ISO INFO

No.3 - December 1988

Newsletter on the Infrared Space Observatory

Introduction

Welcome to the third issue of ISO INFO. In the eighteen months since the previous edition, both the spacecraft and the scientific instruments have made good progress towards the forseen launch date of April/May 1993.

Activities on the satellite have moved into phase C/D with the next significant step forward being the start of integration, next spring, of the first model (structural and thermal) of the Payload Module, i.e. essentially the cryostat and telescope.

The instrument groups have also stepped firmly into the hardware development phases. In total, they must each deliver four models of their instrument to ESA, an alignment, mass and thermal model (AMTM), an engineering qualification model (EQM), a flight model (FM) and a flight spare (FS). The AMTM, due in December 1988, not only is representative of the mass distribution and thermal behaviour of the real instrument but also contains the optical compoments needed to align the instrument to the telescope at room temperature and to check that the alignment is still correct after cooling to liquid helium temperatures. The EQM, due in March 1990, will be representative of the flight instrument and, among other tasks, will be used to verify the compatibility of the four instruments together inside the cryostat.

Later sections of this newsletter give progress reports on the spacecraft and its instruments. To assist those not so familiar with the satellite, the last page contains an overview of the mission.

As stated in the first issue, ISO INFO will be published at irregular intervals during the design and development phases. The frequency of appearance will increase as launch approaches and ISO INFO will be used to inform the community of the observing opportunities available with *ISO* and how to apply for time. This edition, as a first step in this direction, contains a section entitled "Observing with *ISO*".

esa
european space agency
agence spatiale européenne

Satellite Status

In the period since the last newsletter, the phase B definition study of the satellite has been successfully completed and the main industrial development (phase C/D) commenced on 15 March 1988. This start followed the endorsement in February by the Science Programme Committee (SPC) of the continuation of the project with a cost envelope of 387.2 MAU (1AU $\approx$ 2DM) and approval by the Industrial Policy Committee of the proposed contracts. The prime contractor for phase C/D and leader of an industrial team of about 35 companies is Aerospatiale of Cannes, France.

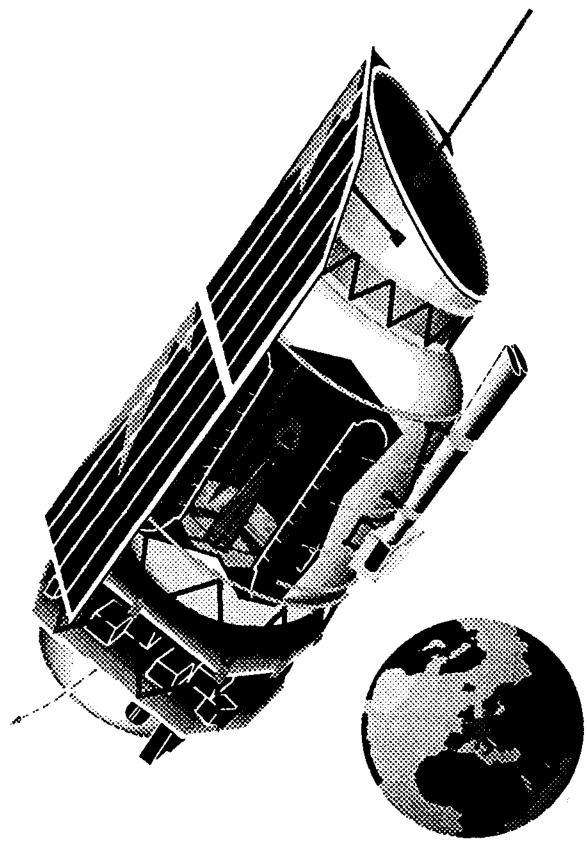

Fig.1: Cut-away view of ISO in orbit.

