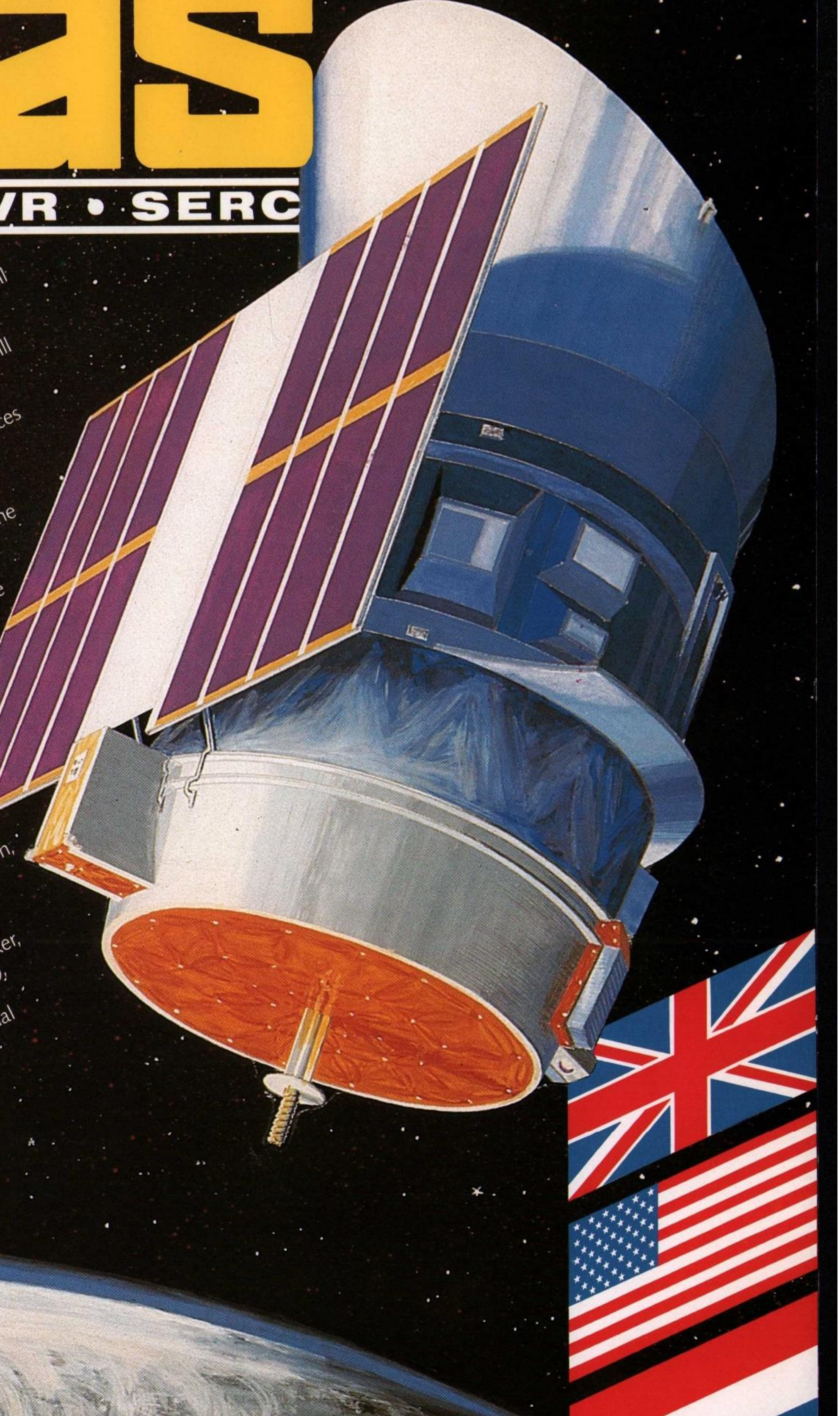
IRAS

NASA • NIVR • SERC



The mission of the Infrared Astronomical Satellite is to perform an all-sky survey in wavebands from 8 to 120 microns and to make further special observations of selected sources. IRAS will extend greatly our knowledge of the heavens in this spectral region and is expected to lead to fundamental advances in our understanding of the Universe.

