Looking Back at ISO Operations

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The Infrared Space Observatory (ISO), the world's first true orbiting infrared observatory, was switched off in May 1998, long after the expiry date foreseen in the specifications for the mission. Instead of the required 18 months, the highly-successful in-orbit operations of this excellent satellite continued for more than 28 months leading to an extensive database of observations which will be providing astronomical surprises for years to come. This article looks back at the way operations were conducted.

Introduction

ISO consisted essentially of a large cryostat which contained at launch about 2300 litres of superfluid helium to maintain the Ritchey-Chretien telescope, the scientific instruments and the optical baffles at temperatures of 2 – 8K. The telescope had a 60-cm diameter primary mirror. A three-axis stabilisation system provided a pointing accuracy at the arc-second level. ISO's sophisticated instrument complement, built by international consortia of scientific institutes and industries, consisted of an imaging photo-polarimeter (ISOPHOT), a camera (ISOCAM), a Short Wavelength Spectrometer (SWS) and a Long Wavelength Spectrometer (LWS). Together the instruments provided a variety of spectral and spatial resolutions across the wide wavelength range of 2 – 240 microns. ISO was placed into a highly-elliptical orbit on 17 November 1995 by an Ariane-4 launcher. The launch and early operations phase was planned and controlled by ESA's main Operations Centre, ESOC. Once the spacecraft status had been checked out, and the perigee-raising manoeuvre was executed, the operations were transferred to ESA's Satellite Tracking Station in Villafranca, Spain (Vilspa).

In orbit, all satellite systems performed superbly with the pointing accuracies being up to ten times better than specifications and with the liquid helium coolant lasting until 8 April 1998, nearly 30% longer than specified, not only leading to more observations but also permitting access to the Orion region of the sky, which was not visible during the nominal mission. All instruments worked very well and returned vast quantities of high quality data. The many scientific highlights of ISO include: the detection of water on Titan, on the giant planets, around young and old stars and in distant galaxies; peering into the cradles of star formation; elucidation of the nature of the mysterious power sources energising some of the most luminous galaxies; and peeking back in time to gather clues to the formation and early evolution of galaxies.

Following exhaustion of the liquid helium supply, a number of technological tests, aimed at gathering data to benefit future missions, were carried out. The satellite was then switched off on 16 May 1998.

Operational concept

The operational concept of ISO was driven by several constraints: severe sky coverage limitations due to pointing constraints on the spacecraft, the complexity of the scientific instruments, and the necessity to conduct many short observations under ground station coverage (no onboard data or command storage for instrument operations). The overall pace of operations and the individual observations in a single programme being widely separated in time meant that 'observers' were not present during the execution of their observations. Thus, ISO was operated in a service observing mode with each day's operations planned in detail up to three weeks ahead in time.

This concept drove the design of the ground segment, which consisted of the Spacecraft Control Centre (SCC) and the Science Operations Centre (SOC), both co-located at ESA's Villafranca premises near Madrid, Spain and two ground stations. ESA provided one ground station, located in Villafranca. The second ground station, located at Goldstone,

More details about ISO, its instruments and its early scientific results may be found in articles in ESA Bulletin numbers 84 and 86. The project information is also available via the ISO WWW server at:
http://www.iso.vilspa.esa.es/

California, was contributed by the National Aeronautics and Space Administration (NASA). Additional resources, enabling ISO to be operated for a longer period per day, were supplied by the Institute of Space and Astronautical Science (ISAS), Japan. Together, both tracking stations provided approximately 22 hours/day of real-time support. Figure 1 gives an overview of the main elements of the ISO Control Centre.

The SCC team, within the Directorate of Technical and Operational Support (D/TOS), was responsible for the conduct and control of the flight operations for ISO, and had full responsibility for spacecraft health and safety, including that of the scientific instruments. The SOC team, within the Directorate of Science (D/SCI), was responsible for the operations of the scientific instruments, including observing programmes, and data reduction and distribution.

Community support

ISO – as an observatory – was open to the astronomical community including expert and non-expert users. The community support task was to facilitate scientifically-effective use of ISO and included handling all requests for observing time as well as providing concise and up-to-date information.

Approximately 45% of ISO's time was reserved for those parties contributing to the development and operation of the scientific instruments and the overall facility, namely: the instrument teams; the Mission Scientists; the scientific staff of the SOC; and ESA's international partners in the mission, NASA and ISAS. Definition and coordination of these guaranteed-time observations started some eight years before launch. In addition to its scientific value, this early start was important both to help define observing modes and also to be able to publish 'worked examples' to the community with the pre-launch call for proposals.

The remaining more than half of ISO's observing time was distributed to the general community via the traditional method of proposals and peer review. One 'Call for Observing Proposals' was issued pre-launch (April 1994) and one post-launch (August 1996). Over 1500 proposals, requesting almost four times more observing time than available, were received in response to these Calls. Some 40% of the proposals arrived in the last 24 hours before the deadlines. All proposals were evaluated scientifically by an 'Observing Time Allocation Committee' consisting of approximately 35 external scientists, supported by members of the Science Operations Centre (SOC) for technical evaluations. The necessary flexibility for follow-up observations during the mission was provided by discretionary time proposals, with over 150 proposals being received, of which 40% were in the last four months of the mission. Despite being very manpower intensive over relatively short periods of time, the proposal process worked very well.

Successful 'proposers' then moved on to the next phase of the process. Here they had to enter full details of their observations into the SOC's databases. Prior to launch, this typically involved a visit of around a week to a specific data-entry centre set up in ESTEC (for US observers, a similar centre was operated at IPAC). The European centre at ESTEC was co-located with the Science Operations Centre during its development phase, prior to moving to Spain. The Infrared Processing and Analysis Center (IPAC) was designated by NASA as the support centre for US ISO observers. Over 500 astronomers visited ESTEC in the first six months of 1995 and were assisted by resident astronomers and technical assistants in finalising and entering their observational programmes. Post-launch as experience and confidence grew, visits were almost completely replaced by remote logins across the Internet.

During the in-orbit operations, observers were permitted to tune up their programmes – via Internet communications with the Science Operations Centre – to take full advantage of results from previous observations and of improving knowledge of how best to use the instruments. The facility was widely used, with – averaged across the entire set of observations – each programme being updated around three times. Because scientific judgement often had to be involved, checking that updated observations did not duplicate existing ones was a very labour-intensive task.

