PACS, SPIRE on the cryo-vibratior table, and HIFI, where the M3 mirror is clearly visible at the extreme right.

the calibration source, the level of which is chosen to balance the power from the telescope in the signal beam. The two output ports have detector arrays dedicated for 200-325 and 315-670 µm, respectively. The maximum spectral resolution varies with wavelength, it will be in the range R~100-1000 at a wavelength of 250 µm, and the field of view is circular with a diameter of 2.6 arcmin.

5.4 HIFI - the very high resolution heterodyne spectrometer

HIFI (Figs. 8, 9, 10; for a full description[15]) is a very high resolution heterodyne spectrometer. It offers velocity resolution in the range 0.3-300 km/s, combined with low noise detection using superconductor-insulator-superconductor (SIS) and hot electron bolometer (HEB) mixers. HIFI is not an imaging instrument, it observes a single pixel on the sky simultaneously in two polarisations, providing redundancy and enhanced sensitivity.

The focal plane unit (FPU) houses seven mixer assemblies, each one equipped with two orthogonally polarised mixers. Bands 1-5 utilise SIS mixers that together cover approximately 500-1250 GHz without any gaps in the frequency coverage. Bands 6L(ow) and 6H(igh) utilise HEB mixers, and together target the 1410-1910 GHz band. The FPU also houses the optics that feeds the mixers the signal from the telescope and combines it with the appropriate local oscillator (LO) signal, as well as provides a chopper and the capability to view internal calibration loads.

The LO signal is generated by a source unit located in the spacecraft service module (SVM; Sect 3). By means of waveguides it is fed to the LO unit, located on the outside of the cryostat vessel, where it is amplified, multiplied and subsequently quasioptically fed to the FPU. The SVM also houses the complement of autocorrelator and acousto-optical backend spectrometers, providing resolution from 0.14 to 1.1 MHz.

6. LAUNCH AND INITIAL IN-ORBIT OPERATIONS

Arianespace will provide the launch services in Kourou. An Ariane 5 ECA launcher shared by the ESA cosmic microwave background mapping mission *Planck* and *Herschel*, will inject its last stage carrying both satellites into a transfer trajectory towards the second Lagrangian point (L2) in the Sun-Earth system (Fig. 14 in[12]). First *Herschel*, then followed by *Planck*, will separate from the launcher, and subsequently operate independently from orbits of different size around L2 which is situated 1.5 million km away from the Earth in the anti-sunward direction. It offers a stable thermal environment with good sky visibility. Since *Herschel* will be in a large orbit around L2, which has the advantage of not costing any ‘orbit injection’ Δv, its distance to the Earth will actually vary between 1.2 and 1.8 million km.

7. SCIENCE OPERATIONS

Once the commissioning and PV phases have been successfully accomplished, *Herschel* will perform a science demonstration phase, before going into the routine science operations for a foreseen minimum duration of ~3 years. A very important activity connected to the science demonstration phase is the organisation of a workshop. In this workshop the actual performance of *Herschel* will be demonstrated and explained, enabling already selected observations to be optimised before being scheduled in the routine phase.

The scientific operations of *Herschel* will be conducted in a ‘decentralised’ manner. The ground segment concept comprises six elements:

- a Herschel Science Centre (HSC), provided by ESA,
- three dedicated Instrument Control Centres (ICCs), one for each instrument, provided by their PIs,
- a Mission Operations Centre (MOC), provided by ESA, and
- a NASA Herschel Science Centre (NHSC), provided by NASA.

The HSC is the prime interface between *Herschel* and the science community and outside world in general. It shall ensure that the scientific productivity and impact is maximised within given constraints, supported by the *Herschel* Science Team (HerschelST) and the *Herschel* Observing Time Allocation Committee (HOTAC). The HSC provides information and user support related to the entire life-cycle of an observation, from calls for observing time, the proposing procedure, proposal tracking, data access and data processing, as well as general and specific information about ‘using’ *Herschel* and its instruments. The NHSC provides user support primarily for the US users of *Herschel*.

