Herschel Mission Overview and Key Programmes

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ABSTRACT

Herschel is the next astronomy mission in the European Space Agency (ESA) science programme. It is currently in the final stages of assembly and verification in ESA's ESTEC facility in Noordwijk, and is scheduled to be flown to the launch site at Europe's Spaceport in Kourou later this year. Herschel will carry a 3.5 metre diameter passively cooled Cassegrain telescope which is the largest of its kind and utilises novel silicon carbide technology. The science payload comprises three instruments: two direct detection cameras/medium resolution spectrometers, PACS and SPIRE, and a very high resolution heterodyne spectrometer, HIFI. The focal plane units are housed inside a superfluid helium cryostat based on ISO legacy. Herschel will be launched by an Ariane 5 ECA together with the Planck satellite into a transfer trajectory towards the operational orbit around L2. When operational Herschel will provide unprecedented observational opportunities in the $55 - 672\,\mu$m spectral range, much of which has never before been accessible from a space observatory. It is an observatory facility available to the worldwide astronomical community, nominally almost 20,000 hours will be available for astronomy, 32 % is guaranteed time and the remainder is open to the general astronomical community through a standard competitive proposal procedure. The initial Key Programme Announcement of Opportunity (AO) was issued in Feb 2007. Both the guaranteed and open time Key Programmes have been selected and are introduced, and future observing opportunities are outlined.

Keywords: Herschel, space observatories, L2, superfluid helium cryostat, far infrared, submillimetre, star formation, galaxy evolution, debris disks, interstellar medium

1. INTRODUCTION

Herschel – in full the 'Herschel Space Observatory' – is the next astronomy mission in the European Space Agency (ESA) science programme. When operational Herschel will provide unprecedented observational opportunities in the $55-672\,\mu$m wavelength spectral range for the entire scientific community, much of which has never before been accessible from a space observatory. Herschel (Fig. 1) was the fourth of the 'cornerstone' (now aka 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 science programme[1].

Herschel is the only space facility dedicated to this part of the far infrared and submillimetre spectral range. It is the first large aperture space facility of its kind and it is the first to venture much beyond $200\,\mu$m wavelength. Its vantage point in space provides several decisive advantages. The telescope is passively cooled, the enabling factor for a significantly larger aperture compared with previous infrared missions. The choice of an operational orbit around L2 provides a stable thermal environment which together with a very low telescope emissivity and 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.

In this paper the driving scientific objectives, spacecraft, and telescope are described, the science instruments introduced, followed by a description of the launch, in-flight operations, and science operations. Then the science management, the approved Key Programmes, and the future observing opportunities are addressed, and the paper concluded by a status and schedule report. Additional information about all aspects of Herschel is available on the Herschel Science Centre (HSC) website[2] at http://herschel.esac.esa.int/, in particular as pertaining to detailed information for the (potential) observer in the form of tools and manuals.

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2. SCIENCE OBJECTIVES – THE ‘COOL UNIVERSE’

Herschel is designed to observe the ‘cool universe’; it has the potential of studying early epoch galaxy building, revealing the cosmologically evolving AGN-starburst symbiosis, unravelling the mechanisms involved in the formation of stars and planetary systems, detailing late stages of stellar evolution, and elucidating the interaction between successive generations of stars and the interstellar medium.

The continuum emission emanating 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.

Several major symposia were held[3,4] to discuss the scientific objectives and arrive at the resulting requirements on the observatory and its instrumentation with potential observing programmes in mind. The key science objectives specifically emphasize the formation and evolution of stars and stellar systems, of galaxies, the interrelation between the two, and the interaction with the interstellar medium (ISM). The main science drivers for the design of Herschel and its instruments have been:

- Wide-area photometric surveys of the extragalactic and galactic sky to measure dust-enshrouded star-formation activity throughout cosmic time and in our own and nearby galaxies today.
- 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.
- 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 the early and late stages of stellar evolution.
- Spectroscopic and photometric study of comets, asteroids and outer planet atmospheres and their satellites; in addition solar system objects are crucial for Herschel calibration.