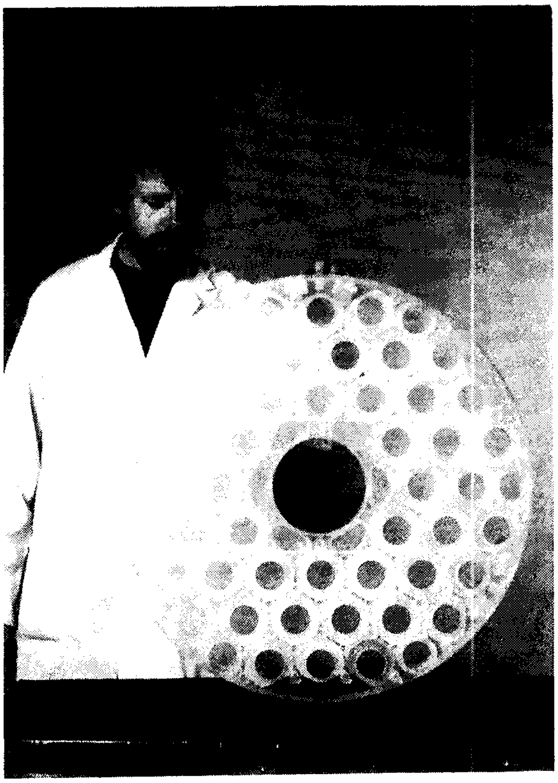

Fig.2: Structural-thermal model of primary mirror.

The emphasis in the industrial work is switching away from design towards manufacture and thus there are no significant design changes to report here. Figure 1 gives an impression of the current *ISO* design.

Expectations are that the scientific requirements on the spacecraft will be met. One exception, however, is the predicted jitter in the pointing; it has proved necessary to relax this specification from 2.1″ (half cone, 95% value over a 30 sec time period) to 2.7″.

In general, the phase C/D activities are continuing as planned although, as might be expected in such a complex project, some delays have been encountered, e.g. in the polishing of the first model of the 60-cm diameter primary mirror (cf. figure 2). The effect of these delays on the overall schedule is being evaluated and the foreseen launch date remains April/May 1993. The next major milestone on the industrial side will be the "System Design Review" to be held in spring 1989. This review, to be conducted by ESA, will be attended by members of the *ISO* Science Team, and has the objective of authorising the start of the integration of the Structural and Thermal model of the *ISO* Payload Module.

Second Ground Station

As will be recalled, a new orbit, with a period of 24 hours, was adopted for *ISO* in Spring 1987. The rationale for this change was to permit the satellite to spend nearly three-quarters of its time outside the Earth's radiation belts and, thereby, dramatically increase the sensitivity of the scientific instruments. In order to offset partially the extra cost of the dedicated Ariane 4 launcher, it was decided to operate *ISO* only for the best 14 hours of each orbit using a single ground station. However, it was recognised at the time that a further increase in the scientific return from the mission could be achieved by addition of a second ground station.

ESA has been actively seeking an international collaboration in which a partner would supply an additional ground station (to act as a relay station). In October and November 1988, two formal proposals were received by ESA, one from Australia and the other from NASA in collaboration with Japan. Both proposals would enable contact to be maintained with the satellite for nearly 24 hours per day; this would be achieved by supplementing the coverage from ESA's Villafranca station with coverage from Gnangara (Australian offer) or from Goldstone (NASA/Japan offer). In return, both potential partners request guaranteed observing time. The proposals are currently being evaluated by ESA. The advice of the *ISO* Science Team is being sought and, after some negotiations, it is hoped to made a final decision before the middle of 1989.

Collaboration with the USA on Instruments

In March 1988, a group of US astronomers, sponsored by NASA, made a whirlwind tour of the *ISO* Principal Investigator institutes in order to identify possible areas for either technical (e.g. detectors and read-out systems) or scientific collaboration. The US group consisted of G. Fazio, F. Gillett, C. McCreight, G. Rieke and M. Werner. Also attending the meetings were M. Harwit (*ISO* Mission Scientist) and, from ESA, M. Anderegg and M. Kessler. During the meetings, it was recognised that the *ISO* instruments' schedules were so far advanced that any major new hardware involvement would not be possible. However, a number of topics were identified for further discussion and subsequently, NASA has started to fund some US co-investigators on the *ISO* instrument teams.

The ISO Camera (ISOCAM)

PI: C.J. Cesarsky, Saclay, F

The past eighteen months have been very busy ones for all the laboratories and industry involved in the ISOCAM consortium. Most of the phase B activities have been concluded during this period. The main critical components had already been selected during phase A. These included cryogenic stepper motors from SAGEM-SEP and the detectors: a 32 x 32 element InSb CID array from Société Anonyme de Télécommunications for the 2.5–5 μm wavelength region and a 32 x 32 array DRO Si:Ga array from LETI-LIR, especially developed for ISOCAM purposes, for the 5–17 μm band. Other components, selected or developed during Phase B include: intermediate preamplifiers, microprocessors, analogue to digital converters, DC-DC converters, an internal source for flat fielding, etc. The manufacturing of the optics and cryomechanics of the cold focal plane unit of ISOCAM is being carried out by Aerospatiale under contract.

