

# Development of the Space Infrared Telescope Facility (SIRTF)

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## ABSTRACT

SIRTF, the Space Infrared Telescope Facility, is to be launched by NASA early in 2003. SIRTF will be an observatory for infrared astronomy from space with an 85cm aperture telescope operating at 5.5K and a 2.5-to-5 year cryogenic lifetime. SIRTF's three instruments with state of the art detector arrays will provide imaging, photometry, and spectroscopy over the 3-180um wavelength range. SIRTF will provide major advances for the study of astrophysical problems from the solar system to the edge of the Universe. SIRTF will complete NASA's family of Great Observatories and serve as a cornerstone of the Origins program. Over 75% of the observing time will be awarded to the general scientific community through the usual proposal and peer review cycle. SIRTF will demonstrate major advances in technology areas critical to future infrared missions. These include lightweight cryogenic optics, sensitive detector arrays, and a high performance thermal system, combining radiative and cryogenic cooling, which allows the telescope to be launched warm and to cool in space. These thermal advances are enabled by the use of an Earth-trailing solar orbit which carries SIRTF to a distance of  $\sim 0.6$  AU from Earth in 5 years. This paper will provide an overview of the SIRTF mission, telescope, cryostat, instruments, spacecraft, orbit, and operations in preparation for an accompanying set of detailed technical presentations.

**Keywords:** SIRTF, infrared observatory, space telescope, infrared astronomy

## 1. MISSION DESCRIPTION

SIRTF is the fourth of NASA's Great Observatories. SIRTF imaging and spectroscopy in the infrared will complement the data acquired from the Hubble Space Telescope and the Chandra X-ray Observatory. SIRTF is on schedule to be launched in January 2003 on a Delta 7920H launch vehicle from Kennedy Space Center. The requirement is for a two

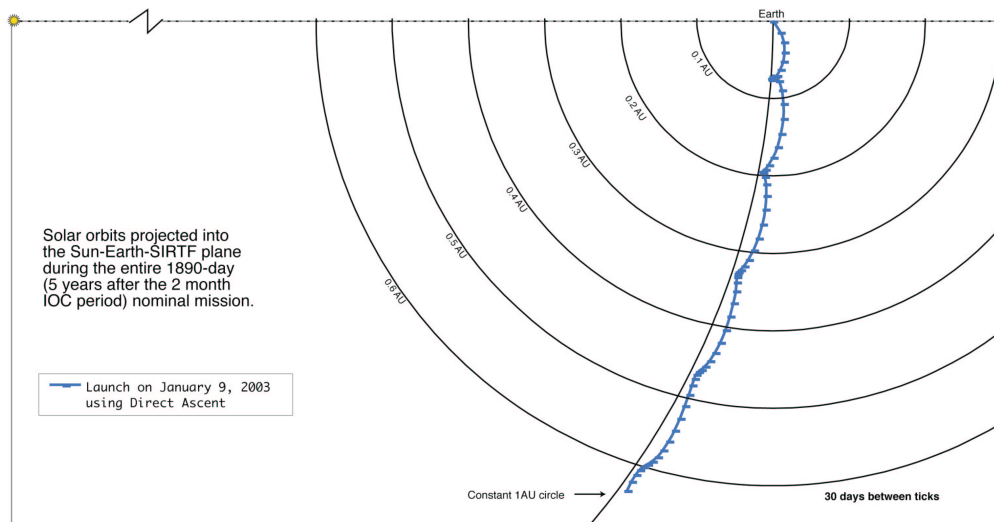
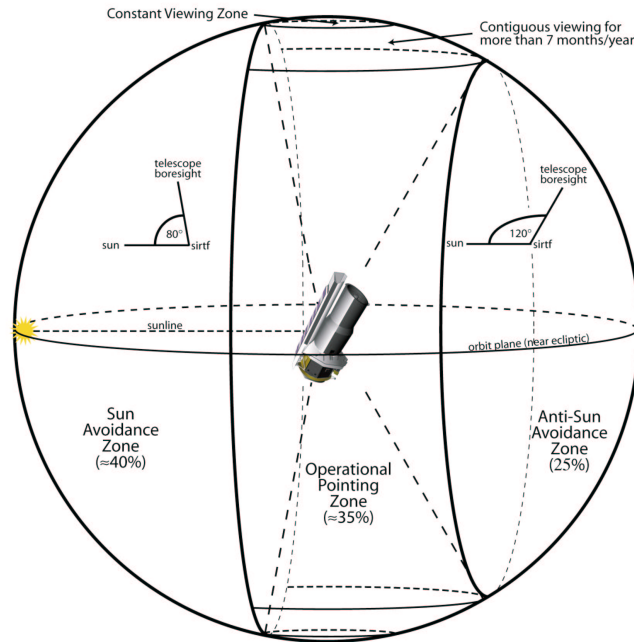


Figure 1. Solar Orbit as Viewed in the Rotating Frame

and a half year mission; consumables have been sized to support a goal of a five year mission. The Project has selected a solar orbit in which the observatory drifts away from the earth at 0.12 AU per year while remaining at about 1 AU from the sun, as shown in figure 1. This orbit improves observing efficiency, simplifies observation planning, and removes the earth as a heat source for the observatory. The SIRTf observatory has been designed to maximize pointing flexibility consistent with cryogen containment efficiency and protection of the cryogenic telescope aperture. As shown in figure 2, the observatory is continuously shaded from the sun by its solar panel while pointing in its operational pointing zone over the range of ten degrees toward the sun and thirty degrees away from the sun with respect to an axis perpendicular to the sunline. This allows each point on the celestial sphere to be visible for at least 40 days every six months.



**Figure 2.** Operational Pointing Zone (OPZ) Definition

Three scientific instruments utilize different parts of the field of view of the telescope. Observing is accomplished with one instrument at a time. Observing sessions will typically be several days long for each instrument with the detailed observing plan dictated by target priority and availability and cryogen utilization efficiency.