Herschel will complement other available facilities by offering space observatory capabilities in the far infrared (FIR) and submillimetre (submm) 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 $50 - 100\,\mu$m range in their rest frames) as well as class 0 proto-star and pre-stellar object SEDs peak in the Herschel ‘prime’ band. Herschel will extend current optical/NIR observations into the FIR/submm, bridging the gap 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 new observing capabilities is made available 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. 1 and[5]) is the ‘space segment’ of the observatory. The spacecraft must provide the required working environment for the science instruments, point the telescope with the required accuracy and autonomously execute the observing timeline while ensuring safety, and communicate with the ground. It

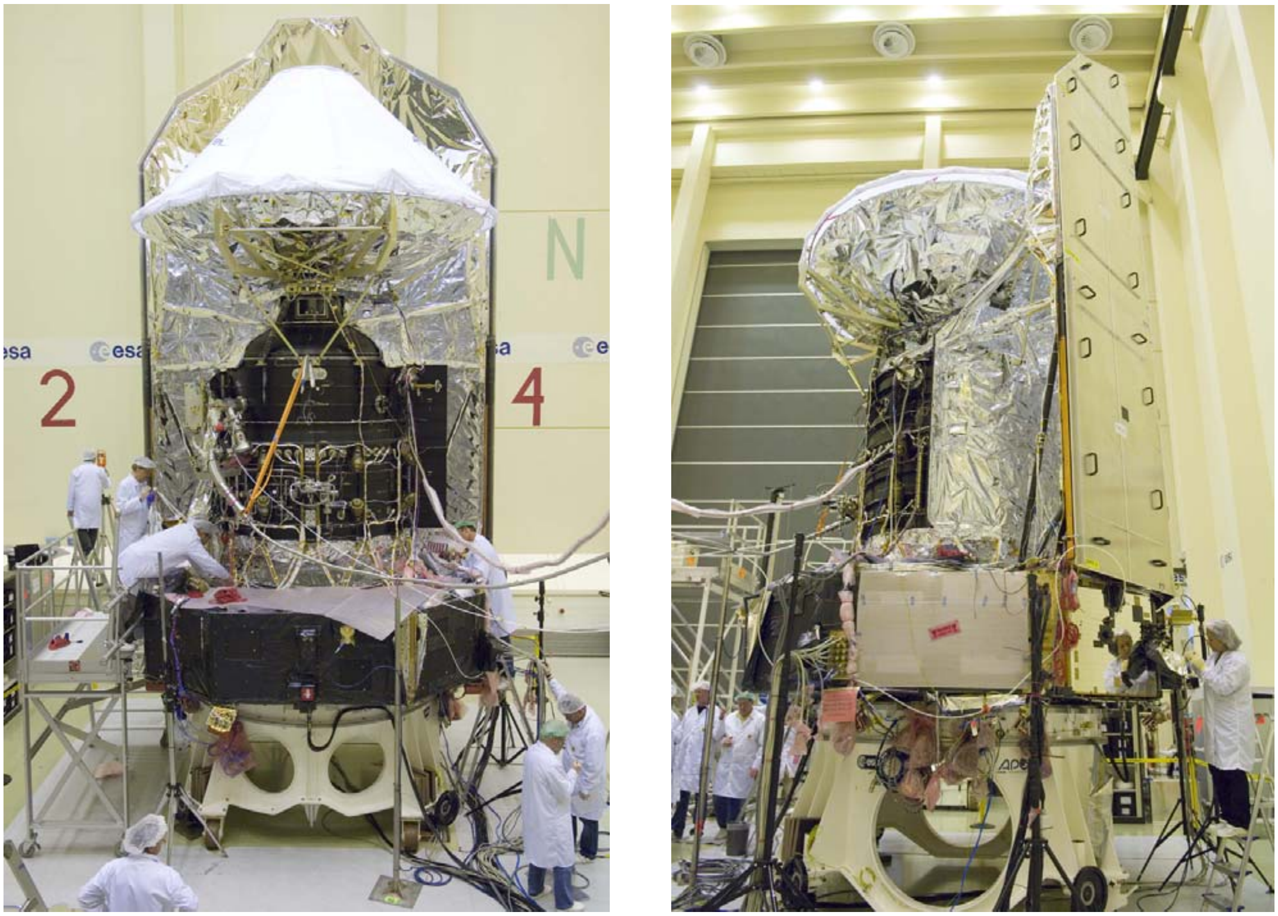

Figure 1. Two images of the Herschel spacecraft in the cleanroom in the ESTEC Test Centre. These pictures were taken on 23 April 2008 at the time when the spacecraft was very close to being mechanically completed in flight configuration. On the left a view of the side facing away from the sun. In the centre the black outside of the cryostat vacuum vessel (CVV) which will always be facing cold space inflight, below it the service module (SVM), and on the top of it the telescope protected by a cover which has its own support structure. Behind the spacecraft the backside of the solar array/sunshade (HSS) which is covered in multilayer insulation (MLI) to minimise thermal coupling. On the right a 'sideways' view, showing that the side of the CVV facing the HSS is also covered in MLI. The 'working' (sunward) side of the HSS is covered by protective elements, the handles for attaching and removing them are clearly visible. Images ESA.

has a modular design, consisting of the 'extended payload module' (EPLM) and the 'service module' (SVM). The EPLM consists of the PLM 'proper' with the 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 on-board data handling and command execution, communications, and safety.

Herschel relies on the successful ISO cryostat technology, but has a cryostat lifetime requirement of 3.5 years. A major difference compared to ISO is that Herschel will be operating from an orbit around 2nd Lagrangian point in the Sun-Earth/Moon system (L2) (Sec. 6). From here both the Sun and the Earth always will be in the same general direction in the sky making it possible to design the spacecraft to have a 'warm' and a 'cold' side, which