At present, breadboard models of various subsystems have been built and tested. A facility to vibrate units at 4K has been set up and used to space qualify a breadboard of the cryomechanisms. Most of the optical components are either ordered or have already been delivered and accepted. The broad and narrow band filters have been delivered and accepted at Stockholm. Circular variable filters (CVFs), with a spectral resolution of $\sim$50, are being made and will cover the range 2.5–16.5 μm. The optical mounts have been tested and qualified; even the fragile CVFs withstood the high level of vibrations specified for *ISO*. The final performances of the optical components, after mounting, will be measured in a special facility set up at Edinburgh.

The development of the detectors has progressed considerably. The first short wavelength focal plane assembly has been received at Meudon; it includes the detector and a hybrid package of cold preamplifiers on an adjacent ceramic. Tests are currently going on in order to find the optimum method of operation. These detectors have low susceptibility to hard radiation. Scientific models of the long wavelength detectors have undergone a series of tests at Saclay. The performances are as expected, with low upper limits on cross talk. The results of radiation tests indicate that, over a large part of the orbit, the effects of high energy particle impacts can be corrected for without much loss of sensitivity. Detector mounts, including active thermal control, have been built.

At Saclay and Meudon, the design of the electronics has been completed and the components have been ordered for the engineering qualification model, as have most of those for the flight and the flight spare models.

An Italian consortium is proceeding with the development of hardware and software for ground support equipment and for the observatory ground segment.

A cryogenic facility for the integration and calibration of ISOCAM has been designed, and is currently ready for installation at Orsay.

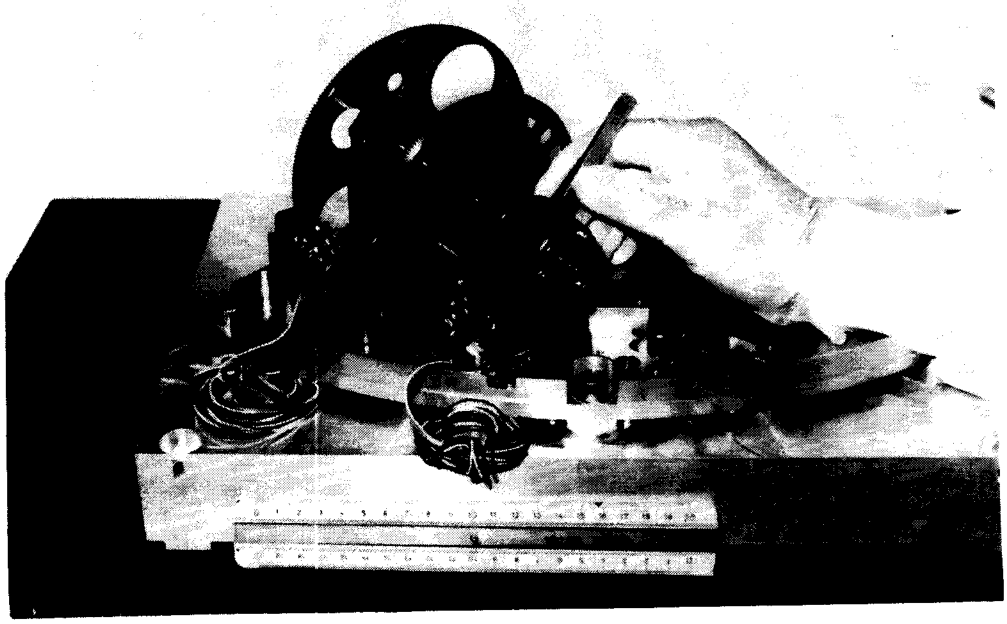

Fig.3: Cryogenic model of ISOCAM.

