FIRST – FAR INFRARED AND SUBMILLIMETRE SPACE TELESCOPE

Göran Pilbratt
Astrophysics Division/Space Science Department of the European Space Agency
ESTEC/SA, P.O. Box 299, NL–2200 AG Noordwijk, The Netherlands
Internet: GPilbratt@estsa2.estec.esa.nl

ABSTRACT

The present status of the ESA cornerstone mission FIRST is presented. The history of FIRST, including its place in the ESA science programme "Horizon 2000", is briefly reviewed as an introduction and background to the ongoing industrial study. Currently an industrial consortium is studying a FIRST concept with a 3 m telescope, employing mechanical cryo-coolers for payload thermal control. The model payload consists of a the Multi-Frequency Heterodyne receiver (MFH), a nine-channel heterodyne instrument covering selected bands in the range 500–1200 GHz (250–600 μm) for very high resolution spectroscopy, and the Far InfraRed instrument (FIR), a dual channel direct detection instrument emplyoing a photoconductor and a bolometer array, dual Fabry-Perots and filters for spectroscopy and photometry in the range 100–400 μm (0.75–3 THz) and an internal ^{3}He/^{4}He dilution sub-Kelvin refrigerator. With this payload FIRST will able to successfully address the great majority of the of the scientific objectives defined for the submillimetre cornerstone observatory from its 24-hour highly eccentric operational orbit, where observations can be conducted up to 17 hours per day. If selected for implementation as cornerstone number 3 later this year, FIRST could be launched in the year 2002/2003 timeframe.

1. INTRODUCTION

The Far InfraRed and Submillimetre Space Telescope (FIRST) is one of the cornerstone missions in the "Horizon 2000" long term ESA science programme plan. FIRST is intended to open up the submillimetre (submm) and far infrared (FIR) part of the electromagnetic spectrum, taken to be roughly 1–0.1 mm (or, equivalently, 300–3000 GHz), which is still mainly inaccessible for observational astronomers.

FIRST was originally proposed in 1982 and an assessment study[1)] was carried out in 1983. It was then reproposed in the context of a call for ideas for missions to be undertaken in the "Horizon 2000" long term science plan. Subsequently a submillimetre mission was incorporated in the plan as one of the four cornerstones, and was then identified with the FIRST concept.

The scientific objectives and mission requirements of the this cornerstone were discussed in 1986 in a workshop in Segovia[2)], and in 1987 a Science Advisory Group (SAG) was established, its terms of reference being to trade off scientific objectives, as defined in the Segovia meeting, against technical complexity and cost constraints.

In 1990–91 a System Definition Study (SDS) was carried out, which resulted in a spacecraft concept[3)] with a passively cooled non-deployable 4.5 m Cassegrain submillimetre telescope and a helium cryostat cooling the focal plane instrument assembly consisting of heterodyne receivers and direct detection imaging instruments for spectroscopy and photometry.

Since the total cost to completion of a mission with this spacecraft was found to be too high for ESA, a rescoped spacecraft employing mechanical coolers for payload cooling, a 3 m antenna, revised payload complement and less stringent pointing requirements is currently being studied, with a view to offer a less costly solution.

2. SCIENTIFIC OBJECTIVES OF FIRST

FIRST will open up the perhaps last major part of of the electromagnetic spectrum yet unobserved. In the "Horizon 2000" document[4)] the Space Astronomy Survey Panel lists 10 outstanding problems, 5 of which are described as directly depending on observations with a space mission for the submm/FIR. They are:

(i) formation and evolution of stars and planets, (ii) structure and dynamics of the interstellar medium, (iii) nature of the galactic centre, (iv) formation and evolution of galaxies, and (v) large scale structure and evolution of the universe.

These topics are still the essential goals, and FIRST will be the first submm/FIR observatory available to the whole scientific community to address them appropriately. Opening up a new part of the spectrum can be expected, as always, also to lead to serendipitous discoveries.

3. FIRST MODEL PAYLOAD

FIRST needs a complement of instruments for high and medium resolution spectroscopy, imaging and photometry covering as much a possible of the submm/FIR range. As presently defined the model payload is being used to define requirements, interfaces, operation and performance of the spacecraft for study purposes. The actual payload to be flown will be proposed by individual institutes or consortia as a response to an invitation issued by ESA; it could well differ from the model payload used in the course of this study.

The cryo-cooler design constrains the science payload to a maximum of two independent instruments. It is comprised of the MultiFrequency Heterodyne (MFH) receiver and the Far InfraRed (FIR) instrument.

The MFH receiver is a nine-channel instrument covering selected bands in the 500–1200 GHz regime. The design is fairly unsensitive to the exact allocation of bands for the individual mixers, and can be tailored in a number of ways. The mixers should ideally all be superconducting-insulator-superconductor (SIS) quasi-particle mixers, however, at the moment the demonstrated high frequency limit for SIS mixers is well below 1200 GHz. In the model payload design provision has been made (quite arbitrarily) to have one Schottky-mixer channel and eight SIS-mixer channels. The operating temperatures of the SIS and Schottky mixers are 4 K and about 25 K, respectively.