The observatory will be commissioned for scientific use during a 60 day in-orbit checkout period followed by a 30 day science verification period.

## 2. SCIENCE

### Basic Principles

SIRTf's scientific potential derives from the combination of the intrinsic sensitivity of a cryogenic space telescope with the tremendous imaging and spectroscopic power of state-of-the art infrared detector arrays. This combination will give SIRTf a 100-to-10,000 gain in capability over previous infrared space missions and also make SIRTf by far the most sensitive instrument for infrared astronomy to be available to the scientific community in the first decade of the 21<sup>st</sup> century.

Almost ten years ago, the SIRTf Science Working Group chose four major scientific themes to define the measurement and performance requirements for SIRTf. These are:

Protoplanetary and Planetary Debris Disks – the study of material around nearby stars which is indicative either of a planetary system in formation or of a more mature planetary system which replenishes the circumstellar matter.

Brown Dwarfs and Super Planets – understanding the formation, composition, and structure of objects with masses between 0.001 and 0.1 times that of the sun, objects which are too low in mass to have star-like brightness but which glow faintly in the infrared due to the heat generated as they form.

Ultraluminous Galaxies and Active Galactic Nuclei – the exploration of the most luminous objects in the nearby and distant Universe, objects which may radiate predominantly at infrared wavelengths and have thousands of times the power output of our own Milky Way galaxy.

The Early Universe – the study of the formation and evolution of galaxies, looking back to an epoch when the Universe was no more than one-fifth of its current size and age.

These themes have been of ongoing scientific importance and are heavily featured in the selected Legacy Science programs (see below) and in the scientific plans of the SIRTf Guaranteed Time Observers. Although only the requirements of these four themes were allowed to drive the SIRTf design, the resulting facility can and will be used for a very wide variety of scientific investigations.

### **SIRTf's Instruments**

The three SIRTf instruments, their capabilities, and sample science programs are:

#### **i. The Infrared Array Camera (IRAC: Principal Investigator Giovanni Fazio, SAO)**

IRAC provides wide-field imaging over two adjacent 5x5 arc minute fields of view. One is imaged at 3.6 and 5.8 $\mu$ m, simultaneously via the use of a beamsplitter; the other at 4.5 and 8 $\mu$ m. InSb arrays with 256x256 pixels are used at 3.6 and 4.5 $\mu$ m; Si:As IBC arrays with 256x256 pixels at 5.8 and 8 $\mu$ m. Bandwidths are ~25% (~40% at 8 $\mu$ m). Expected sensitivities at high galactic latitude (all quoted sensitivities are 5-sigma in 500 s) are 3, 4, 10, and 15 $\mu$ Jy at 3.6, 4.5, 5.8, and 8 $\mu$ m, respectively. IRAC will be used extensively for studies of red-shifted starlight from galaxies in the early universe and to characterize the distribution of protoplanetary material around young stars.

#### **ii. The Multiband Imaging Photometer for SIRTf (MIPS: Principal Investigator George Rieke, Arizona)**

MIPS provides imaging and photometry in bands at 24, 70, and 160 $\mu$ m, optimized either for efficient large area surveys or to provide excellent sampling of the Airy disk. The arrays are 128x128 pixel Si:As IBC at 24 $\mu$ m, 32x32 pixel Ge:Ga at 70 $\mu$ m, and 2x20 Ge:Ga (stressed) at 160 $\mu$ m. The survey fields of view is 5x5 arcmin at 24 $\mu$ m and 70 $\mu$ m and 5x0.5 arcmin at 160 $\mu$ m. Expected survey sensitivities at high galactic latitude are 0.2, 1.5, and 30mJy at 24, 70, and 160 $\mu$ m, respectively – the 160 $\mu$ m sensitivity is limited at this level by confusion due to extragalactic sources. In addition, the MIPS provides spectrophotometry with resolving power ~15 and sensitivity ~10mJy over the 53-to-100 $\mu$ m band. MIPS investigations will include searches for evidence of planetary systems around nearby solar-type stars and determination of the power output of ultraluminous galaxies and active galactic nuclei.

Both IRAC and MIPS will be used for surveys intended to define the evolution of normal and unusual galaxies as a function of cosmic time. Among the fields to be surveyed by SIRTf will be those already targeted for deep surveys by other observatories across the electromagnetic spectrum, including NASA's other Great Observatories, the Hubble Space Telescope and the Chandra X-ray Observatory.

#### **iii. The Infrared Spectrograph (IRS: Principal Investigator James Houck, Cornell University)**

IRS is a modular instrument with four separate spectrograph modules. In order to reduce instrument development costs it has no moving parts. The two low-resolution modules provide long slit imaging spectroscopy from 5.3-to-14 $\mu$ m and 14-to-40 $\mu$ m, respectively. Typical sensitivities are expected to be ~0.5mJy in the shorter wavelength module and

~1.5mJy in the longer wavelength module. The resolving power is in the range 60-120 for these modules. The two high-resolution (resolving power 600) modules cover the wavelength ranges 10-to-19.5 $\mu$ m and 19.5-to-37 $\mu$ m. Each operates in echelle mode so that the entire spectral octave is covered in each exposure. Projected emission line sensitivities are  $\sim 3 \times 10^{-18}$  W/m<sup>2</sup> for each module. Each of the four modules is equipped with a Si:xx IBC array in 128x128 format. The dopant is As for the two shorter wavelength modules and Sb for the longer wavelength ones. The IRS will study the composition of the material associated with forming and mature planetary systems and the physical processes, which power the high luminosity infrared-emitting galaxies. In addition, the IRS will be used for detailed study of interesting targets found by IRAC and MIPS in the surveys described above.