has enabled optimisation of the thermal design including equipping the 'cryostat vacuum vessel' (CVV) with radiators on the 'cold' side significantly lowering the outside temperature of the cryostat. The resulting helium boil-off rate for Herschel, just over $2\,\mathrm{mg\,s^{-1}}$, is only approximately half that of ISO, while the fraction of the total cryogen heatload contributed by the science payload has doubled to $\sim 20\,\%$.

The Herschel spacecraft is approximately 7.5 m tall, 4 m wide, with a launch mass of slightly over 3 tons. A large industrial consortium led by Thales Alenia Space, Cannes (formerly Alcatel Space Industries), as prime contractor, with Astrium, Friedrichshafen, being responsible for the EPLM, and Thales Alenia Space, Torino (formerly Alenia Spazio), for the SVM, and a host of subcontractors from all over Europe, are building, integrating, and testing the spacecraft. More information can be found via the HSC website[2].

4. TELESCOPE

In order to fully exploit the favourable conditions offered by being in space Herschel has a precise, stable, low background telescope, feeding a complement of appropriately capable scientific instruments with photons. In order to maximise its size the Herschel telescope is passively cooled.

The Herschel telescope[6] has been specified to have a total wavefront error (WFE) of less than 6 μm – corresponding to 'diffraction-limited' operation at $< 90\,\mu$m – during operations, while having a low mass and the required mechanical and thermal properties. 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-flight the telescope will radiatively cool to an operational temperature in the vicinity of 80 K, with a near uniform and very stable temperature distribution.

The chosen optical design is a classical Cassegrain with a 3.5 m diameter primary and an 'undersized' secondary. The telescope (Fig. 2) is provided by Astrium, Toulouse, and has been constructed almost entirely ($\sim 90\,\%$ by mass) of silicon carbide (SiC). The primary mirror has been made out of 12 segments. 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), figure, and surface accuracy, providing positive control of the overall telescope WFE driver.

Figure 2. Two images of the Herschel telescope in the cleanroom in the ESTEC Test Centre. These pictures were taken shortly after unpacking during incoming inspection activities in late Jan 2008. In the left picture localised particulate contamination from the transport is removed, in the right picture preparations for a M1-M2 measurement are performed. Images ESA.