The project is an international venture involving the UK, the USA and the Netherlands.

UK: Ground station, control centre and software for data acquisition, engineering and preliminary science analysis. (Rutherford Appleton Laboratory, Chilton, Oxon.).

USA: Telescope system, survey instrument and final data analysis. (Jet Propulsion Laboratory, California. Main contractor for telescope system —Ball Aerospace Systems Division, Colorado.) Launch by two-stage Delta 3910. (Western Test Range, California.)

NETHERLANDS: Spacecraft (Fokker, Signaal, National Aerospace Laboratory), additional instruments package (Space Research Department, Groningen), partial responsibility for control centre software. (National Aerospace Laboratory).

ASTRONOMICAL OBJECTS IN THE FAR INFRARED

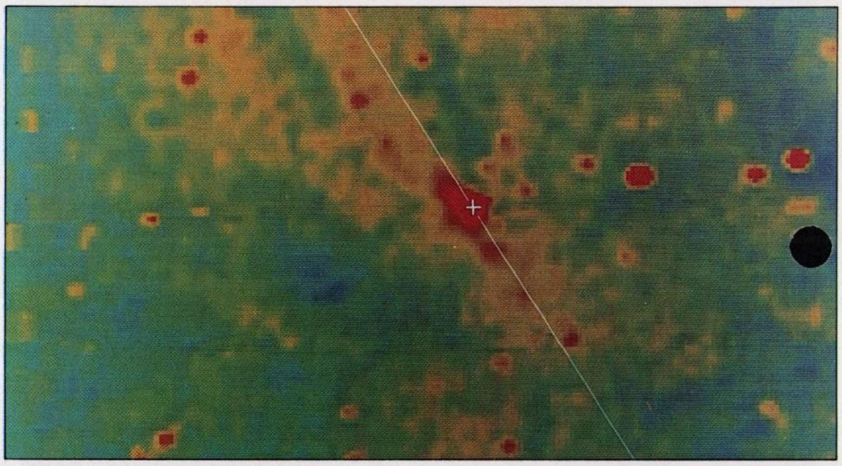
Introduction

Many of the sources which we study astronomically radiate approximately as "black bodies" – i.e. the spectrum of their radiation has a particular form which peaks sharply at a certain wavelength, λ_{max}, given approximately by $\lambda_{max} = 2900/T$, where λ_{max} is in μm ($1\ \mu m = 10^{-6}$m) and and T is the temperature of the body in K. Over the IRAS detection range of around 10 to 100 μm we expect therefore to observe thermal sources having characteristic temperatures between 40K and 400K; these are of a very different nature from those which peak at optical wavelengths (e.g. yellow light would correspond to a blackbody source of about 6000K). These infrared sources may be intrinsically cool – possibly because they are at the beginning or end of their lifecycles; more commonly they are hotter sources surrounded by dust, which absorbs and degrades the shorter wavelength radiation

Star Formation Regions. Stars are believed to form in high-density regions of gas and dust; within a spiral galaxy like our own, these conditions pertain primarily in the massive clouds which populate the Galactic Plane. The newborn stars radiate at first as intense infrared sources, as they remain cocooned in the dust clump from which they were formed. The Eta Carinae nebula is believed to be a site of star formation.