The ICCs are responsible for the successful operation of their respective instruments, and for providing software and procedures for the processing of the data generated. The ICCs are responsible for most instrument related operational issues; instrument monitoring and calibration, developing and maintaining instrument specific software and procedures, and supporting operations. Each ICC performs tasks dedicated to its particular instrument.

The tools needed to carry out the above tasks are being developed jointly between ESA, the instrument consortia, and NASA. The *Herschel* observing planning tool, HSpot (Fig. 11), has been built based on the *Spitzer* Spot tool, and a data processing (DP) system (Fig. 12) is being built which will offer the observer a means to work on *Herschel* data without buying licenses. The DP system provides an ensemble of services in a single coherent platform independent system. This system is designed to be used not only by observers for data processing but also for instrument and calibration scientists for the validation of proper instrument functioning and of observing modes, as well as for calibration. The DP system is built in Java with Jython wrappers for scripting. The HSC will use it for pipeline processing to generate scientific products and to populate the *Herschel* archive with *Virtual Observatory* compliant products.

The fact (Sect. 9) that *Herschel* observers will want to build on and follow-up their own observations put stringent timescale implications on being able to successfully process *Herschel* data in a timely manner, and thus by implication, on the calibration of *Herschel* instruments. It is currently planned to carry out ‘large’ observing programmes early on in the *Herschel* mission. To follow up on these observations, it is necessary not only to have the capability to process these data im-

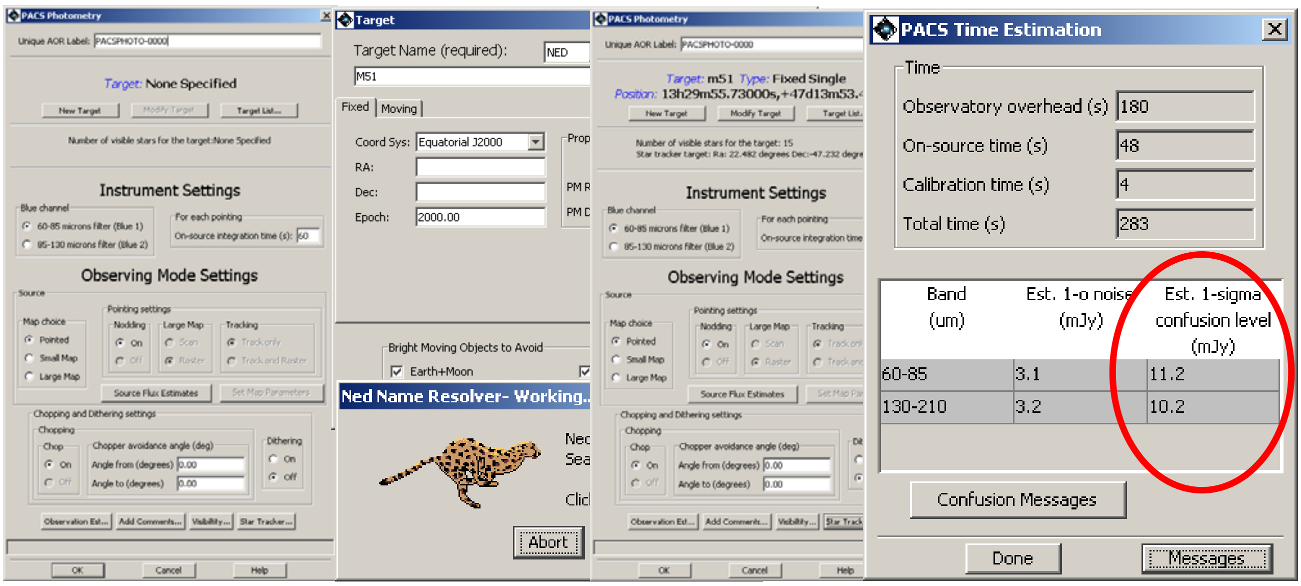

Figure 11. The *Herschel* observing planing tool, HSpot, has been built based on the *Spitzer* Spot tool, thanks to a collaboration between ESA and NASA. An obsever with *Spitzer* observing experience will need to learn about *Herschel* and its instruments, but will recognise the way the observing planning tool works.