### **Utilization and Community Access**

Like NASA's other Great Observatories, SIRTf is an observatory which is available for the use by the entire scientific community. SIRTf's scientific users will interface with the observatory through the SIRTf Science Center (SSC) on the Caltech campus. The SSC will solicit proposals, award observing time, schedule and execute observations, and provide pipeline processing and higher level data products. Interested scientists can stay abreast of the schedule and plans for community utilization by checking the SSC website: [sirtf.caltech.edu](http://sirtf.caltech.edu).

On behalf of the SIRTf user community, the SSC will conduct a First-Look Survey (FLS), immediately following the completion of the nominal 60-day In-Orbit Checkout (IOC) and 30-day Science Verification (SV) periods. The primary goals of this ~100-hour survey are (1) to provide a characteristic "first-look" at the mid-infrared sky at sensitivities that are ~100 times deeper than previous systematic large-area surveys; and (2) to process the data rapidly and place it into the public domain in time to impact early SIRTf investigations. All FLS data will be available to the community immediately following processing and verification.

There are three principal categories of scientific users for SIRTf:

#### **i. The SIRTf Legacy Program**

Legacy Science projects are large investigations aimed at exploiting SIRTf's unique capabilities, at creating a significant scientific legacy in the form of scientific publications and archival data products, and at encouraging follow-on observations with SIRTf during the mission's limited lifetime. Consistent with this latter objective, the pipeline-processed data from Legacy Science observations are to be released publicly via the SIRTf archive at the same time they are passed on to the team executing the program. Upward of 3000 total hours have been awarded to the six Legacy teams selected by a peer-reviewed competition in 2000. The six selected projects include deep and wide area extragalactic surveys, detailed infrared investigations of many nearby galaxies, a galactic plane survey, and extensive studies of planetary systems at all stages of evolution around both young and mature stars in the solar neighborhood.

#### **ii. General Observers**

The community will be given multiple opportunities to propose General Observer projects and/or Archival Research with SIRTf. On our current schedule, the first call for General Observer proposals will be issued in November, 2002, with proposals due in June, 2003. The first General Observer observations would take place in October, 2003, on this schedule. Subsequent opportunities for General Observer and Archival Research proposals will occur on approximately one-year centers. Over 75% of the observing time on SIRTf will be allocated to the community through the combined General Observer and Legacy programs, and the community may also apply for Director's Discretionary Time.

#### **iii. Guaranteed Time Observers**

About 20% of the observing time is reserved for the three instrument teams and the other members of the SIRTf Science Working Group who have guided the development of SIRTf over the past two decades. The Guaranteed Time Observers have largely defined their scientific programs and selected and prioritized targets for the first 2.5 years of the SIRTf mission. Interested scientists can learn more about the plans of the Legacy Science teams and the Guaranteed Time Observers from the information posted on the SSC website.

### 3. OBSERVATORY DESCRIPTION

The Observatory is the space portion of the SIRTf Facility, and is comprised of five major subsystems. There are three scientific instruments, the Cryogenic Telescope Assembly (CTA), and the Spacecraft. The observatory configuration is optimized to minimize heat flow from the spacecraft to the CTA. SIRTf has a mass of about 950 kg and is about 5 meters tall. The observatory is shown in figures 3 and 4.

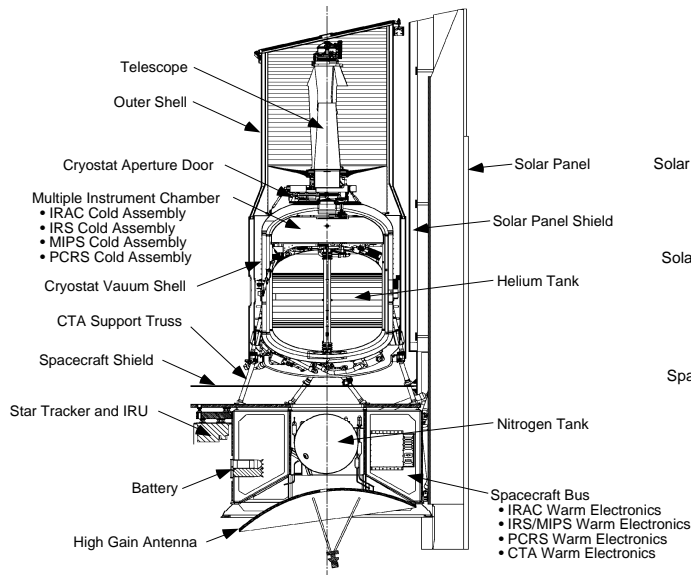


Figure 3. Observatory Internal Configuration

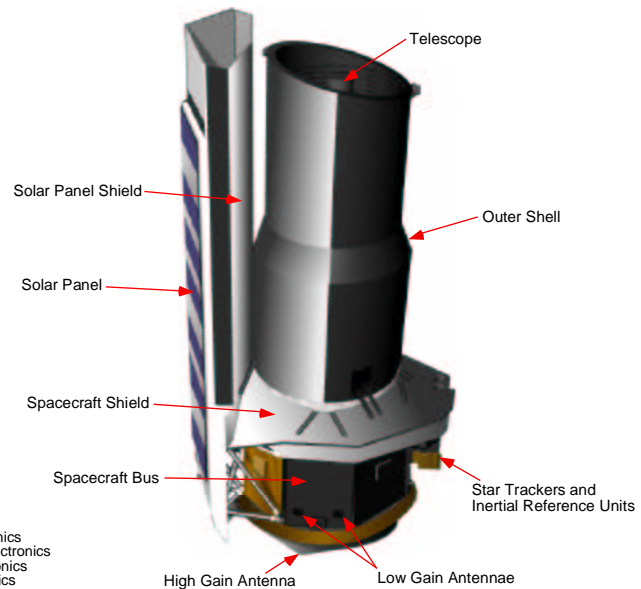


Figure 4. Observatory External Configuration

#### Scientific Instruments

The three science instruments are the Infrared Array Camera (IRAC), the Multiband Imaging Photometer for SIRTf (MIPS), and the Infrared Spectrograph (IRS). Each instrument consists of a cold sensor assembly located in the cryostat and a redundant warm electronics assembly located in the spacecraft. IRS and MIPS share a common warm electronics assembly. Cold assemblies are located in the multiple instrument chamber, within the CTA. Instrument descriptions have been provided in section 2.