Prior to launch, user documentation (such as observers' manuals, data reduction manuals, information notes, etc.) was mainly paper-based. However, during the operations, this completely switched to being Web-based. The ISO WWW site opened in 1994 and had over 1 million hits (from non-ESA machines) during operations. It rapidly became the essential way of communicating with observers. The site was continually upgraded, e.g. with the addition of galleries of science results and of tools for detailed monitoring of execution of observing programmes.

By its nature, community support is a labour-intensive and open-ended task and will always be limited by available resources. On ISO, it

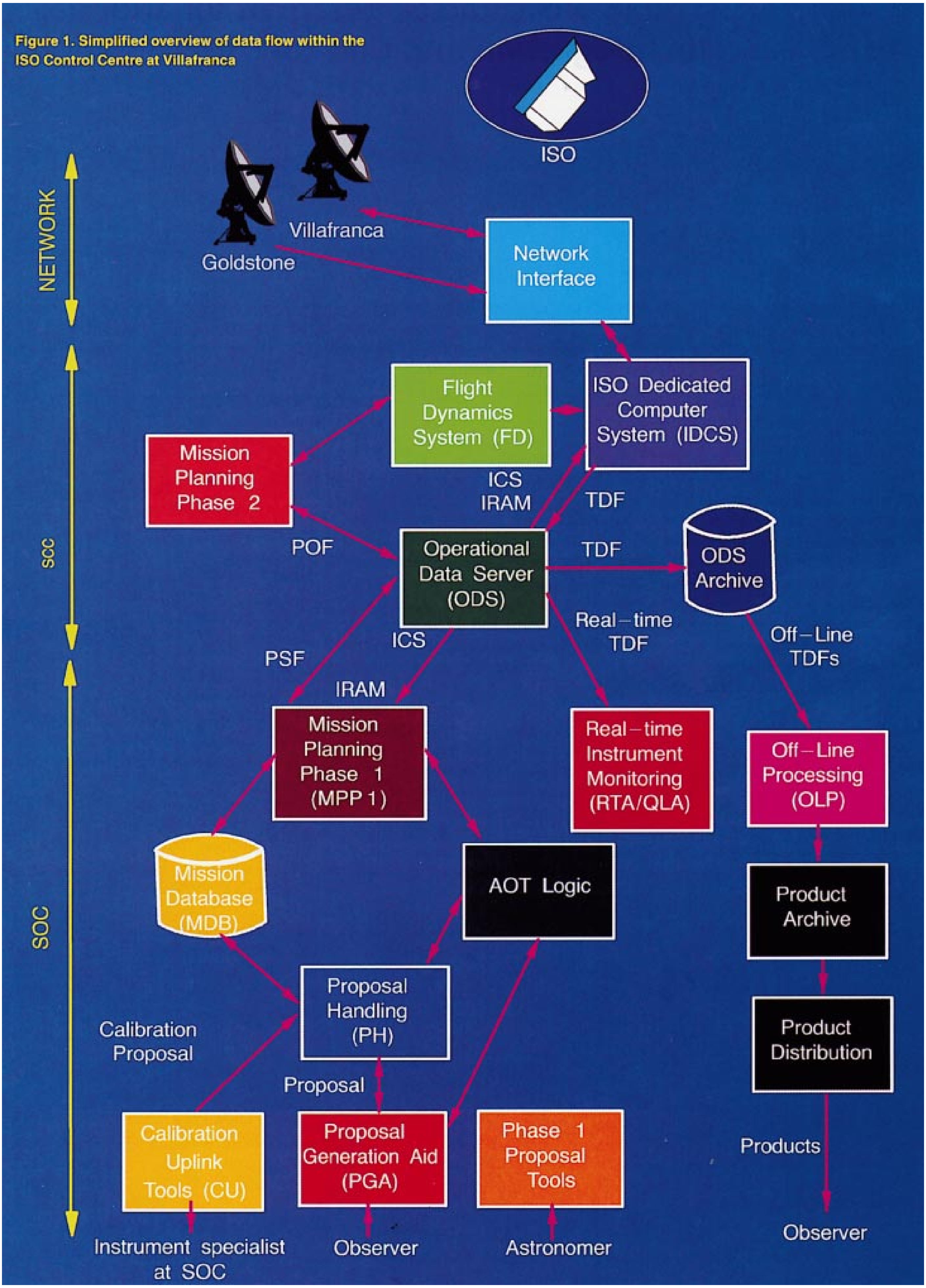


Figure 1. Simplified overview of data flow within the ISO Control Centre at Villafranca

worked very well; however, looking back, one would have liked to have been more proactive in getting even more information out to the community.

Science operations

ISO science operations were organised almost as a factory 'production line'. The starting point was the databases into which observers had entered all the details required to implement their observations in service mode. Each observation was technically validated and then loaded into the so-called Mission Data Base (MDB), which at the end of the mission included more than 40 000 observations.

The next step was to generate a long-term plan, showing when and how the most scientifically-important observations could be implemented. This was particularly important in the case of a mission like ISO with a short lifetime and with only a limited part of the sky accessible at any given time. A coarse pre-scheduling of the next three months was made. This process was extremely time- and resource-consuming and never worked quite as expected since one was dealing with a 'moving target'. In other words, the flexibility offered to the observers to optimise their observing programmes meant that the input changed faster than the plan. This flexibility was necessary and greatly enhanced the scientific return. However, extensive and complex manual work was required to enable ISO to successfully execute nearly 98% of the highest priority observations. Similar missions in the future should be able to generate a representative long-term plan within a few days with minimal human intervention.

Next in the production line came the detailed planning of each day's observations to the level of instrument commands at a granularity of 1 second of time. The goal here was to minimise slew and dead time, and generate efficient schedules while preserving the scientific content (i.e. carrying out the high priority observations). The system worked very successfully and produced schedules with an average efficiency of 92%, where efficiency is defined as the ratio of the time the satellite was accumulating scientific data to the available science time. In fact, the actual efficiency achieved can be considered to be even higher since nearly two-thirds of the time for slewing between targets was used to gather serendipitous data at previously-unsurveyed infrared wavelengths with the photometer, and since the camera and Long Wavelength Spectrometer collected data in parallel modes when the observer had specified use of another instrument. Part of the trick was to do 'overbooking'. In other words, the mission database was filled up so that it always contained about twice as many observations as could be accommodated during the remaining ISO lifetime. In essence, short lower-grade observations were used to fill in gaps between high-grade ones.