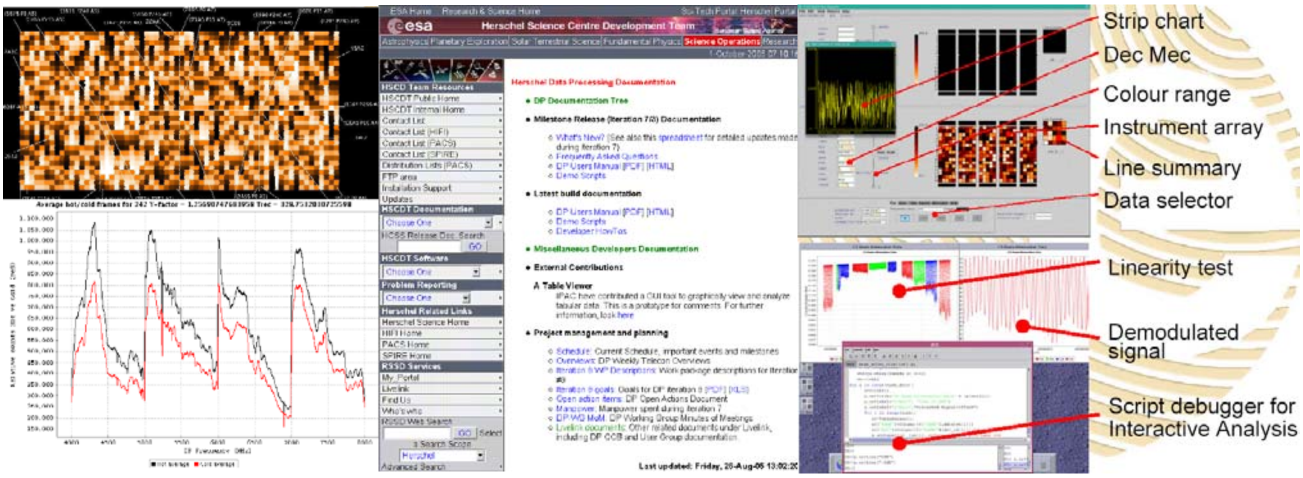

Figure 12. The *Herschel* data processing system is being built. It is designed to offer all users of *Herschel* data a suitable ensemble of platform independent tools. It is Java/Jython based, and features interactive analysis with online help. The HSC will pipeline process all Herschel data to generate and populate the *Herschel* archive with *Virtual Observatory* compliant scientific products.

mediately, but in order to collect them in an optimal fashion it must be possible to properly process and assess the data collected in the performance verification and science demonstration phases before proceeding to decide just how to perform these large programmes.

We are thus requiring being able to process the data - at least for the observing modes to be selected for performing the large unbiased programmes - just a few months into the in-orbit phase of the mission. This is a challenging task, especially considering the wide range of *Herschel* instrument detector technologies (Sect. 5), and this is where the legacy of missions such as *ISO* and *Spitzer* will be crucial for *Herschel* in providing a guideline.

8. SCIENCE MANAGEMENT

The 'rules of the road' for the science management of the *Herschel* mission are laid down in the (then *FIRST*) Science Management Plan (SMP), which recently has been updated and will constitute part of the Announcement of Opportunity (AO) for *Herschel* observing time.