The ISO Photopolarimeter (ISOPHOT)

PI: D. Lemke, MPI für Astronomie, Heidelberg, D

After completion of the competitive phase B industrial studies, DORNIER was selected as prime contractor and the phase C/D development work started in March 1988. The cold focal plane unit will be built by ZEISS, the detectors by BATTELLE and the cold read-out systens by IMEC. In addition to the detailed design, some critical components were developed during phase B. The focal plane chopper and the filter wheel have successfully undergone cold vibration testing and extensive trials at cryo-vacuum conditions (e.g. 300 000 turns of the wheel). The new cold readout electronics (CRE, consisting of integrating amplifiers and a multiplexer) were coupled to the 64-pixel Si:Ga array and an NEP well into the 10^{-17} W/$\sqrt{\mathrm{Hz}}$ region was achieved. A second generation of CRE's, designed to achieve even lower noise levels, is now undergoing extensive tests.

In ISOPHOT-A, the 3 linear detector arrays have now been replaced by a two-dimensional camera covering the range 8–30 μm. An array of 8 x 8 Si:P elements read out by a 2D-CRE is used. This camera is equipped with four broadband filters. A possible alternative to this array –namely a Rockwell 10x50 Si:As BIBIB camera– was also investigated and excellent performance was found at *ISO* operational conditions. However, an export licence to Europe for this array was denied by the American authorities and, thus, the cameras had to be returned to the USA.

The final filter concept for the multiaperture photopolarimeter (PHT-P) has been chosen. Among the 14 bands, there are several dedicated to dust features, thereby permitting spectophotometry of polycyclic aromatic hydrocarbons, silicates and ices with high sensitivity in wide beams ($\leq$ 180$''$). The 12 different far infrared filters developed at MPI für Radioastronomie are based on resonant meshes with blockers of capacitive mesh and several crystals aiming for a 10^{-6} out-of-band attenuation. The MPI für Kernphysik has also developed a qualification procedure for its near infrared filters and polarizers.

ISOPHOT has two internal calibration sources, each composed of two small thermal radiators. The beams can be deflected via the focal plane chopper to all detector channels and the original f/15 beam from the telescope is simulated. Calibration concepts covering all aspects from ground acceptance tests to inflight checks using the internal sources and celestial standards are being studied. There is an obvious lack of photometric and polarimetric celestial standards at long wavelengths and ideas are being considered for a campaign to set up a network.

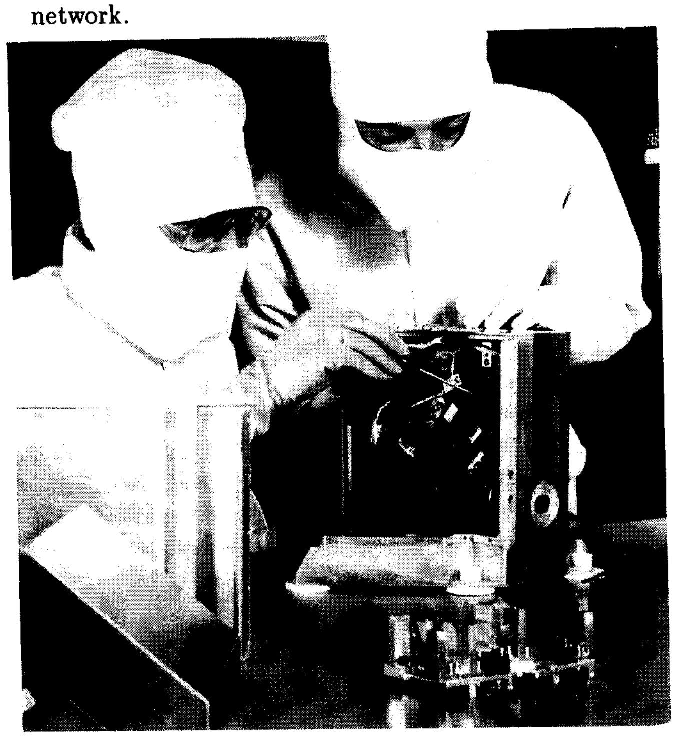

Fig.4: The ISOPHOT alignment mass thermal model.

Definition of the serendipity sky survey with the 200 μm camera is continuing. A computer simulation of the data extraction from the scans has been made, with the result that a surprising high accuracy can be achieved for measurements of flux and position of 200 μm sources crossing the field of view.

The Alignment Mass Thermal Model (cf. figure 4) of ISOPHOT, to be delivered to ESA this December, is close to completion. It has undergone cold vibration tests in the new shaker-proof helium cryostat built by LINDE with only relatively minor problems.