The SOC monitored the instruments in real time as the observations were executed automatically, but had the capability to intervene manually if necessary. There were few instrument anomalies; typical interventions were, for example, the 'closing' of the camera if a bright target entered its field of view. This was required to avoid saturation and its long-lasting effect on the detectors.

The final steps in the production line involved the processing, quality control, archiving and finally the distribution of the data on CD-ROMs. From an operational point of view, the processing and archiving of the data worked flawlessly. Over 10 000 CD-ROMs were distributed to observers. The processing algorithms and calibration were initially far from perfect and, in fact, improvements will continue for the coming years. However, within one year of launch, an ISO-dedicated issue of Astronomy and Astrophysics containing nearly 100 scientific papers, had been published. Given the inherent complexity of the instruments and in particular of the behaviour of the IR detectors, this is a significant achievement.

One of the major factors in the successful operation of ISO's sophisticated instruments was the assignment to each of an 'Instrument Dedicated Team' (IDT) of experts at Villafranca. The teams' responsibilities included: the overall maintenance of the instruments (including the real-time monitoring software and procedures); the calibration; and the design and much of the coding and testing of the data processing algorithms. Other experts, back at the Principal Investigator institutes, worked in close cooperation with the SOC's Instrument Dedicated Teams. These teams were crucial in making instrument operations run smoothly by rapidly diagnosing and fixing anomalies, by optimising the observing modes and by getting the instruments properly calibrated.

Much of the necessary complexity of science operation was embedded in the over one million lines of code of the SOC software. More than 1700 Software Problem Reports (SPR) were responded to and over 250 System Change Requests and Extra Wishes (SCREW) implemented in the course of the mission. This comes on top of the ~1000 SPRs and ~100

SCREWs implemented pre-launch, during and after the period of integration, tests and simulations. All of the SOC's software maintenance team had been involved in the development of the SOC software before launch. Such breadth and depth of experience turned out to be a major factor in the success of ISO science operations.

The SOC benefited greatly from having all functions (e.g. from establishing observing programmes to data distribution; from system design to software maintenance) integrated into the one centre as this streamlined interfaces and improved communications. For the same reasons, the co-location with the Spacecraft Control Centre was also very beneficial.

Another key factor was the extensive period of end-to-end tests and simulations through which the entire ground segment software and procedures were exercised prior to launch. Not only was this essential in uncovering bugs not found by lower level tests, but it also ensured that the whole SOC was fully trained and operational at launch. In particular, the full 58 days of the Performance Verification phase had been scheduled and validated on the software simulator prior to launch. This permitted that, 2.5 months after launch exactly as planned, the routine phase could start with over two-thirds of the observing modes fully commissioned and ready for use by the scientific community.

The Spacecraft Control Centre (SCC)

The Launch and Early Orbit Phase (LEOP) was supported directly from the Operations Control Centre at ESOC, Darmstadt; all subsequent operations were successfully supported from the SCC. The mission phases were as follows:

- Launch and Early Orbit Phase:
  17 to 20 November 1995
- Satellite Commissioning Phase:
  21 November to 8 December 1995
- Performance Verification Phase:
  9 December 1995 to 3 February 1996
- Routine Mission Phase:
  4 February 1996 to 8 April 1998
- Operations Run-Down Phase:
  9 April to 16 May 1998

Given the large number of relatively short observations, operations had to be carried out in an automated way. Starting from manual use of the Flight Operations Plan and associated procedures, operations were gracefully automated during the commissioning phase to use, by the end of this phase, a fully pre-programmed Central Command Schedule (CCS), reflecting the output product of the Mission Planning Phase 1 (SOC) and of the Mission Planning Phase 2 (SCC). This schedule contained all platform and payload commands. On average, some 10 000 commands had to be uplinked to the spacecraft every day. Therefore, only minimum operator intervention was required for spacecraft and instrument operations.

The CCS contained dedicated 'windows' during which either spacecraft or science operations could be scheduled. Additionally, 'event designators' and 'keywords' were defined that triggered certain command operations to be inserted in those windows, when required. A skeleton schedule for a revolution (orbit) is shown in Figure 2. The baseline approach during routine operations was that all four instruments were activated and de-activated automatically by the schedule, irrespective of whether a particular instrument was scheduled for use in that orbit or not.

To optimise the time available for scientific observations, spacecraft operations and instrument activation and de-activation were placed along an orbit in such a way that they did not use science time (defined as the time the satellite spent outside the main parts of the van Allen belts, i.e. above an altitude of approximately 40 000 km). Interleaved manual commanding was, in principle, only required to support ranging, ground station handover, and a few specific operations of the Attitude and Orbit Control Subsystem. The schedule offered 'hold', 'resume' and 'shift' functions in order to recover from, and to minimise the impact of, spacecraft, instrument or ground segment anomalies. When required, recovery from problems was initiated following the relevant Flight Control Procedures (FCPs) and Contingency Recovery Procedures (CRPs) of the Flight Operations Plan. It is worth noting that approximately 1000 FCPs and 500 CRPs had been written and validated with the platform simulator before launch.

During pre-launch testing, it was already realised that the command schedule was highly susceptible to ground-segment problems because of the very high scientific instrument command rate. In the event of problems, e.g. when commands could not be verified due to loss of telemetry, the schedule was suspended. In the worst case, a short drop in telemetry could cause the loss of a scientific observation of several hours' duration.