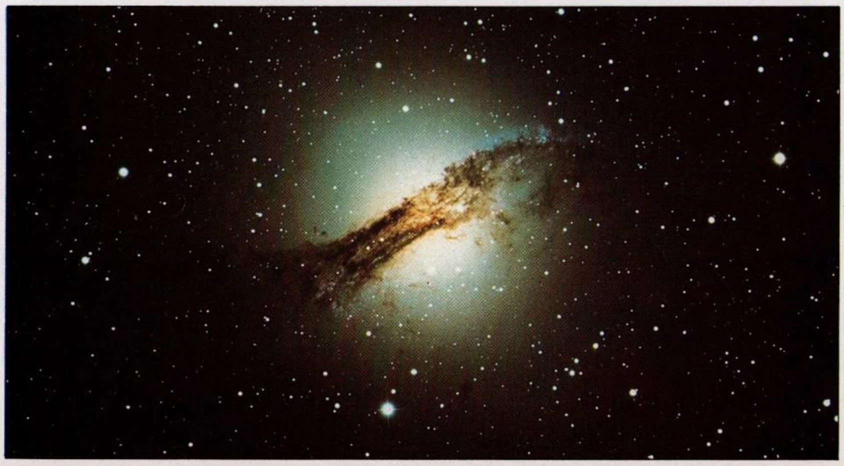
Anglo Australian Telescope Board

The Galactic Centre. At optical wavelengths we are not able to see the actual centre of our own Galaxy, because the dust which populates the Galactic Plane (the "Milky Way") absorbs the short optical waves before they reach us. However, the longer infrared waves are able to travel through this dust barrier, and reveal a fascinating variety of sources, the nature of which is not yet fully understood. Shown opposite is a computer-generated, near-infrared picture of the Galactic Centre (2.2 μm, Becklin and Neugebauer).



Active Galaxies. An "active" galaxy is one whose luminosity at a given wavelength is much greater than that anticipated from its expected stellar content. One of the major discoveries of infrared astronomy to date is that many galaxies exhibit an enormous infrared "excess". Among these objects there are Seyfert, radio and peculiar, dusty galaxies, as well as relatively normal-looking objects previously thought to be quite ordinary galaxies.

Centaurus A (=NGC 5128) is a well-known radio galaxy containing infrared sources behind the dark, obscuring matter which appears to bisect the galaxy.