#### Cryogenic Telescope Assembly (CTA)

The Cryogenic Telescope Assembly is comprised of four key parts. The Ritchey-Chretien Telescope, the superfluid helium cryostat, the outer shell group and the multiple instrument chamber (MIC) which houses the science instruments. Figure 5 shows the key elements of the Cryogenic Telescope Assembly. The CTA features a light weight 85 cm aperture, all beryllium telescope, which will be cooled to 5.5 K. It has been figured warm and tested at  $\sim 10^{\circ}\text{K}$  at a cryogenic optics test facility at JPL. Distortions which occur as the telescope is cooled have been reversed figured into the primary mirror in a process called "cryo figuring". More details on the performance of SIRTf's telescope can be found in Reference 2. The SIRTf telescope exceeds its goal of being diffraction limited at  $6.5\ \mu\text{m}$ .

A unique feature of the CTA is the warm launch architecture. Previous infrared space telescope designs have enclosed both the telescope and instrument payload in the cryostat. In the case of SIRTf, only the science instrument sensor sections are enclosed in the cryostat. This allows for significant reductions in both observatory mass and required

cryogen. Passive cooling will allow the outer shell to cool to ~40 K. Cryogen boil off will cool both the outer cryostat tank and the telescope to ~5.5K, virtually eliminating any parasitic heat load on the cryogen once in space. The warm launch architecture allows SIRTf to achieve a >2.5 year lifetime with only 360 liters of liquid helium. This is about 15% of the amount of helium carried by the ISO mission, which used the cold launch approach and had a 2.5 year lifetime in Low Earth Orbit. More details on the Cryogenic thermal system for SIRTf can be found in references 3 and 4.

The CTA is mechanically mounted to, but thermally isolated from, the Spacecraft bus by means of low conductivity gamma-alumina struts. The solar panel, which is structurally cantilevered from the Spacecraft bus, shades the CTA from the sun at all times. The CTA is also thermally isolated from the solar panel and Spacecraft bus by means of the outer shell group's low emissivity radiation shields.

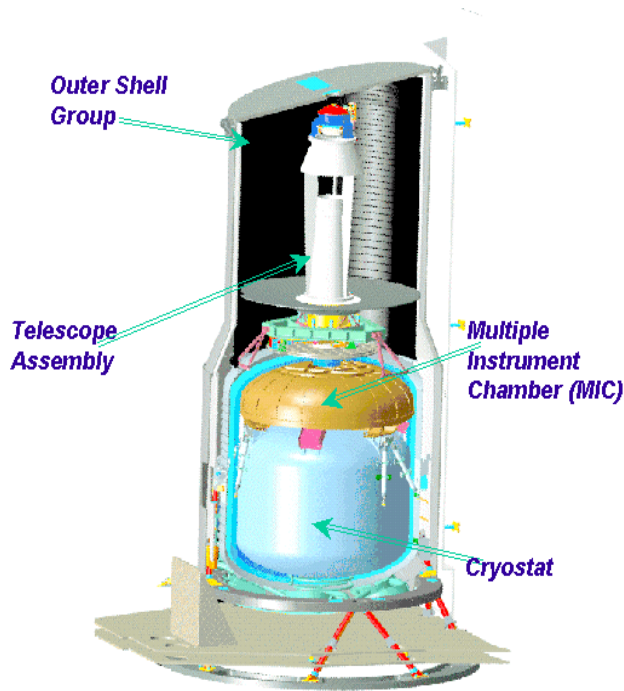


Figure 5. Cryogenic Telescope Assembly

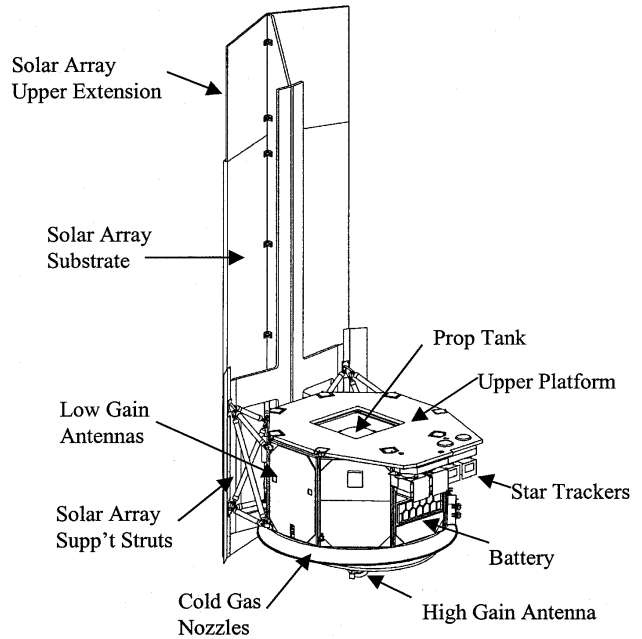


Figure 6. Spacecraft

### Spacecraft

The spacecraft provides electrical power, command and data handling, pointing control, thermal control, and communications with the ground as well as providing a stable structure for the CTA mounting surface. Substantial block or functional redundancy is provided for enhanced reliability. The spacecraft is designed to function autonomously for up to one week. The spacecraft is capable of absolute pointing accuracy of 5 arc sec and pointing stability of .2 arc sec. The spacecraft bus is comprised of nine bays in an octagonal configuration. The CTA mounts in eight locations on the upper platform of the Spacecraft. Heat pipes maintain a constant temperature across the mounting points. The platform is made of aluminum honeycomb sandwiched between composite face sheets. As shown in figure 6, the solar array is cantilevered from the bus.