Throughout the in-orbit operations, a wide variety of efforts were successfully undertaken by the SCC to prevent or minimise the loss of

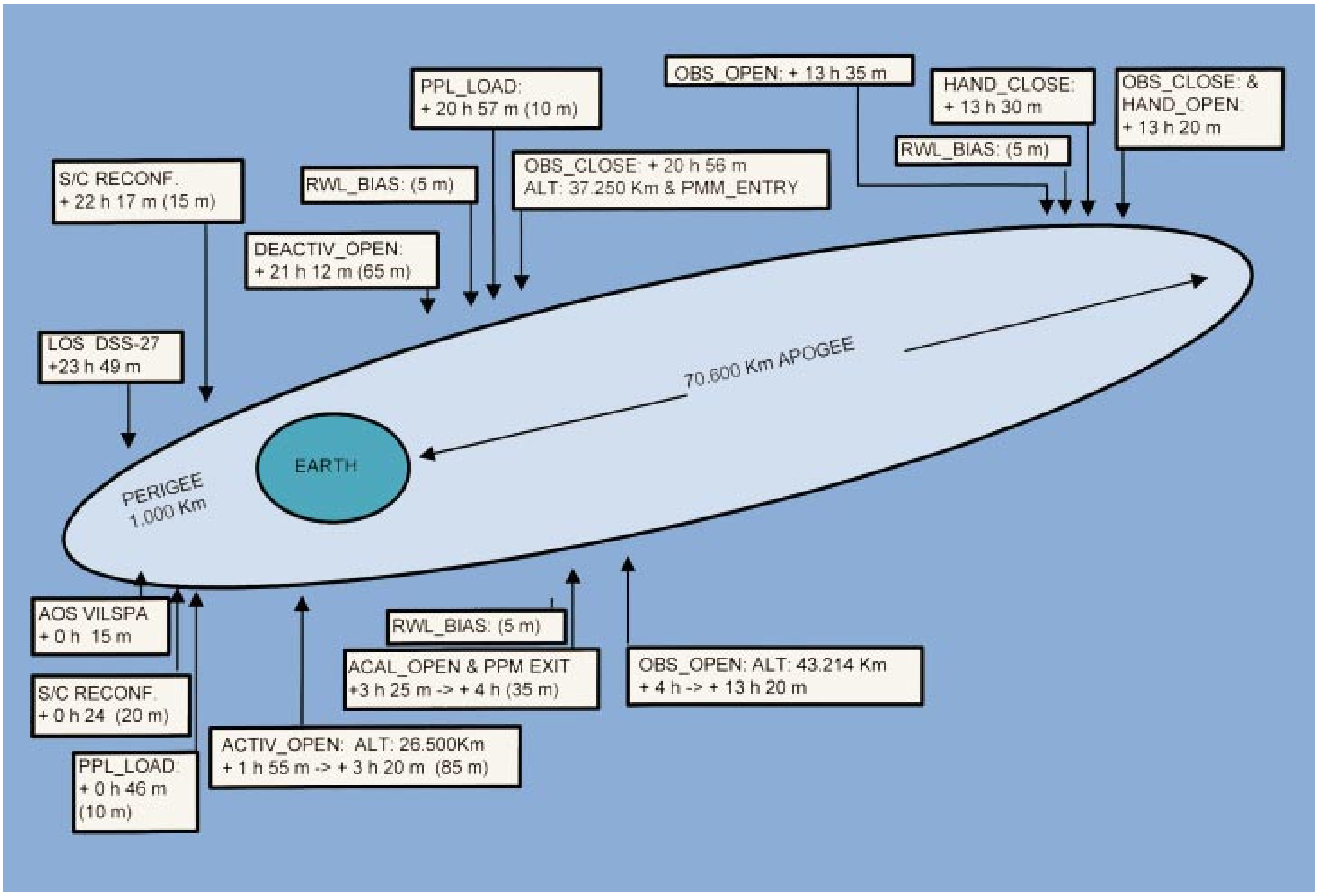


Figure 2. Skeleton schedule for ISO activities along an orbit, showing activities from acquisition of signal (AOS) at Vilspa to loss of signal (LOS) from the Goldstone DSS-27 antenna. Times are given in hours and minutes since perigee passage, and the duration of an activity is shown in brackets. Science observations started with the opening of the observation window (OBS_OPEN) about 4h after perigee passage and continued – with a short break at the time of handover from Vilspa to Goldstone – until OBS_CLOSE nearly 21h after perigee passage. The instruments were activated and de-activated during specific windows (ACTIV and DEACTIV), which also contained instrument calibration and trend analysis activities. PPL and PPM refer to a programmed pointing mode for autonomous pointings to an uplinked list of safe attitudes. During the ACAL window, various spacecraft attitude calibrations were carried out. Depending on the planned observing programme, the reaction wheels (RWL) had to be biased at various times during the day's operations

science. Major improvements included the implementation of an automatic telemetry link re-configuration on the ISO Dedicated Control System, which reduced the impact of telemetry drops considerably. The implementation of the Hipparcos/Tycho Guide Star Catalogue in the Flight Dynamics System (FDS) contributed greatly in solving the guide star acquisition problems encountered early in the mission. In a joint effort between the SOC and the SCC, a new observing mode was implemented for the Long Wavelength Spectrometer, enabling it to gather science data even when not scheduled as the 'prime' instrument.

Another improvement, which made a major contribution to the science output, was the reduction of the satellite's absolute pointing error from 4 arcsec during the commissioning phase to the 1 arcsec level in the routine phase, especially since the system specification was < 11.7 arcsec.

The ISO Mission Control System (see Fig. 3) performed all aspects connected with the operations and safety of the spacecraft, including safety monitoring of the scientific instruments. The hardware of the control system consisted essentially of two VAX 4600 redundant Spacecraft Monitoring and Control computers (ISORT/ISODV), six associated Sun SPARC-20 workstations, associated spacecraft control software, and the mission planning system software as far as Mission Planning Phase 2 was concerned. The system was designated as the ISO Dedicated Control System (IDCS). The FDS consisted of a set of five Sun workstations and dedicated software. These systems were networked on a partially-redundant OPSLAN to prevent single point failures and isolated the SCC from the outside world.

Two redundant micro-VAX 3100-76 computers formed the Operational Data Server system (ODS-1/2). The ODS constituted the interface between the spacecraft control system of the SCC and that of the SOC as far as science real-time data reception in the form of Telemetry Distribution Formats (TDF) was concerned. The latter contained not only telecommand history data, but also specially provided derived telemetry parameters. These parameters were utilised within the SOC for instrument monitoring and control purposes, using the Real-Time Technical Assessment (RTA) and Quick-Look Analysis (QLA) software, which ran on the four instrument workstations (one dedicated per instrument). The ODS was also the interface between the Mission Planning Phase 1 (MPP1) of the SOC and that of the SCC (MPP2) for interchanging mission planning files.