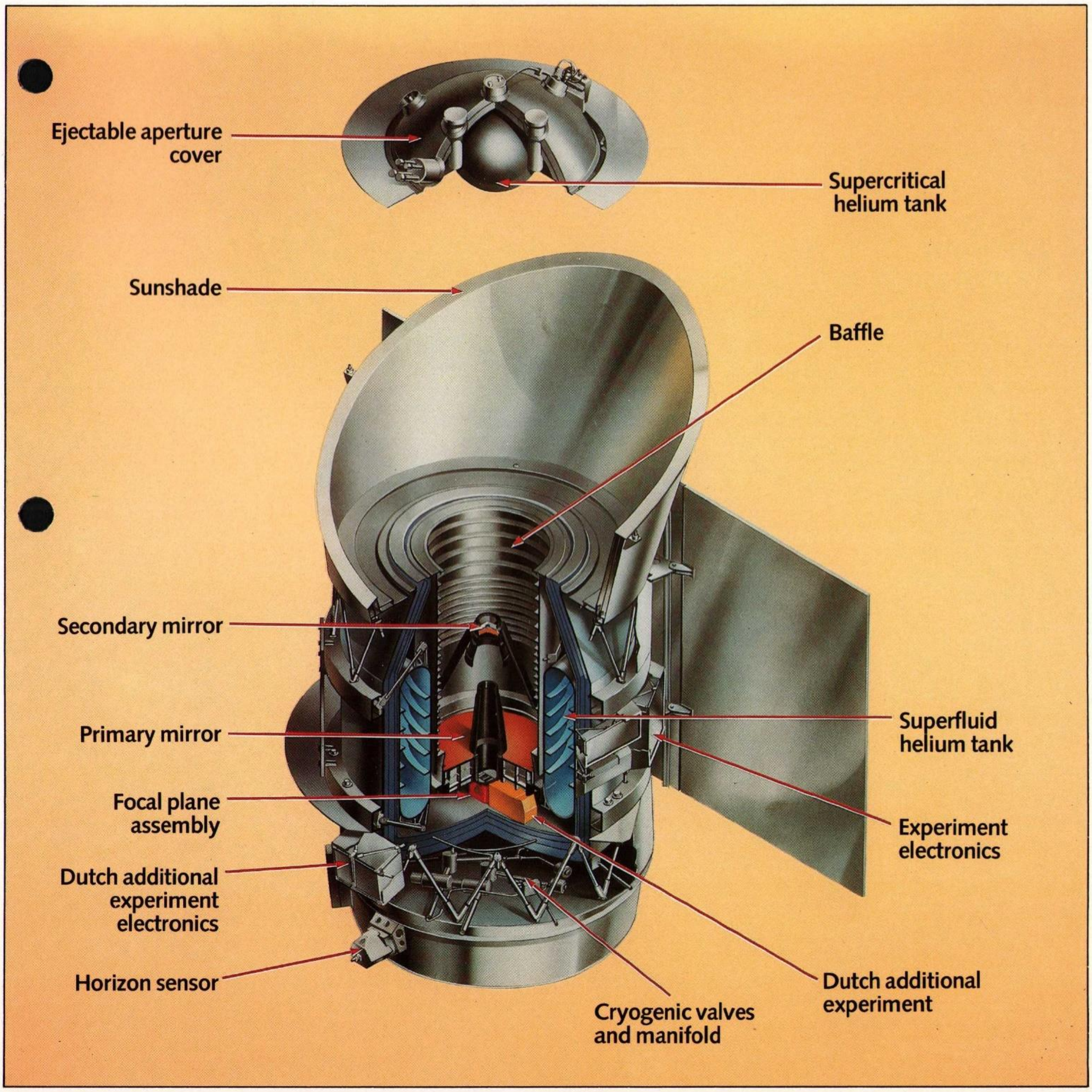
Photolab, ROE

IRAS A COOLED TELESCOPE IN SPACE

The IRAS is composed of two major units, namely the infrared experiment hardware and the spacecraft. Together they form a cylinder with a length of 3.5 metres and a diameter of 1.5 metres which, at launch, will weigh about 1100kg. The experiment hardware is comprised of a cooled, Cassegrain like (Ritchey-Chrétien) telescope with a 60cm beryllium primary mirror and (situated at the focal plane of the telescope) an array of 62 infrared detectors for the survey, a low-resolution infrared spectrometer, a mapping photometer and a star-counting instrument for statistical work. Visual star sensors provide accurate attitude checks.

In order to detect the weak infrared signal from astronomical objects above that from itself, the telescope system is surrounded and cooled by a liquid helium cryostat which, by virtue of its extremely low temperature ($\lesssim$ 16K) emits negligible infrared radiation. The boil-off rate of the liquid helium dictates the mission lifetime of around 9 months.

The spacecraft part of the satellite contains the hardware and software for controlling its attitude while in orbit, and for storing the collected data and relaying it to the ground station at RAL.