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 telescope alignment and optical performance have been measured on ground in cold conditions. The measured wavefront performance in cold in best focus is 5.7 μm – fully in line with the requirements. The back focus position, however, was found to deviate from the initially predicted position. The measured position has been found reproducible on a number of cooldown cycles and has been 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 initially unexpected discrepancy between predictions and measurements has been subject to a dedicated study by an independent team.

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 $\sim 10\,$g of the total telescope mass of $\sim 320\,$kg, or a fraction of only about 0.003 %.

5. SCIENCE PAYLOAD

The Herschel science payload complement has been conceived and optimised driven by the prime science goals (Sec. 2) subject to spacecraft environment constraints. 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 have been provided by large international instrument consortia led by Principal Investigators (PIs):

- The Photodetector Array Camera and Spectrometer (PACS) instrument will be provided by the consortium led by A. Poglitsch, MPE, Garching, Germany.
- The Spectral and Photometric Imaging REceiver (SPIRE) instrument will be provided by the consortium led by M. Griffin, University of Wales, Cardiff, UK.
- The Heterodyne Instrument for the Far Infrared (HIFI) instrument will be provided by the 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 70 to $500\,\mu$m, 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' and 'warm' parts of the satellite. The instrument FPUs (Fig. 3) 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.

Below follows a concise description of the payload instruments, further information can be found in the following three papers[7,8,9] in the current volume, and on the HSC website[2], including the 'Observers' Manuals' that are part of the Announcement of Opportunity (AO) documentation package (Sec. 10).

5.2 PACS - the short wavelength camera and spectrometer

PACS[2,7] is a camera and low to medium resolution spectrometer for wavelengths up to $\sim 210\,\mu$m. 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 used exclusively for spectroscopy. PACS can be operated either as an imaging photometer, or as an integral field line spectrometer.

PACS offers three broadband ($R \sim 2$) photometric bands. The short wavelength 'blue' array covers the $60-85$ and $85-130\,\mu$m bands, while the long wavelength 'red' array covers the $130-210\,\mu$m band. In photometric

Figure 3. Two images of Herschel flight instrument integration onto the optical bench in Astrium, Friedrichshafen. On left SPIRE is being lifted, on the right all three focal plane units in place; on left HIFI, on right SPIRE, and in the background PACS. Images courtesy Astrium.

mode one of the 'blue' bands and the 'red' band are observed simultaneously. The two bolometer arrays both fully sample the same $1.75' \times 3.5'$ field of view on the sky, and provide a predicted point source detection limit of $\sim 3\,\mathrm{mJy}$ ($5\,\sigma$, $1\,\mathrm{hr}$) in all three bands. An internal ^{3}He sorption cooler will provide the $300\,\mathrm{mK}$ environment needed by the bolometers.

For spectroscopy PACS covers $55-210\,\mu$m in three contiguous bands, using different grating orders, providing a resolution $R \sim 1500-4000$ corresponding to a velocity resolution in the range $75-300\,\mathrm{km\,s^{-1}}$ and an instantaneous coverage of $\sim 1500\,\mathrm{km\,s^{-1}}$. 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 $\sim 4-5\times 10^{-18}\,\mathrm{W\,m^{-2}}$ ($5\,\sigma$, $1\,\mathrm{hr}$) over most of the band, rising to $\sim 8-10\times 10^{-18}\,\mathrm{W\,m^{-2}}$ ($5\,\sigma$, $1\,\mathrm{hr}$) for the shortest wavelengths.

5.3 SPIRE - the long wavelength camera and spectrometer

SPIRE[2,8] is a camera and low to medium resolution spectrometer for wavelengths above $200\,\mu$m. 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 $2F\lambda$ feedhorn, and JFET readout electronics. The bolometers are cooled to a working temperature of $\sim 300\,\mathrm{mK}$ by an internal ^{3}He sorption cooler similar to the PACS one.