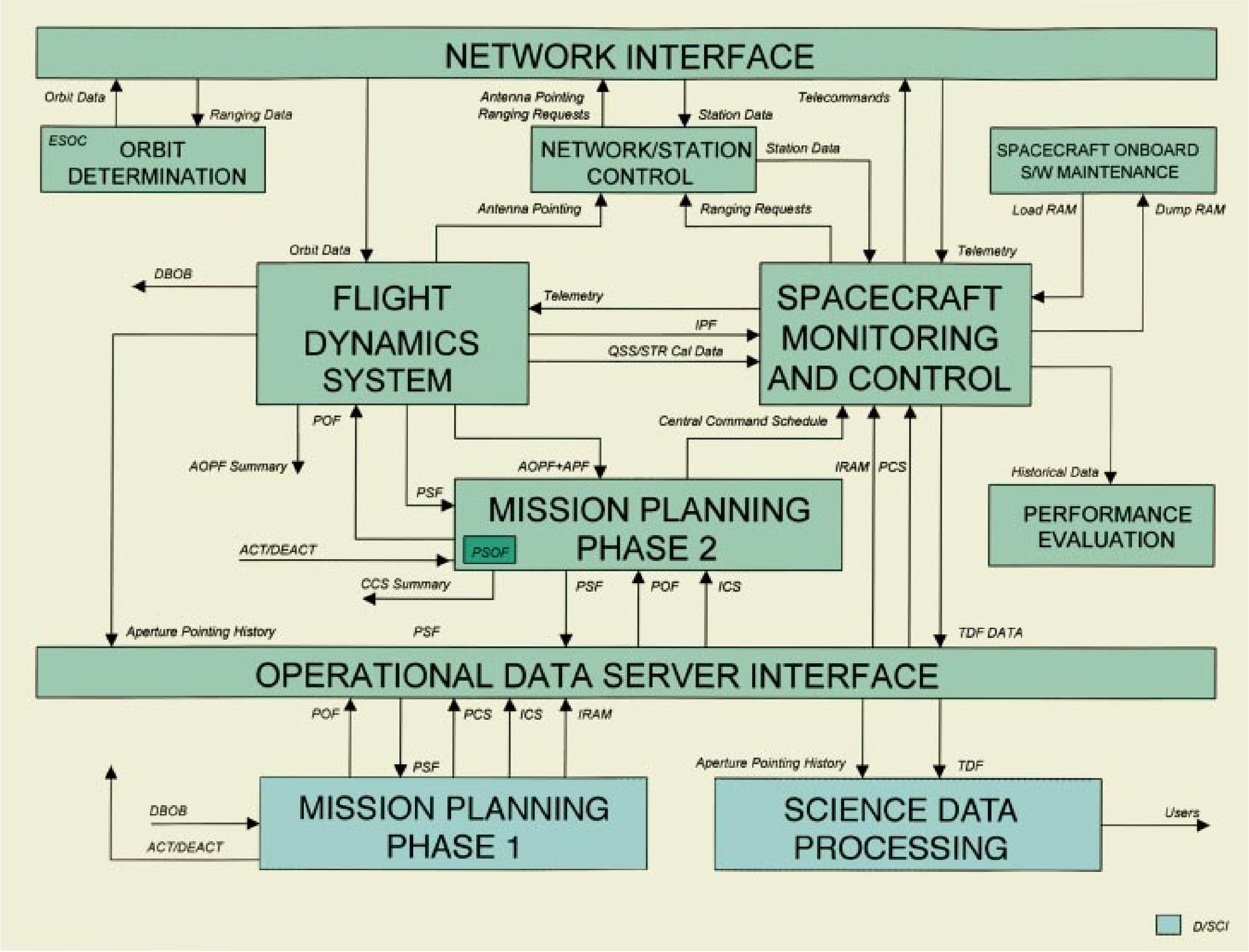
Furthermore, the ODS provided the short history archive of the science telemetry and archived TDFs onto optical disks for access from the SOC Science Data Processing system. The network interface provided the connectivity of the IDCS with the ground stations through the Integrated Switching System (ISS), as part of the OPSNET. Support functions were provided for: Spacecraft Performance Evaluation (SPEVAL), required to determine all aspects of spacecraft performance which could impact the life of the mission and mission efficiency; and spacecraft on-board software maintenance for the AOCS, STR and the OBDH. Communications Services were provided to interface with the ground stations, and with ESOC for ranging and orbit-related activities. Two spacecraft hybrid simulators were provided to support a variety of tasks, such as testing and validating procedures, AOCS on-board software maintenance and validation, and spacecraft anomaly investigation.

Extended mission

One very significant achievement was the mission extension beyond September/October 1997. During this time, ISO's orbital geometry was such that it underwent eclipses of exceptionally long duration. Additionally, during early September, marginal violations of the Earth constraint on the pointing direction could not be avoided for some minutes each day as ISO went through perigee. Since the spacecraft was required to be operated beyond design specifications with respect to power, Sun and Earth constraints, it was necessary to develop and implement a new operations strategy, which deviated considerably from the well-proven routine-phase operations concept. In addition to the above, there was a strong requirement from the scientific community to observe the Orion and the Taurus regions of the sky, which became visible to ISO during this period for the first time in the mission.

During the period 7 September to 7 October 1997, when eclipses reached a maximum of 166.5 minutes, i.e. more than twice as long as the baseline design of 80 minutes, the power of the two batteries had to be preserved by switching off non-essential units, by restricting scientific pointings to one observation during eclipse, and by restricting the use of the

Figure 3. The ISO Mission Control System



instruments to two out of four during the peak eclipse period. To ensure proper pointing stability in eclipse, a second ‘roll star’ was used by the Star Tracker. This star, some 2° away from the guide star, was used to control the gyro drift with respect to the satellite x-axis and hence the telescope boresight. At the same time, the Earth warning and forbidden regions had to be violated, since no constraint-free corridor was left around perigee. This was crucial for the Attitude and Orbit Control Subsystem (AOCS) and therefore for the telescope pointings around perigee. In order to reduce the impact of the penetration into the Earth-constraint region, the Sun constraint had to be relaxed.

All of the above required disabling most of the autonomous fallback functions of the AOCS and On-Board Data Handling Subsystems, i.e. the satellite was safeguarded by relying on ground control only. Both on-board batteries showed excellent performance with less than expected depth of discharge and reached full charge each revolution. The effect of violating the Earth constraints was less than predicted. The telescope upper baffle temperatures increased by just under 4 K, returning to nominal temperatures within 45 minutes thereafter. The AOCS pointing performance was very stable and hence scientific observations performed during eclipses did not suffer from any degradation in pointing. The period passed uneventfully and routine operations continued until the helium was depleted on 8 April 1998.