## 4. OPERATIONS

### Introduction

The SIRTf Observatory will be launched in January, 2003 from Cape Canaveral aboard a Delta II Launch Vehicle. At the point that the observatory leaves the ground, the responsibility transfers from the development team to the mission operations team. SIRTf mission operations is divided into two phases. They are in-orbit checkout/science verification (IOC/SV) and nominal mission. Each is discussed below.

### In-Orbit Checkout/Science Verification

The In-Orbit Checkout (IOC) phase begins after launch and is planned for a 60 day duration with the Science Verification continuing for an additional 30 days. IOC contains the majority of the SIRTf Mission Critical Events. The first task is to get into a power positive, sun-safe attitude, and establish communications. After about five days (and sufficient outgassing) dust cover ejection will take place. Following successful dust cover ejection, the cryostat aperture door will be opened. The telescope is launched warm but cools down due to a combination of radiative cooling and Helium boiloff, reaching the operational temperature range about 35 days after launch. During the remainder of IOC, all of the Spacecraft systems and the Science Instruments will be checked out and calibrated. The formal purpose of IOC is to verify that the Observatory meets its Level 1 requirements. While coarse calibration may begin during the first 60 days (as the telescope is cooling down), during the ensuing 30-day science verification period fine instrument calibration will be completed and Early Release Observations will be performed. During the IOC/SV period there will be near-continuous communication with the ground via the Deep Space Network (DSN). More details on IOC plans for SIRTf can be found in reference 5.

### Nominal Mission

The nominal mission phase begins when SV is over and extends until the helium is depleted. The level one requirement is for a 2.5 year mission, however current projections indicate that a five year mission is possible. If the observatory is still operating nominally following helium depletion (and telescope warm-up), the IRAC 3.6 and 4.5  $\mu\text{m}$  bands can still operate effectively, thus allowing useful astronomical observations to be made.

The SIRTf observatory will communicate with earth via the DSN. There will be two passes per day of 1 hour each in which all uplink and downlink activities will take place. The nominal plan is to uplink seven days worth of sequenced activities once per week. Depending on the uplink file size, the upload can be broken into smaller pieces and uplinked over several passes. As much as 4 Gbits of science data can be stored in a single 12 hour observing block, which can then be downlinked in approximately 30 minutes to the DSN (at the maximum rate of 2.2 Mbps). The onboard storage capacity is sized to accommodate one missed DSN pass without losing data. The majority of the Observatory's time during the nominal mission will be spent executing science observations. When not observing, the Observatory will be carrying out calibration observations, ground communications, engineering activities, and slewing.

### Organization

The SIRTf Operations is divided into Mission Operations and Science Operations as shown in figure 7 below. A general description of each follows.