The spectrophotometer, PHT-S, is under development at CASA, Spain, with predevelopment and hardware support by Imperial College London and the PI institute. The scientific responsibility in Spain has been transferred to the Instituto d'Astrofisica de Canarias in Tenerife. Work in Spain has been delayed due to funding problems but these now seem to have been sucesssfully resolved.

A review of the ISOPHOT status before the phase C/D start was held in March 1988. The international review board, headed by Dr. Volker Schönfelder, Garching, came to a favourable conclusion and made valuable recommendations, most of which have been already adopted. On the management side, the industrial phase C/D contract is now managed by DFVLR. This allows the MPIA at Heidelberg to concentrate on all scientific and technical aspects of the instrument and the mission.

The Short Wavelength Spectrometer (SWS)

PI: Th. de Graauw, Lab. for Space Research, Groningen, NL

The development of the Short Wavelength Spectrometer is progressing satisfactorily. The first model of the instrument (the Alignment, Mass and Thermal Model) is now being tested in order to deliver it to ESA this December.

The production of the second model (the Engineering Qualification Model, EQM) is well advanced. The main structure with the optical components in place was delivered to Groningen in October, after it had successfully gone through a thermal vacuum test at liquid nitrogen temperatures at TPD, Delft. The measured reflection and efficiency data were as expected. The unit is now being prepared for tests at liquid helium temperatures (see figure 5). Other EQM subunits such as detector blocks, grating scanning mechanisms, Fabry-Pérot (FP) scanning mechanisms, shutters etc. are either in production or already being tested. A grating scanner and an FP scanner, mounted on the main structure, were successfully vibrated to qualification levels. This test also identified the need for a small design change in the fixation of the mesh holders.

The MPE in Garching have already produced and tested FP etalons for the 25–35 μm range; a finesse of 20 or more has been shown. The meshes for the 15–25 μm range have been manufactured but not yet tested.

The detector programme is well under way. The development model detectors from Battelle (Si:Ga, Si:P and Ge:Be) have been extensively tested and evaluated. The silicon detectors show low dark current ($<40\,e^-\ s^{-1}$); however, the germanium detectors show too large a dark current when compared to previously-tested samples; this is being investigated further. The 2.4–4.5 μm wavelength range will now be covered by InSb detectors (made by Cincinati Electronics) rather than by the previously-planned Si:In units. A licence to export these InSb detectors from the USA has been obtained.

After extensive testing and evaluation, it was decided that the SWS will use, for its four 1 x 12 detector arrays, the twelve-channel JFET integrating amplifiers from Infrared Laboratories. The expected read noise is less than $30\,e^-$. The four FP detectors will use single JFET integrators which will have read noise levels below $20\,e^-$.

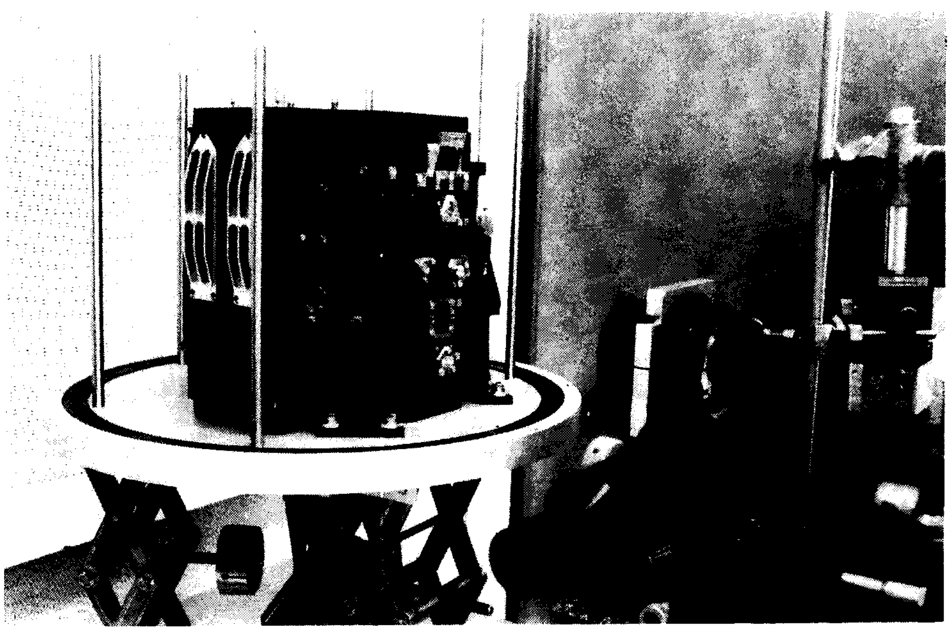

Fig.5: The SWS-EQM unit in a clean room.