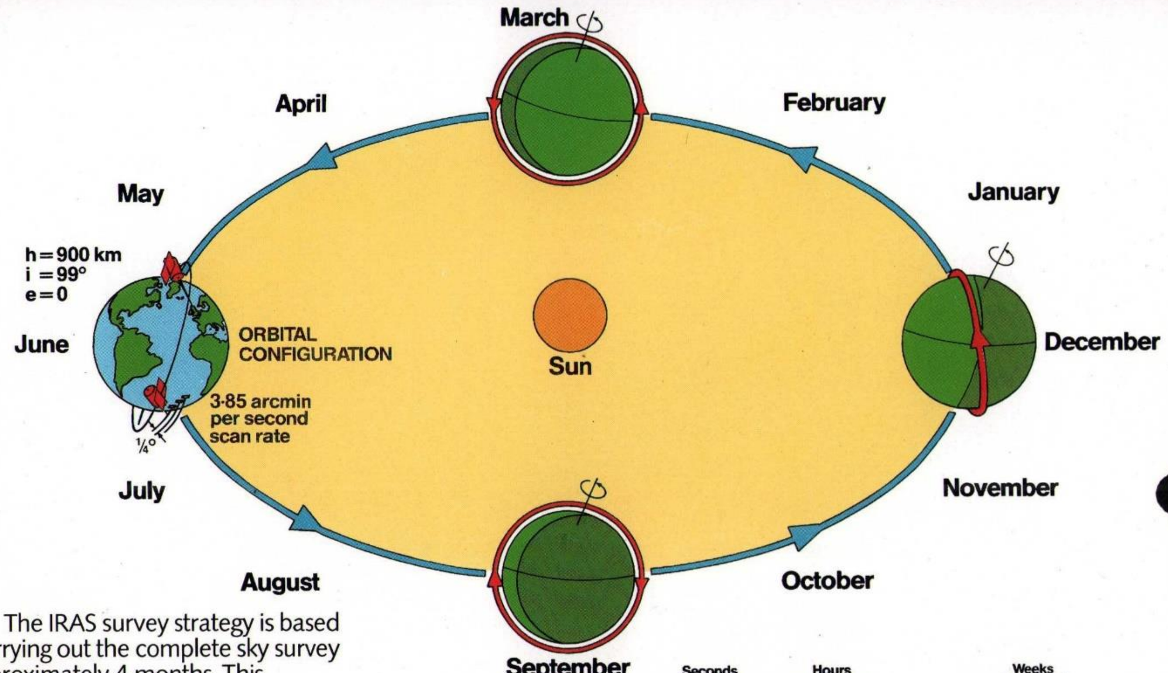
THE IR SURVEY AND ADDITIONAL OBSERVATIONS

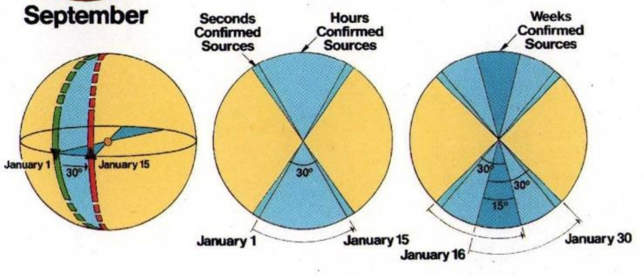
The need for an Infrared Survey. Had an intelligent species developed on the surface of Venus, the history of their astronomy would have been very different from ours. Unable to see through their perpetual cloud, but detecting radio emission from outside the planet, they would first have developed radio astronomy. The picture of the Universe emerging from this would look strange to our eyes. The Galaxy would appear as a continuous plane of emission containing more or less compact hot spots at various wavelengths produced by ionised hydrogen and molecular cloud emission. Here and there would be a few point-like pulsating objects. Only one star would be seen – the Sun.

Objects seen outside the galaxy would be mainly radio galaxies and quasars and the predominant structure observed would be jets and large radio lobes. Some spiral structure would be seen in nearby galaxies.

The development of space vehicles would lead to optical observations which would obviously be concentrated initially on known radio objects. A complete optical picture of the Universe, such as we are familiar with, might take long to emerge.

Infrared astronomy on Earth is in an analagous position to optical astronomy in the hypothetical Venerian society. Because of problems caused by the Earth's atmosphere, infrared observers have concentrated on objects detected at optical and radio wavelengths. One has only to reflect on the astronomical revolutions produced by radio and X-ray surveys to realise how strong is the call for an unbiased infrared sky survey. We have no way of predicting the infrared equivalent of radio quasars or X-ray bursters, which is precisely why the IRAS survey must be done.





The IRAS survey strategy is based on carrying out the complete sky survey in approximately 4 months. This strategy makes use of the one-degree daily precession of the satellite orbit.