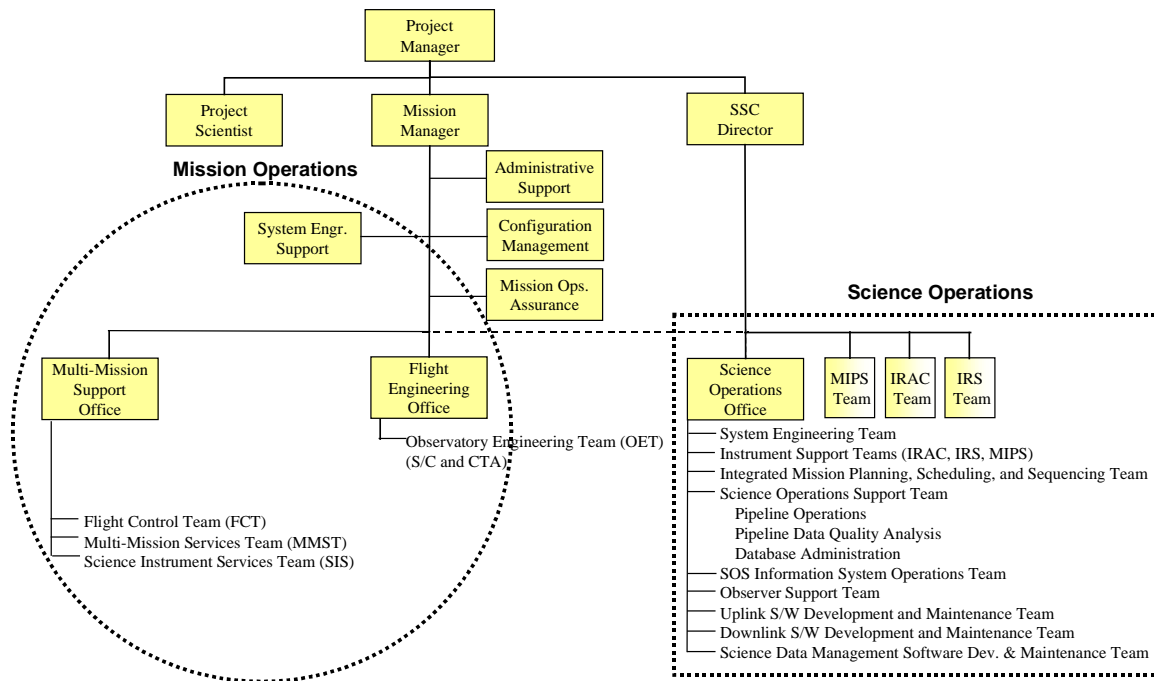


Figure 7. SIRTf Operations Organization

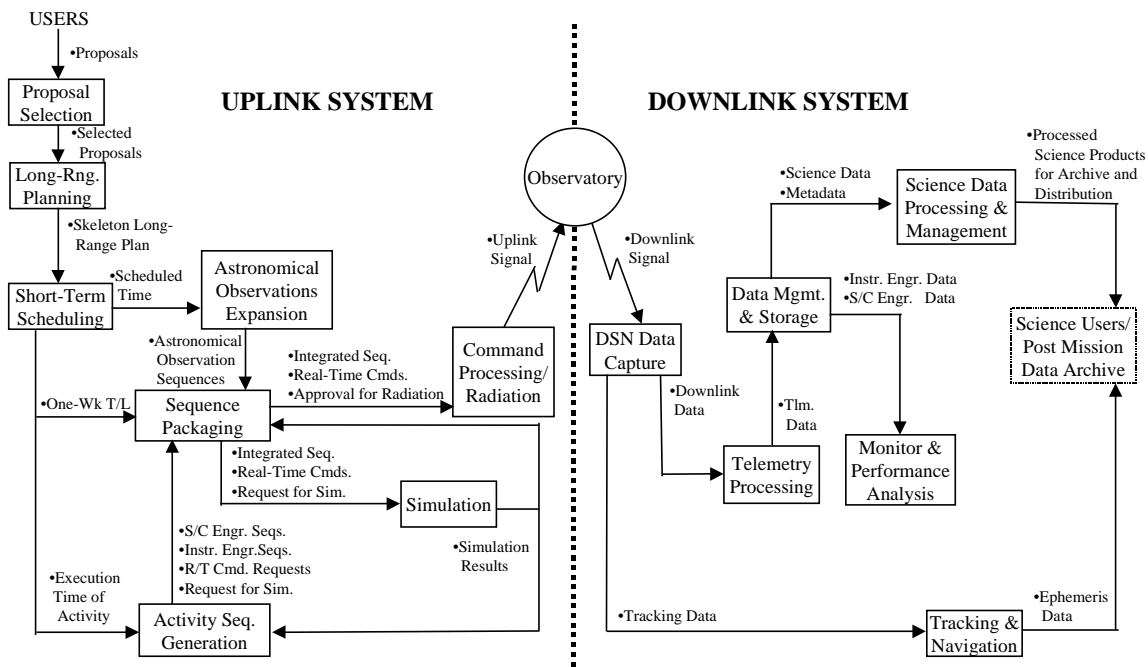
## Mission Operations

The Mission Operations System (MOS) is the hardware, software, people, processes, and procedures that enable and execute SIRTf flight operations. MOS is responsible for operating the Observatory and maintaining its health and safety. MOS builds the sequences containing the integrated science and engineering requests and radiates them to the observatory where they are stored awaiting execution. After execution, MOS receives and processes telemetry from the Observatory and is involved in fault recovery and in first order pointing reconstruction based on Observatory engineering data. MOS is responsible for scheduling engineering activities, interfacing with the DSN and delivering science and engineering data to the SIRTf Science Center (SSC).

The Mission Operations team is comprised of the Multi-Mission Support office (MMSO), the Flight Engineering Office (FEO), and the System Engineering and Coordination office (SE&C). The MMSO is responsible for all of the data management and support activities as well as navigation and all activities related to Deep Space Network support. In addition, the MMSO is home to the flight controllers. The SE&C office does just what the name implies and is responsible for Mission Operations systems engineering. The Flight Engineering Office is responsible for managing the Observatory Engineering Team (OET) as well as the Mission Sequence Team (MST). The OET monitors observatory health and safety on an ongoing basis and is also tasked with performance trending. The MST performs the sequencing role described earlier.

The MOS team is geographically distributed with each piece playing a specific role. The Observatory Engineering Team is located at Lockheed Martin in Denver while the aforementioned office managers and teams reside at JPL. There is also telescope factory support at Ball Aerospace in Boulder, CO. There are two key Mission Support Areas (MSA) for SIRTf operations. They are located in Denver and at JPL. The JPL MSA is the lead MSA and will house the Mission Manager and flight control teams and be the location from which commands are sent. Two testbeds built around flight-like avionics hardware will be maintained for the duration of the mission to support any necessary troubleshooting, testing, or software development.





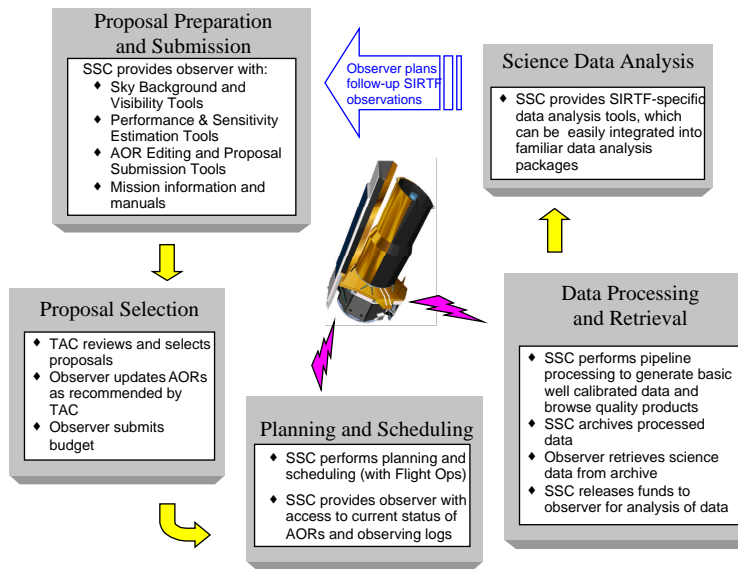
**Figure 8.** End-to-End Operations Data Flow

The Science Instruments teams are considered to be a part of the Mission Operations Team during the In-orbit checkout/science verification period. Once that period has completed, the Instrument teams will transition to be part of the Science Operations team at the SIRTf Science Center. The end-to-end operations data flow is shown in figure 8.