After helium depletion

After depletion of the liquid helium supply, an extensive ‘technology test programme’ was carried out with the spacecraft. Interleaved with these technical tests were observations using the shortest wavelength detectors of the Short Wavelength Spectrometer instrument to extend a stellar spectral classification scheme to the infrared. Various software and hardware systems that, due to the superb performance of the spacecraft, did not have to be used during the operational phase were subjected to detailed tests. Results from these tests will benefit future ESA missions, e.g. XMM and Integral, which use some of the same components, such as the Star Trackers guiding the spacecraft.

Operations summary

Operations ran very smoothly from the start. They were well served by a superb spacecraft, working much better than specified, and by robust instruments which, in general, suffered only a few anomalies of a relatively minor nature. All elements of the ground segment also performed excellently, leading to an overall system availability during routine-phase operation of 98.3% of the time scheduled for science. Taking into account all possible reasons for failure, only 4% of observations were lost.

Very few anomalies occurred with the spacecraft and the instruments. The largest single spacecraft anomaly occurred in May 1996, when a sequence of on-board events led to the Earth entering ISO’s field of view for about 2 minutes. No damage was done to the satellite and full science operations were resumed within 36 hours. On the instrument side, the main anomalies were periodic increases in noise for some of the detectors of the photometer and some positioning difficulties with an exchange wheel of the Long Wavelength Spectrometer. Scientific usage of the instruments was temporarily interrupted while solutions were determined, tested and implemented.

During the routine operations phase, some 50 000 pointing requests (slews) were executed in order to carry out over 31 000 observations (including astronomical calibration observations). In total, over 26 450 science observations were carried out successfully for nearly 600 observers in over 1000 separate research programmes. About 400 hours of science observations were carried out per month, with an average of 41 observations per day but ranging from 6 to 238. The average observation duration was 24 minutes, with the shortest single observation having had a duration of 36 secs (a camera calibration) and the longest single observation having been nearly 8 hours on Titan. Figures 4 and 5 give information covering the relative usages of the different instruments and observing modes.

Organisation

The SCC was led by the Spacecraft Operations Manager and, throughout the routine operations phase, there were 28.3 staff in post (Fig. 6).

The SOC was organised into two teams: the science team, led by the Project Scientist, which was responsible for community support and for setting the overall policy for the SOC; and the operations team, led by the Science Operations Manager, which was responsible for instrument operations and the SOC infrastructure. On average during the routine phase, the SOC had 92 members (Fig. 7).