A major constraint on the mission is the need to avoid radiation from the Sun entering the telescope. The IRAS sunshade has been designed so that the telescope can be pointed within the range 60° to 120° from the Sun and the survey strategy has been designed so as to be well within this constraint. On the assumption that the survey commences on say, 1 January, two 30° wide lunes are defined on the celestial sphere and these are scanned until 15 January. The design of the focal plane array permits "seconds-confirmation" with a single traversal of a source. Also, since the instrument's ½° wide field is overlapped ¼° on successive orbital scans, sources in the first lune may be "hours-confirmed."

From 16 January until 30 January two further lunes are scanned, which overlap the previous two lunes by 15°. Continuing in this way the complete celestial sphere will be scanned and all sources seconds, hours and weeks confirmed, within ~ 4 months.

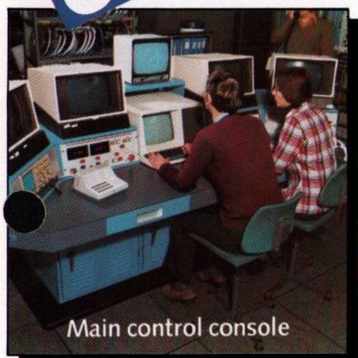
For a nominal forty per cent of its mission IRAS will perform non-survey or "additional observations" of astronomical objects of special interest. U.K. astronomers must compete for some of this time just as they would for time on ground-based telescopes. Both survey and non-survey instruments may be utilized for additional observations.

THE IRAS OPERATIONS CONTROL CENTRE AT RAL

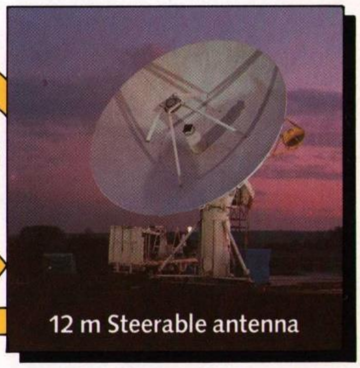
The IRAS on-board tape-recorder can store up to 14 hours worth of observed data. Twice a day, when the satellite passes over the Chilton Ground Station, the recorded data are relayed over an S-band link to earth and received by a 12 metre, steerable, Cassegrain antenna.

Commands

Data



Main control console



12 m Steerable antenna

Twin PDP 11/34 system

Real-time operations, science data pre-processing, non-survey data preliminary analysis.

Science and attitude data

DATA DISTRIBUTION → NASA WIDE-BAND DATA LINK → JPL FOR PRODUCTION OF FINAL CATALOGUE

Engineering, attitude and survey science data

ICL 2960

Observation planning, engineering analysis and preliminary science analysis.

The received signals are converted from S-band to 50 Mhz before being passed by cable to further receiving equipment in the Control Centre, where they are demodulated before input to a twin PDP 11/34 system for processing. During the same pass over Chilton the satellite's next 12-hour sequence of observations, or Satellite Observation Plan (SOP), stored on the PDP11s is transmitted via the antenna to the IRAS on-board computer.

As well as being responsible for the above "real-time" tasks, the PDP11s sort the various data streams, i.e. science, engineering and attitude data, and process and/or distribute it to other computers. Science and attitude data go to JPL for final processing and eventual compilation of the survey catalogue, all data other than non-survey science data go to the Control Centre's ICL 2960 and, finally, non-survey science data are processed on the PDP11s by Dutch scientists resident at RAL.

The survey science data are pre-processed on a PDP11-linked AP 120B array processor for rapid extraction of point and compact sources from the raw data stream. A magnetic tape file of these sources is passed to the 2960 for further processing.