### Science Operations

The SIRTf science program will be conducted by the SSC which is located on the Caltech campus. The operations processes within the SSC are shown in figure 9. The SSC will be responsible for the selection of the SIRTf science program and for the preparation of a set of observation requests, which execute that program. These Astronomical Observation Requests (AORs) are generated via the use of Astronomical Observation Templates (AOTs). An AOT is a web-based electronic form which prompts the observer for the astronomical information (e.g., source position and brightness, size of region to be mapped, etc.) and observing strategy (integration time, dither pattern, etc.) that specifies an observation. To simplify operations, there is only one AOT per observing mode and only 7 distinct observing modes. A database of completed and prioritized AORs for both observation and calibration purposes is created and maintained by the SSC. These AORs are then combined with Spacecraft Engineering Requests (SERs – used for scheduling routine spacecraft engineering activities such as momentum management, PCS calibrations, and data downlink) and Instrument Engineering Requests (IERs – instrument activities not directly related to science data acquisition) by the MOS team and used to create the actual sequence of events scheduled for execution by the spacecraft. Only one instrument is to be powered on and taking science data at a time. Block scheduling will be used so that a given instrument is operating for about one week at a time. After this period, the instrument is powered down and science data collection cycles to one of the other two instruments.

The SSC is also responsible for establishing the archive of all SIRTf science and supporting engineering data. At the SSC the data are run through a science processing pipeline which converts the instrument frames into calibrated, cosmetically cleaned images and spectra in the Flexible Image Transport System (FITS) format. There is a well-defined, basic pipeline product for each type of data product. The processed data, raw data, suitable intermediate data products and calibration frames are placed in the SIRTf Science Archive.



**Figure 9.** Operations Processes within the SIRTf Science Center

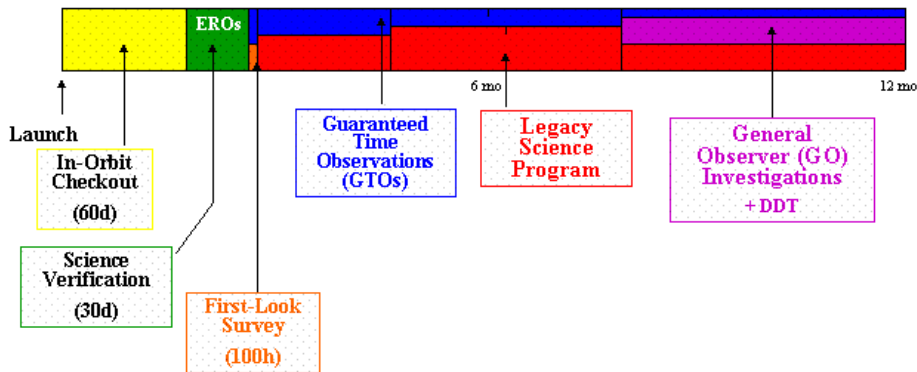
There will be multiple opportunities for the community-at-large to propose observational programs on SIRTf. In support of the solicitation process, the SSC will design, build, and maintain Web-based electronic software tools. The focus of these tools is to enable investigators to prepare scientifically valuable programs that maximize the efficiency and utility of the Observatory. These tools include: (i) comprehensive descriptions of the instrument observing modes; (ii) estimates of exposure and wall clock times and expected sensitivity levels; (iii) geometrical and graphical depiction of sky visibility and orientation constraints; (iv) geometrical depiction of mapping patterns used in the relevant observing modes; and (v) estimates of the celestial foregrounds and backgrounds at appropriate wavelengths. The Calls for Proposals, Observatory and Instrument Manuals, and supporting software tools have been made available via the Web. Proposals are also submitted electronically. These electronic exchanges will reduce costs to the SSC and to the user community, while providing the most reliable updated technical information in a timely manner.

### Science Operations Timeline

Following IOC/SV, and after the completion of the FLS, Guaranteed Time Observations by the SIRTf Science working group begins and the Legacy Program also commences. Although GTO and Legacy Science dominate the first ~ six months of the SIRTf science mission, by the end of the first year and throughout the remainder of the mission the majority of the time will be given over to the General Observer (GO) programs. GO's will be selected on approximately annual cycles via a peer-reviewed proposal process.

SIRTf will be able to respond quickly to Targets of Opportunity (ToO) such as supernovae and newly discovered comets. A target of opportunity can be scheduled and observed within 48 hours of receipt of a valid AOR for the observation. Known classes of targets of opportunity will be observed by pre-selected teams, as has been the policy with NASA's other observatories. Completely unanticipated objects could be observed using Director's Discretionary Time.

The first year of SIRTf activities is show below in figure 10.