SPIRE has been designed to maximise mapping speed. In its broadband ($R \sim 3$) photometry mode it simultaneously images a $4' \times 8'$ field on the sky in three colours centred on 250, 350, and $500\,\mu$m. 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 $8-11\,\mathrm{mJy}$ ($5\,\sigma$, $1\,\mathrm{hr}$). Since the confusion limit for extragalactic surveys is estimated to lie in the range $10-20\,\mathrm{mJy}$, SPIRE will be able to map somewhere in the range $0.25-0.5$ square degrees on the sky per day to Herschel 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 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 $194-325$ and $315-672\,\mu$m, respectively. The maximum spectral resolution varies with wavelength, it will be in the range $R \sim 100-1000$ at a wavelength of $250\,\mu$m, and the field of view is circular with a diameter of $2.6'$.

5.4 HIFI - the very high resolution heterodyne spectrometer

HIFI[2,9] is a very high resolution heterodyne spectrometer. It offers velocity resolution in the range 0.3 − 300 km s^{-1}, 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 to 5 utilise SIS mixers that together cover approximately 480 − 1250 GHz virtually without any gaps in the frequency coverage. Bands 6 and 7 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 SVM (Sec. 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 EARLY IN-FLIGHT OPERATIONS

Arianespace will provide the launch services in Europe's Spaceport in Kourou. An Ariane 5 ECA launcher, shared with the ESA cosmic microwave background mapping mission Planck, will inject its last stage carrying both satellites into a transfer trajectory towards the 2nd Lagrangian point (L2) in the Sun-Earth/Moon system, which is situated 1.5 million km away from the Earth in the anti-sunward direction (Fig. 4). Herschel, followed by Planck, will separate from the launcher, and subsequently operate independently from orbits of different sizes around L2. The operational orbit was chosen because it offers a stable favourable thermal environment (Sec. 3) and good sky visibility, the Earth constraint is to a large degree covered by the Sun constraint, and at any one time about 30 % of the sky is visible. In addition multiple crossings of the Earth's radiation belts are avoided. Herschel will cross the orbit of the Moon already in the first days after launch, and will be a distance in excess of 1 million km from the Earth after two weeks. Since Herschel will be in a large orbit around L2, which has the advantage of not costing any 'orbit injection' delta-v, i.e. propellent mass, its distance to the Earth will actually vary in the range 1.2 − 1.8 million km.