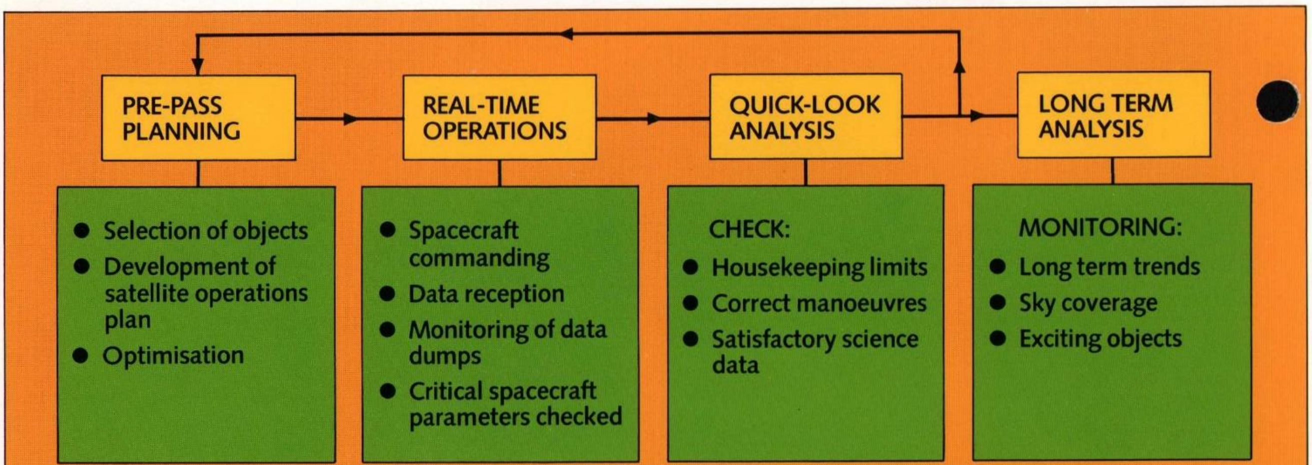
The Control Centre mainframe, an ICL 2960, is responsible for the production of each SOP, analysis of engineering data and preliminary analysis of science data. A large, interactive software package enables scientists and survey planners to produce Experiment Target Lists which are converted into SOPs and then passed to the PDP11s for subsequent transmission to the satellite. To help spacecraft and telescope engineers understand the day-to-day and long term functioning of IRAS, a Satellite Evaluation software package is provided. Finally, a Preliminary Analysis Facility helps scientists monitor the daily functioning of the infrared survey experiment and perform quick-look analysis of science data.

MISSION OPERATIONS AND PRELIMINARY ANALYSIS

The Mission Operations organisation at RAL comprises a number of teams whose main functions are:-

1. To plan and to incorporate the observations to be performed by the satellite into a daily operations schedule.
2. To implement the schedule during a satellite pass over the Chilton Ground Station by sending commands to the satellite and observing the telemetry data being received.
3. To assess the current state of the satellite by monitoring engineering, pointing direction and scientific data during and immediately following a satellite pass.
4. To assist in the long term planning of observations by monitoring trends, ensuring that the sky is being covered and monitoring the scientific data to ensure that unusual infrared sources are adequately observed.

The tasks of the various teams broadly divide, therefore, into pre-pass planning, pass execution and post pass analysis. To do these tasks about 100 scientists and engineers will work at RAL during the satellite lifetime, augmented during the critical post launch phase by up to 50 specialist hardware and software systems engineers.



Quick-look analysis is concerned with a rapid assessment of the scientific quality of the survey data. The objective is to assess the data from any pass sufficiently quickly that corrective action or recovery scans can be carried out on the next prime pass, approximately 12 hours later. The assessment is made by comparing the point-source detections with known infrared sources, thus providing a check on the efficiency of the individual detectors. Checks are also made on detector noise characteristics and on detection statistics.

Long term analysis is concerned with setting up three main data bases for subsequent analysis by the astronomers. These data bases are for selected objects, selected fields and new sources. The first two are specified by the astronomers as objects or regions of the sky of special interest: the third may be termed "IRAS discoveries." Confirmation techniques on time scales of seconds, hours and weeks are applied to eliminate false sources from the data bases. The astronomers are provided with an interactive computer graphics capability to perform preliminary science analysis on each of the data bases.

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