Future scientific activities

A collaborative effort, coordinated by the ESA

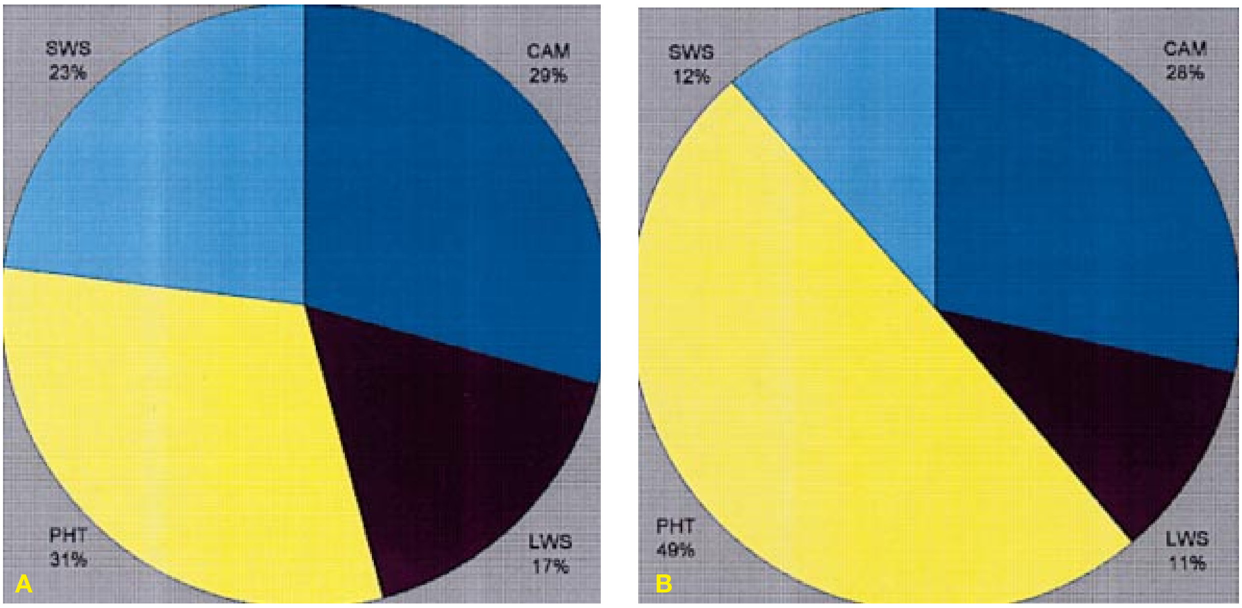


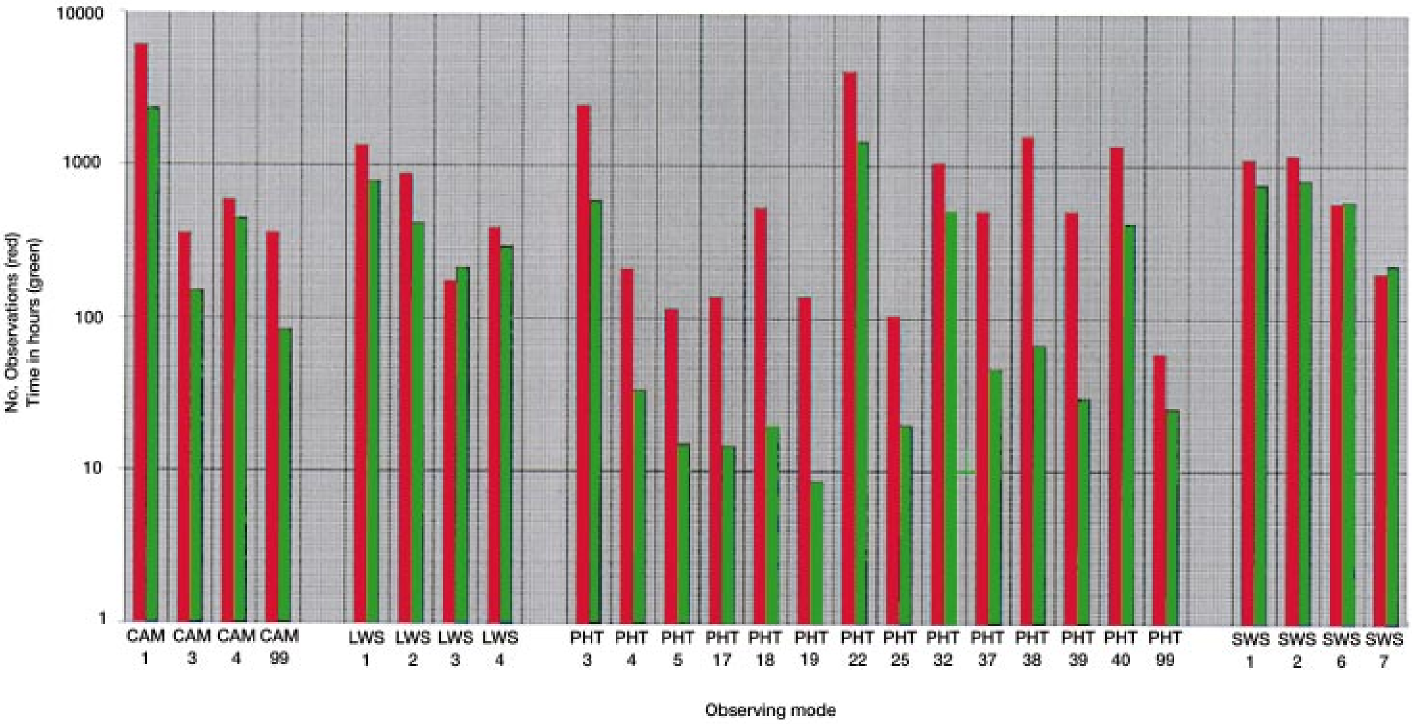
Figure 4. Relative usage of the four ISO instruments by (a) time and (b) number of observations.
(CAM = Camera; PHT = Photometer; SWS = Short Wavelength Spectrometer; LWS = Long Wavelength Spectrometer)

ISO Data Centre at Villafranca in Spain, is already underway to maximise the scientific return of the mission by facilitating effective and widespread exploitation of the data and by preparing the best possible final archive to leave as ISO's legacy. This effort is expected to last until the end of 2001 and includes deepening the understanding of the performance of the instruments and the satellite, improving the data processing and supporting the general community in the usage of ISO data products. The first homogeneously-processed archive of ISO data will open via the WWW in autumn 1998.

The centres involved in this effort are:

- ISO Data Centre at Vilspa in Spain
- Five Specialist National Data Centres (NDC):
  - French ISO Centres, SAp/Saclay and IAS/Orsay, France
  - ISOPHOT Data Centre at MPIA in Germany
  - Dutch ISO Data Analysis Centre at SRON in the Netherlands
  - ISO Spectrometer Data Centre at MPE in Germany
  - UK ISO Data Centre at RAL in the United Kingdom
- ISO Support Centre at IPAC in the United States.

Figure 5. Usage of the different observing modes of the four ISO instruments by time (green) and number of observations (red)