At the Laboratory for Space Research Utrecht, the warm electronics design has been completed and the layout is being made for most of the printed circuit boards. Several boards have already been completed and some of them are under test. The development model is expected to be completed by March '89 and will be used for most of the test programme of the EQM focal plane unit. The cryogenic test equipment is approaching completion. The test cryostats have hold times of ~24 hours. Testing of the EQM focal plane unit will start in December followed by further integration.

Testing and calibration of the complete unit will start in the summer of '89 using the development model warm electronics. The EQM warm electronics will be incorporated early in 1990, leading to delivery of the engineering qualification model to ESA in spring 1990.

The Long Wavelength Spectrometer (LWS)

PI: P.E. Clegg, Queen Mary College, London; GB

A significant change to the design of the LWS has been the adoption of integrating amplifiers (IAs) in place of transimpedance amplifiers (TIAs). This was made possible by the change in *ISO*'s orbit which freed the instruments from most of the effects of particles trapped by the Earth's magnetic field. The performance of the TIA amplifiers, originally used by the LWS, was limited by the Johnson noise of their feedback resistors. The IAs have no feedback resistor and their performance is limited by the shot noise associated with the dark current of the detectors. The measured NEPs are currently 1-3 x 10^{-18} W/$\sqrt{\text{Hz}}$, an improvement of up to an order of magnitude over TIAs, and ways of reducing the dark currents further are being investigated.

A prototype diffraction grating of very high quality has been delivered and marks a breakthrough in technique. The blaze is particulary well defined and tests at optical wavelengths show that almost all the radiation is at the blaze angle, ensuring that very little infrared radiation will appear in the zeroth order; this will considerably reduce stray light and the problems which this causes. A model of stray light within the LWS has been made and a satisfactory method of "blacking" critical surfaces has been devised.

A very thorough theoretical and experimental study has been made of the meshes which will form the Fabry-Pérot "plates"; this work allows the parameters of the meshes to be chosen so as to optimise the efficiency and resolving power of the LWS Fabry-Pérots. The performance of prototype Fabry-Pérots follows closely the predictions of the theoretical model and is near the goal of a resolving power greater than 10^4 over the instrument's whole wavelength range. Although commercially available meshes give good results, a new method of manufacture has also been devised which produces meshes with markedly improved characteristics. Order-sorting filters are needed in front of the individual detectors and bandpass filters have been made with out-of-band rejection better than 99%.

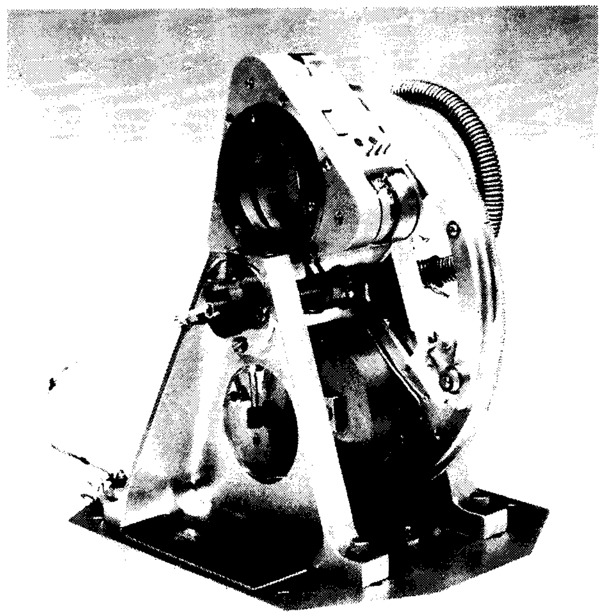

Fig.6: Engineering model of the LWS-FP assembly.

A tunable far-infrared laser has been purchased for testing the performance of the LWS. Initially, this is being used in the optimisation of the Fabry-Pérot meshes but it will soon be incorporated into the LWS test facility, which includes a cryostat for the complete instrument and a simulator of the ISO telescope. The use of the laser will greatly simplify testing the spectral performance of the LWS including its resolving power and spectral purity. The possibility of putting a spectral source on the cover of the ISO telescope is being investigated. If it proves feasible, this will allow the spectral performance of the LWS to be verified after it has been integrated into the telescope subsystem.