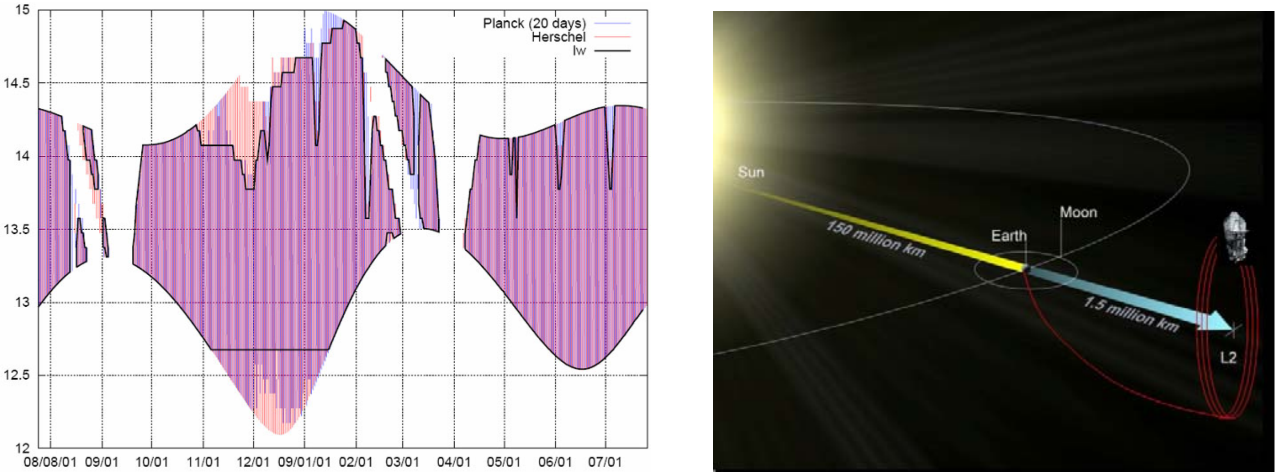

Figure 4. The possible launch windows are shown on the left, for UT time of the day and from 1 Aug 2008 and a year into the future. There are multiple constraints governing the Herschel launch, some of which come from Planck. Nevertheless the launch can be carried out on most days, avoiding the equinoxes, but the duration of the daily launch window is relatively limited. On the right the operational orbit around L2.

The initial in-flight activities are the Commissioning and Performance Verification (PV) phases, with 'first light' currently expected to take place approximately 30 days after the launch. Once they have been successfully accomplished, Herschel will perform a science demonstration phase. A very important activity connected to the science demonstration phase is the organisation of a major 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 upcoming routine phase, and the issue of the the next call for proposals based on actual in-flight experience (Sec. 10). It is foreseen to enter the routine science operations six months after launch for a minimum duration of 3 years, ultimately limited by the supply of cryogen.

7. SCIENCE OPERATIONS

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

- The Herschel Science Centre (HSC), provided by ESA;
- Three dedicated Instrument Control Centres (ICCs), one for each instrument, provided by their PIs;
- The Mission Operations Centre (MOC), provided by ESA;
- The 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 (Herschel ST) 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 additional user support primarily for the US users of Herschel, and offers science exploitation funding for investigators based in the USA.

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, has been built based on the Spitzer Spot tool, thanks to a collaboration between ESA and NASA. The Herschel data processing (DP) system[2] is being built jointly. It will offer all users of Herschel data a suitable ensemble of platform independent tools. This system is designed to be used not only by observers for data processing but also by 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 systematic pipeline processing to generate scientific and quality control products to populate the Herschel Science Archive (HSA) with Virtual Observatory (VO) compliant products for the observers to retrieve. The DP system will also be available for download for further (interactive) processing by the original and later by archive observers.

The fact (Sec. 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 to have the capability to process these data without delay.

However, in order to perform the observations in an optimal fashion in the first place the capability to properly process and assess the data collected in the PV phase is required, before proceeding to conclude on how to best use the observatory under in-flight conditins. We thus have the need to being able to process the data during the PV phase well enough to be able to validate the observing modes. This is a challenging task, especially considering the wide range of Herschel instrument detector technologies (Sec. 5), and this is where the experience gained by missions such as ISO and Spitzer is helpful for Herschel in providing guidance.

8. SCIENCE MANAGEMENT

The Herschel observing time will be shared between guaranteed and open time (GT and OT). In the 3 years of routine science operations 19,776 hours are nominally available for astronomy observations, 32 % is guaranteed time (GT), the remainder is open time (OT). The GT is owned by contributors to the Herschel mission (mainly by the PI instrument consortia) and will be defined by them. The OT is allocated to the general community (including the GT holders) on the basis of calls for observing time.

A small amount (max 4 %) 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. KEY PROGRAMMES

As opposed to ISO which had the benefit of the IRAS all sky survey, for much of its wavelength coverage Herschel will need to be its own pathfinder. To a certain degree of course it will benefit from IRAS and ISO, Spitzer observations, and the all sky survey by 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 Herschel Science Management plan (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 (the KPs) 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 call for the KPs was issued on 1 Feb 2007, being the first call for Herschel observing time. It had two deadlines, the initial for GT KPs on 4 Apr 2007, which were assessed by the HOTAC and publicly announced on 9 Jul 2007, followed by a second deadline for OT KPs on 25 Oct 2007. The GT KPs comprise 21 programmes with a total of 5878.9 hours ($\sim 93\,\%$ of the available GT) of observing time allocated. At the OT KP deadline 62 proposals had been received, requesting a total of 17984.6 hours of observing time, a factor 3.34 over the maximum available. The outcome was announced on 28 Feb 2008, by coincidence also 21 KP OT programmes were awarded observing time. The total allocated observing time for the 42 KP programmes is 11257.7 hours, corresponding to approximately 57 % of the nominally available Herschel routine mission science time (Tab. 1 and Fig. 5). These programmes are listed and some additional statistics are provided on the HSC website[2], with links to the proposal abstracts and also where available links to existing KP consortia websites are provided.