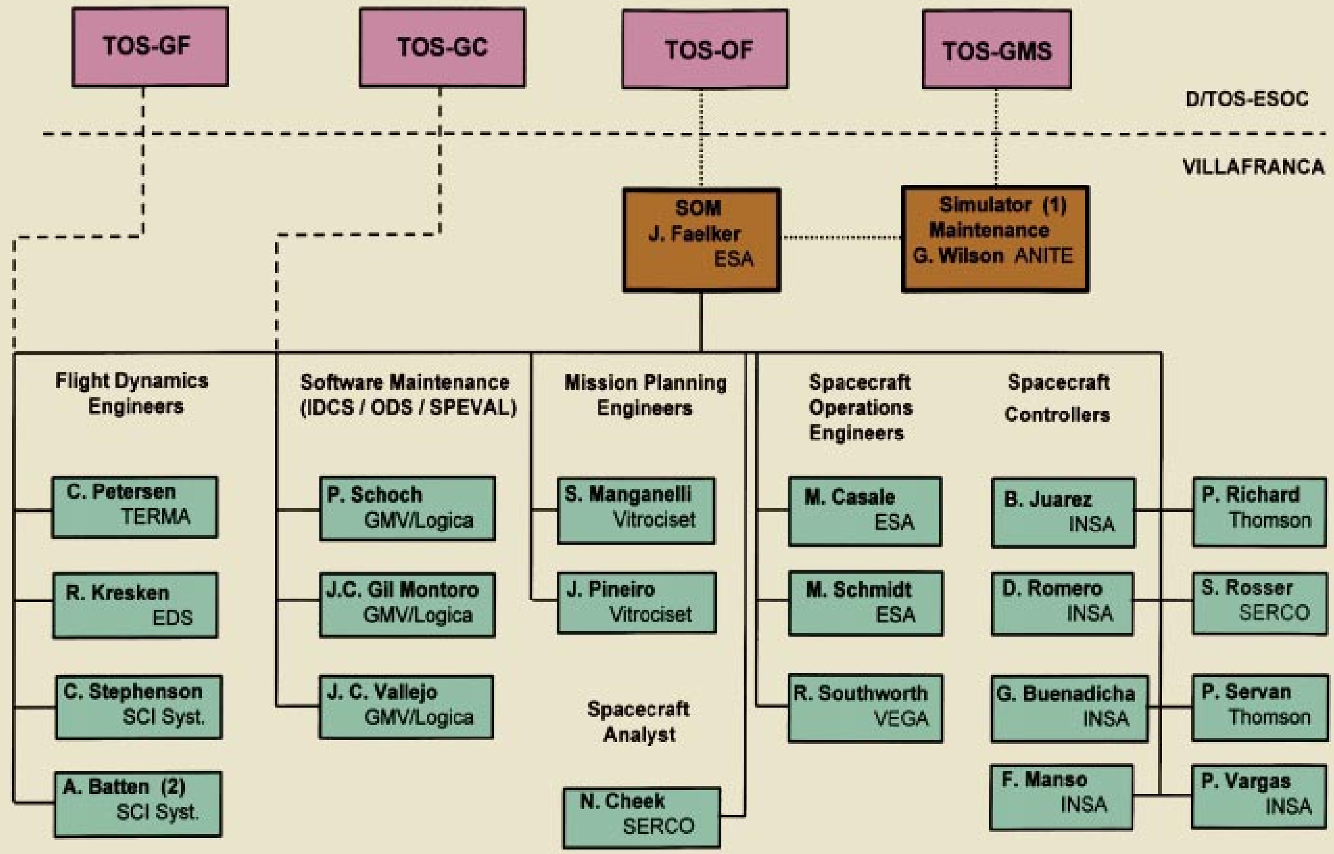


Figure 6. Organisation of the ISO Spacecraft Control Centre (SCC), showing routine phase staffing levels

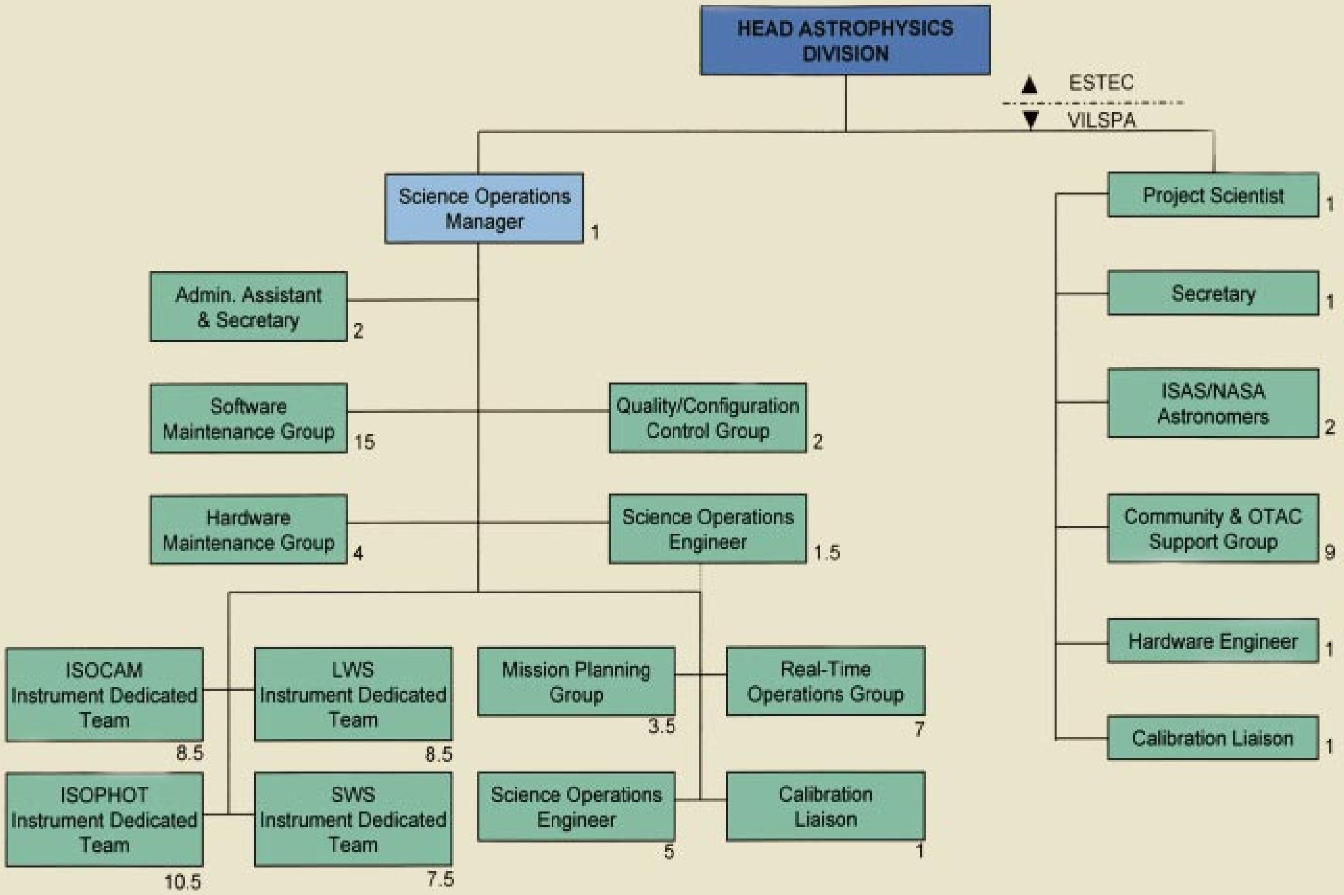


Figure 7. Organisation of ISO Science Operations Centre (SOC), showing average staffing levels during the routine operations phase

Figure 9. The ISO Spacecraft Control Room

The ESA ISO Data Centre is responsible for the archive, the general off-line processing ('pipeline') software and supporting the general European user community. The National Data Centres (NDCs) are responsible for detailed instrument-specific software and expertise, including the provision of software modules for the pipeline, and for supporting their local and national user communities. IPAC is responsible for supporting the US user community.

Conclusions

ISO was an outstanding technical, scientific and operational success. Operations were conducted effectively and efficiently by the teams of the Spacecraft Control Centre and the Science Operations Centre, co-located in Villafranca, Spain. The satellite commissioning and performance verification phases were carried out as planned, enabling the scientific data gathering phase to start on time with a well-understood satellite. There was very little down time, with overall system availability in the routine phase being above 98%. Taking into account all possible reasons for failure, only 4% of observations were lost and at least some of these will be recovered during the post operational phase. The timelining system for the observations yielded an average scheduling efficiency of 92%.

All of this was made possible by the professionalism, competence, dedication and sheer hard work of all personnel involved in the preparation, testing and execution of this challenging but highly rewarding mission.

ISO's lasting legacy to the scientific community is a huge treasure trove of tunique and top-quality data, exploitation of which has barely started. Doubtless, over the coming years, many more ISO provided astronomical surprises await us!

Figure 10. The ISO Instrument Control Room