The LWS employs three cryogenic mechanisms, a drive for the grating, the Fabry-Pérot drives, and a wheel (cf. figure 6) which is used to select either the long or short wavelength Fabry-Pérots or the grating alone. Each of these mechanisms includes its specially designed electrical motor. All have been successfully tested at liquid helium temperature and have met their specifications.

A computer model of the optical performance of the LWS, including the effects of diffraction and aberration, has been made. This model has been used to calculate the overall efficiency of the transmission of radiation from the telescope to the entrance apertures of the detectors.

Much of the design of the warm electronic units is complete and breadboard models have been constructed and tested. The design of the on-board software, which will control the instrument in orbit under command from the ground, is progressing well. The first deliverable hardware, the Alignment, Mass and Thermal Model, is soon to be handed over to ESA. The Critical Design review of the LWS will be held early in 1989.

Observing with ISO

About two-thirds of *ISO*'s observing time will be competitively available to the scientific community via the submission and selection of proposals. The remaining time will be reserved for the groups who provide the instruments, for the Mission Scientists and for the Observatory Team who operate the satellite. A so-called "Central Programme", aimed at providing a balanced and coherent core to the *ISO* observations, will be carried out in the guaranteed time. Detailed discussions on what this programme should contain and how best to set it up have started both within the *ISO* Science Team and also within the instrument groups.

It is planned to issue the first "Call for *ISO* Observing Proposals" to the scientific community about 18 months before launch, i.e. around October 1991. The deadline for proposals will be 3–6 months later, i.e. early in 1992. This Call will contain the best available instrument calibration and sensitivity data, together with details of the central programme. Due to the large number of proposals expected, the method of proposal submission will almost certainly be electronic file transfer over the networks. After peer review, time will be awarded on a "per-object" basis, as was the case for *EXOSAT*, rather than on a "per-shift" basis as is done with *IUE*. From the response to this Call, the overall observing programme for the first eight months of routine orbital operations will be established. Further Calls will be issued during *ISO*'s lifetime.

The in-orbit operation of the *ISO* spacecraft and instruments will be carried out by a team of scientists and engineers located at the *ISO* Control Centre in Villafranca, Spain. During scientific operations, *ISO* will always be in contact with the ground segment; however, it is planned to minimise real-time modifications to the observing programme in order to maximise the overall efficiency of the satellite. Within a few hours of an observation being completed, a preliminary output, adequate for judging the scientific quality of the data, will be available. A final product with more detailed data reduction and calibration will be supplied later. This product will be the one from which the observers make their astronomical analyses.

More detailed definition of the *ISO* operations is underway by a working group, consisting of representatives of the instrument teams and of ESA. The requirements on the *ISO* ground segment will be formally examined early in 1989.

Personnel News

The *ISO* Science Team includes a group of "Mission Scientists", whose rôles are to represent the interests of the general astronomical community and to provide scientific input to the project. We are happy that their initial three year appointment has been extended for a further three years up to June 1991. The Mission Scientists are: Thérèse Encrenaz (Meudon), Harm Habing (Leiden), Martin Harwit (Washington), Alan Moorwood (ESO) and Jean-Loup Puget (Paris).

We welcome Gael Squibb and Julian Sternberg, who are now working in the Space Science Department (SSD) of ESA on the definition of the scientific operations of *ISO*. Gael is at ESTEC on a two year sabbatical from JPL, where he was involved in *IRAS* operations and science data processing from 1981 onwards. Julian was involved in all the ground segment activities for *EXOSAT* and since then has been similiarly occupied with preparing the operations of *Hipparcos*.

We also greet Leo Metcalfe and Alberto Salama, who have been recruited into SSD as the "Instrument and Calibration" scientists for *ISO*. Leo is already familiar with ESA as he has been working as a Research Fellow in ESTEC for the past two years. Alberto has spent the same period at MPI für Astronomie, Heidelberg, where he was working on the detector systems for ISOPHOT.