Table 1. Key Programme approved proposals by science area. The table shows the number of proposals awarded time, and the amount of awarded time, per science category and in KP GT, KP OT, and KP in total.

Science category	KP GT		KP OT		KP total	
	#props	hours	#props	hours	#props	hours
Solar system	1	293.7	1	372.7	2	666.4
ISM/star formation	10	2337.5	10	2113.2	20	4450.7
Stars	2	544.6	0	0	2	544.6
Galaxies/AGNs	5	983.7	8	1930.3	13	2914.0
Cosmology	3	1719.4	2	962.6	5	2682.0
Total	21	5878.9	21	5378.8	42	11257.7

Initially in the routine operations pahse, the observing schedule will be dominated by these programmes. The programmes scheduled early will be preferentially selected among those that most likely will require follow-up Herschel observations, subject to overall sky visibility and scheduling efficiency constraints.

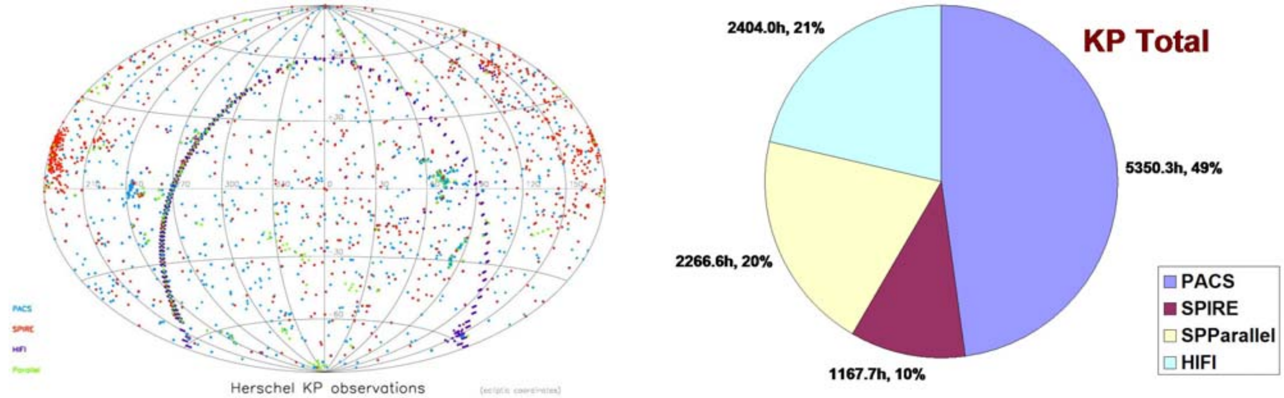

Figure 5. Key Programme observations[2]. In the left image the sky positions of the KP observations are plotted in ecliptic coordinates, with colour coding showing which instrument is being used. In the right image the fractional use of the instruments is given. In both images there are four 'logical' instruments, in addition to PACS, SPIRE, and HIFI, there is also the SPParallel 'instrument' which is using the PACS and SPIRE photometers simultaneously; note they will be viewing sky positions approximately 20 arcmin apart.

10. FUTURE OBSERVING OPPORTUNITIES

In addition to the already completed KP AO cycle two additional AO cycles for awarding the remainder of the Herschel observing time are planned. Both of these will contain a small amount of GT (only 7 % is remaining) which will be awarded first, followed by substantial amounts of OT (60 % is remaining); each cycle will allocate half of the remaining time.