The *Herschel* observation time will be shared between guaranteed and open time (GT and OT). The guaranteed time (approximately one third of the total time) is owned by contributors to the *Herschel* mission (mainly by the PI instrument consortia) and will be defined by them. The open time will be allocated to the general community (including the guaranteed time holders) on the basis of calls for observing time. A small amount of the open time will be reserved (discretionary time) for targets that could not have been foreseen at the time of a proposal deadline. All proposals will be assessed by the HOTAC, and all data will be archived and will be available to the entire community after the proprietary time has passed.

9. OBSERVING OPPORTUNITIES

As opposed the situation for *ISO* which had the benefit of the *IRAS* all sky survey, for much of its wavelength coverage *Herschel* to a certain degree it will need to be its own pathfinder, while benefitting from *IRAS* itself and *ISO*, *Spitzer*, and hopefully also from the yet to be conducted all sky survey by the recently launched *Akari*, as well as other space and ground based work.

Taken together with the science objectives of the *Herschel* mission, it was recognised very early that most likely 'large' observing programmes would be important. The SMP states that 'it is anticipated that 'Key Projects' in the form of large spatial and spectral surveys will constitute very important elements of the observing programme, requiring a substantial fraction of the available time of the overall mission'. It goes on to say that these programmes should be performed early, so that they can be followed up by *Herschel* itself; this was referred to as 'a phased approach.

As required by the SMP the current planning foresees issuing the call for 'Key Projects' upfront, before any observing time has been assigned. It will have two deadlines, the initial for GT 'Key Projects', which will then be assessed by the HOTAC and finally announced, and then a second deadline for OT 'Key Projects'. After the awarding of the 'Key Project' time the first call for 'regular' GT proposals will be done. The first call for OT 'regular' programmes will be issued only after the science demonstration phase (Sect.7), in parallel with the start of the routine science operations phase. For information of the relevant dates regarding the AO- which are currently being decided upon - consult the HSC *Astronomers' website* at *http://www.rssd.esa.int/herschel/*.

Initially, the observing schedule will be entirely dominated by 'Key Project' (GT and OT) and GT programmes. The programmes scheduled early will be dominated by those that most likely will require follow-up *Herschel* observations. It is foreseen to conduct at least another GT/OT 'regular' proposal cycle.

9. STATUS AND SCHEDULE

The current status of activities ongoing in the areas of the space segment (satellite), telescope, science payload, and operations areas can be summarised as:

- The industrial satellite activities commenced with phase B in Apr 2001, the Preliminary Design Review (PDR) at the end of phase B took place in autumn 2002. In the course of 2004 various levels of Critical Design Reviews (CDRs) took place culminating with the satellite CDR autumn 2004, followed by the Mission Level CDR in winter 2004/2005. In 2005 various testing at module level has been performed, and launch load tests at satellite level took place in early 2006 (Fig. 1).
- The telescope activity was started in mid-2001, the Critical Design Review (CDR) was held successfully in Apr 2002. The primary mirror was manufactured, warm vibrated, polished, and finally metallised in 2003-05. Other telescope parts such as the secondary mirror, hexapod legs, and 'barrel' (M2 support) structure were also completed. The telescope was assembled, and warm aligned and characterised in the summer of 2005. The cryotesting was carried out over winter 2005-06.
- The instrument consortia delivered the cryogenic qualification test models (CQMs) in early 2005. The flight models are being finalised. Instrument level testing is underway for SPIRE and HIFI, and will commence for PACS in summer 2006 for instrument deliveries towards the end of 2006.
- The science ground segment is being developed, it is being used in support of instrument level testing. The tools needed for supporting the first call for proposals are being tested, and the AO itself is being written.

The current planning envisages a series of milestones, including instrument and telescope flight model deliveries towards the end of 2006, to be followed by spacecraft integration and extensive system level ground testing and verification in 2007, leading to a launch in 2008.

Additional information - including online versions of some of the references listed below - and updates can be found on the HSC *Astronomers' website* at the following URL: *http://www.rssd.esa.int/herschel/*.

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