Summary of ISO and its Instruments

The Infrared Space Observatory (*ISO*), a fully approved and funded project of the European Space Agency (ESA), is an astronomical satellite, which will operate at wavelengths from 2.5–200 μm. *ISO* will provide astronomers with a unique facility of unprecedented sensitivity for a detailed exploration of the universe ranging from objects in the solar system right out to the most distant extragalactic sources. In keeping with *ISO*'s rôle as an observatory, about two-thirds of its observing time will be made available to the general astronomical community via proposal submission and peer review.

The satellite essentially consists of a large cryostat, the payload module, containing about 2300 litres of superfluid helium to maintain the Ritchey-Chrétien telescope, the scientific instruments and the optical baffles at temperatures between 2K and 8K. The telescope has a 60-cm diameter primary mirror and is diffraction-limited at a wavelength of 5 μm. A pointing accuracy of a few arc seconds is provided by a three-axis-stabilisation system consisting of reaction wheels, gyros and optical sensors. *ISO* will be launched in early 1993 by an Ariane 4 into an elliptical orbit (apogee 70000km and perigee 1000km) and will be operational for at least 18 months.

The *ISO* scientific payload consists of four instruments: a camera (ISOCAM), an imaging photopolarimeter (ISOPHOT), a long wavelength spectrometer (LWS) and a short wavelength spectrometer (SWS). Each instrument is being built by an international consortium of scientific institutes using national funding and will be delivered to ESA for in-orbit operations. Each of the consortia is headed by a Principal Investigator (PI), who is the formal point of contact between ESA and the instrument team. The instruments view adjacent areas of the sky and switching between them will involve a repointing of the satellite. In principle, only one instrument will be operated at a time; however, when the camera is not the main instrument, it can be used in a so-called "parallel" mode either to gain extra astronomical data or to assist the other instruments in acquiring and tracking their targets. Whenever possible during satellite slews, the photopolarimeter will be operated in a so-called "serendipity" mode so as to make a partial sky survey at wavelengths around 200 μm, a region not included on *IRAS*. As befits a true observatory, the individual instruments are being optimised to form a complete, complementary and versatile package.

The **ISOCAM** instrument (PI: C.J. Cesarsky) consists of two optical channels, each with a 32 x 32 element detector array, operating respectively in the wavelength ranges 2.5–5 μm and 5–17 μm. Each channel contains wheels for selecting various filters (including CVFs) and variable pixel fields of view. Only one channel is operational at a time. Polarisers are mounted on an entrance wheel common to both channels.

The **ISOPHOT** instrument (PI: D. Lemke) consists of four sub-systems:
- PHT-C: a photopolarimeter which also provides imaging capability at close to the diffraction limit in the wavelength range from 30 μm to 200 μm,
- PHT-P: a multi-band, multi-aperture photopolarimeter for the wavelength range from 3 μm to 110 μm with wide beam capability for faint extended sources,
- PHT-A: an multi-band array of 8 x 8 discrete detectors for the wavelength range from ~8 μm to 28 μm,
- PHT-S: a dual grating spectrophotometer which simultaneously provides a resolving power of ~90 in two wavelength bands 2.5–5 μm and 6–12 μm.

A focal plane chopper with a beam throw of up to 3′ is also included in ISOPHOT.

The **LWS** instrument (PI: P.E. Clegg) consists of a reflection diffraction grating used in 1st and 2nd order with an array of discrete detectors to provide a spectral resolving power of ~200 over the wavelength range from 45 μm to 180 μm. Either of two Fabry-Pérot interferometers can be rotated into the beam to increase the resolving power to ~10^4 across the entire wavelength range.

The **SWS** instrument (PI: Th. de Graauw) provides a resolving power of 1000–2000 across the wavelength range from 2.5 μm to 45 μm by means of two reflection diffraction gratings used in 1st, 2nd and 3rd orders. Over a part (15–30 μm) of the SWS's operating range, the resolution can be increased to ~2 x 10^4 by using the scanning mirrors to deflect the incident radiation through either of two Fabry-Pérot interferometers.

ISO INFO is edited by:
Martin F. Kessler, *ISO* Project Scientist,
Astrophysics Division, Space Science Department,
ESTEC, Postbus 299,
2200AG NOORDWIJK, The Netherlands.
Telephone: +31-1719-83623
Telefax: +31-1719-84690
Telex: 39098 estc nl
SPAN: ESTCS1::MKESSLER
EARN/BITNET: MKESSLER@HNOESA10