A Herschel AO consists of the following:

- The actual AO from the Director of Science and Robotic Exploration – the invitation to propose;
- An Executive Summary – also serves as the 'readme' document for the AO;
- The Policies and Procedures – this is the 'rules', providing all necessary information about the policies adopted and the procedures to be followed;
- Five Observers' Manuals: Herschel, HIFI, PACS, SPIRE, SPIRE-PACS Parallel mode – provides user information about the use of its subject matter;
- HerschelFORM PDFLaTex package – with proposal templates, it is compulsory to write your proposal using this package;
- Herschel Reserved Observation Search Tool (HROST) – allows you to search in the database of reserved observations;
- HSpot observing planning tool with its own Users' Guide – you must use HSpot to plan and submit your observations.

The lastest AO is always available on the HSC website[2], also when there is no current proposal deadline.

The first cycle, AO-1, will be conducted as soon as the routine operations phase has commenced. At this point in time the 'real' in-flight characteristics of the observatory will have been established and implemented in the observation planing tool HSpot and associated documentation including Observers' Manuals. The second cycle, AO-2, will be conducted about a year later. The exact timing will be finetuned wrt to the remaining expected lifetime, and also taking the availability of Planck early catalog releases into account. Should the Herschel lifetime significantly exceed the nominal lifetime, a third cycle, AO-3, will likely be contemplated.

11. STATUS AND SCHEDULE

Herschel is currently in ESA's European Research and Space Technology Centre (ESTEC) in Noordwijk. Here it is undergoing the final stages of integration, and the required qualification, verification, and performance assessments are being conducted. This work is performed by the industrial contractors with ESA supervision and support.

Figure 6. Herschel testing in the ESTEC Test Centre in May 2008. On the left Herschel in the Maxwell EMC chamber after conclusion of the testing with part of the industry and ESA team, on the right Herschel in a unique horisontal position for SPIRE spectrometer testing and M1-M2 reference measurements before spacecraft mechanical (vibration/acoustics) qualification. Images ESA.

The current activities are the culmination of a process that started more than 25 years ago. Herschel only got its name in the Toledo symposium[3] in Dec 2000, in honour of the 200th anniversary of the demonstration of the existance of infrared light by William Herschel.

The Herschel science payload was selected in $1997-98$ and finally confirmed the year after. The phase B industrial activities started in Apr 2001. After a long sequnce of events the flight instruments were delivered in Mar-Jul 2007, and integrated in the flight cryostat in the Astrium facilities in Fredrichshafen. The SVM and the cryostat were mated in Sep 2007 and in this configuration Herschel was transported warm by truck to ESTEC, Noordwijk in the very first days of this year, arriving on 5 Jan 2008.

Since arriving in ESTEC the spacecraft integration has continuued, functional testing has been conducted, and the cryostat with the instrument FPUs has been baked out and subsequently cooled down to 'normal' helium conditions, a full cryostat main tank (helium two tank - HTT) was achieved on 1 Mar 2008 having used of order 10,000 litres of helium in the process. During the preparations for the cooldown a leak in the auxiliary tank (helium one tank - HOT) was detected and confirmed real – leading to a decision not to use this tank at all. The unavailability of the HOT complicates certain cryogenics operations, in particular during the last days leading up to the launch and will cost some mission lifetime, but the predicted lifetime is still well above the applicable requirements.

As this paper is written at the end of May 2008 the Herschel spacecraft is ready to undergo mechanical (vibration and acoustic) qualification. When this has been completed the transition into superfluid helium conditions will take place. A period of science payload performance validation tests will be performed followed by end-to-end tests with the mission operations centre an the science ground segment. The final part of the qualification activities will be conducted in the Large Space Simulator (LSS) where the thermal vacuum and thermal balance (TB/TV) tests will be performed as well as instrument – in particular HIFI – special performance tests that require the environment provided only by the LSS.

With results from all the above qualification activities in hand the Flight Acceptance Review (FAR) will be held. A successful FAR clears the spacecraft for transportation – by air – to the launch site for the launch campaign. The actual launch date is currently under negotiation, the currently predicted launch readyness date is in Jan 2009. The adventure is about to become reality!

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