The local oscillator (LO) sources are phase-locked solid state oscillators followed by multipliers. A combination of digital autocorrelators and acousto-optic spectrometers will be used. LOs and spectrometers are operated at "room" temperature.

The FIR instrument employs a stressed Ge:Ga photoconductor array, as well as a bolometer array, to cover the range 100–400 μm. Two Fabry-Perot interferometer system wheels, and a filter wheel, are used for selecting the mode of the instrument, which can be high or medium/low resolution spectroscopy, or photometry.

The photoconductors must be operated at approximately 1.6 K and the bolometers at 0.15 K, necessitating further cooling from the 4 K provided by the spacecraft. A $^3He/^4He$ dilution cooler, internal to the instrument except for its helium tanks, will be used for this purpose.

4. FIRST SPACECRAFT AND MISSION

The cryo-cooler FIRST spacecraft concept (cf. Fig. 1) is split into a payload module (PLM) and a service module (SVM). The PLM is made up of the submillimetre telescope, the focal plane assembly with its associated cryo-cooler thermal control, attitude measurement sensors and thermal shield. The change from a cryostat to cryo-coolers has necessitated a total redesign of the PLM. The SVM provides the general infrastructure, e.g. power, attitude control, and telemetry.

The most challenging items on the spacecraft are probably the telescope and the cryo-coolers. The telescope is of Cassegrain design, protected from direct Sun- and Earth-shine by a fixed thermal shield, and has a non-deployable 3 m diameter main reflector. The baseline main reflector design concept is an all-CFRP sandwich monolithic "panel-only" construction, without a separate backing structure. A "shaped" subreflector may be used to further minimize the wave-front error.

The focal plane instruments will be provided with a 4 K environment by the spacecraft mechanical cryo-coolers. Three different but related types of coolers will be employed; single-stage and dual-stage Stirling cycle coolers ("65 K" and "20 K" coolers) and the dual-stage cooler with a Joule-Thomson (JT) stage added ("4 K" cooler). The "65 K" cooler has never failed in space and the other two are in various stages of space qualification.

The pointing accuracy is specified as 6″ (with a goal of 4″) absolute, with a stability of 3″ (goal 2″). After a shared launch by Ariane 5 to geo-stationary transfer orbit, FIRST will propel itself into its operational orbit, which is a highly eccentric (1000 x 70600 km) 24-hour (ISO-type) orbit with low (10 degrees) inclination, potentially offering 17 hours of observations per orbit. There will be no observations while in eclipse, and the operative mode will be near real-time with direct transmission of data to either of two ground stations.

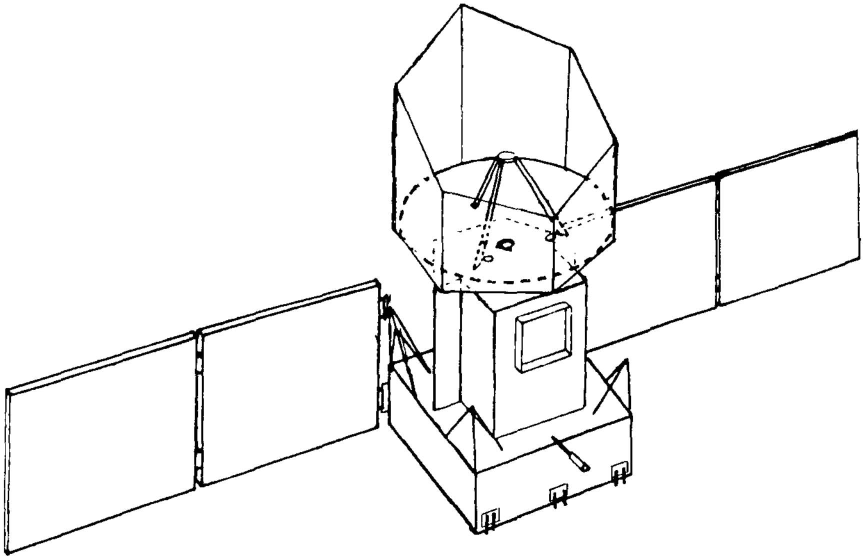

Fig. 1. Line drawing of the FIRST spacecraft, as of April 1993. It is approximately 7 m long and 14 m across, with a mass of roughly 2500 kg.

5. CURRENT AND FUTURE ACTIVITIES

The present study will be completed in the early summer of 1993. The future schedule depends on the outcome of the selection of the order of implementation of the two remaining cornerstones (FIRST and ROSETTA, an asteroid/cometary mission), due to be made by ESA in the second half of 1993.

The current approximate schedule for the third (the fourth four years later) cornerstone is: announcement of opportunity (AO) for experiments in 1994/95, invitation to tender (ITT) in 1996, start of phase B in 1997, followed by phase C/D leading to a launch in 2002/2003.

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REFERENCES

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4). "Space Science Horizon 2000", ESA SP–1070, December 1984