**Figure 10.** The First Year of SIRTf Activities

### Efficiency and Readiness

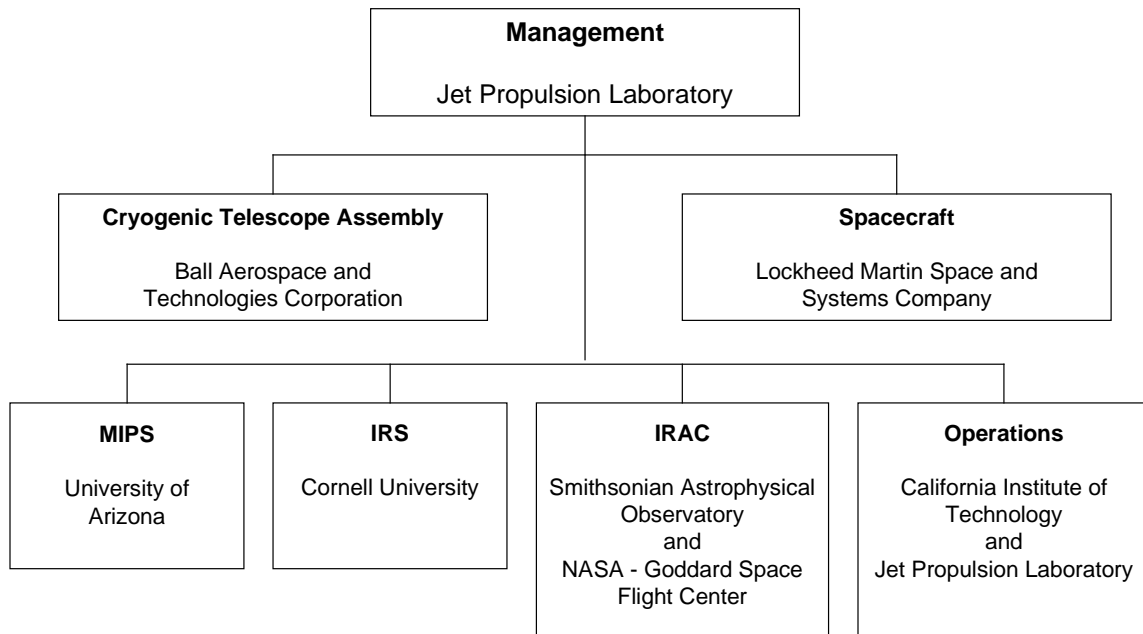
SIRTf operations must be efficient because of the use of an expendable cryogen for cooling the telescope. In addition, because there is no cruise phase, Mission Operations must be ready to go at launch. High sensitivity means that observations will be short and the observation queue will need to be full at all times. This high sensitivity also means that SIRTf will likely be the primary means of following up on its own discoveries, so the entire process from Proposal to data delivery must run smoothly and efficiently.

The SIRTf Operations team is nearing the final stages of operations readiness. The most important activity remaining is the running of end-to-end Operations tests on the Observatory flight hardware. These tests are run by exercising the entire operations process chain, from proposals submitted at the SIRTf Science Center to the science data being put into the archive. There are many tests planned to be run in this end-to-end format. While several testbeds are available on which to run these tests, we have elected to designate many of them as required to be run on the observatory flight hardware. These include Mission Critical Events, many IOC activities, the launch sequence, science instrument tests, and a seven day autonomous test intended to run uninterrupted as in flight.

Special care has been taken to include significant time in the schedule for training. We are using planned flight operations policies and procedures, including planned meetings and command conferences during the test phase to get the team ready for flight. We have gone to great lengths to staff our operations team with members of the development team such that proper technical handover takes place. In addition, the operations teams play a key role in pre-launch Observatory testing. More details on the SIRTf Science Operations System can be found in reference 6.

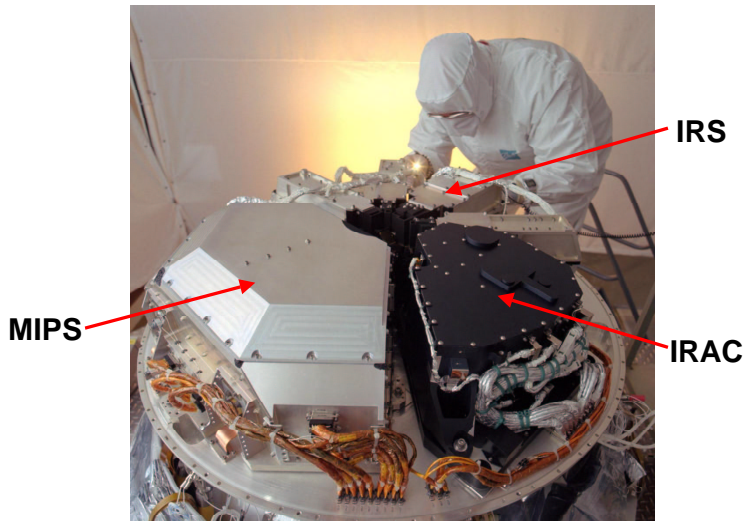
## 5. PROJECT MANAGEMENT AND STATUS

The project is funded by NASA and managed by the Jet Propulsion Laboratory. Management of the project has featured a largely successful experiment in project team cooperation. The SIRTf project is a collaborative effort among industry, academia and government in which the team participants were selected for their expertise rather than for a specific proposed implementation and cost. Design requirements and detailed mission architecture were developed in a joint effort under JPL's leadership prior to NASA's approval to proceed with implementation. In addition, few standards were imposed on industry and academic team members when proven processes and standards were already in place. The project team composition is shown in figure 11.



**Figure 11.** The SIRTf Project Team

Since the status report provided in reference 1, the SIRTf team has encountered and resolved several significant development challenges which have necessitated changing the launch date from December 2001 to January 2003. None of these challenges have resulted in any significant changes to the SIRTf mission plan, which was prepared in 1997 when the project was formally started. At about 7 months before launch, all scientific instruments have been completed and integrated into the CTA (figure 12). The CTA has successfully completed functional and environmental test. The spacecraft has also been completed and the spacecraft and CTA have been integrated to form the complete SIRTf observatory as shown in figure 13. Functional and environmental testing are nearly complete. Test results point to a SIRTf observatory which will meet all of its performance objectives. The SIRTf mission operations team is nearly fully staffed and mission operations training is underway. Flight-like sequences have been prepared and successfully executed on the observatory. Mission support areas for science, engineering and mission control are completed and operational. The scientific program for the first six months of normal operations has been defined and is available for scheduling, and plans are being put in place for the IOC/SV phase.



**Figure 12.** SIRTf Instruments Installed in Cryostat



**Figure 13.** The Completed SIRTf Observatory

Current information on all aspects of the SIRTf Project can be found at <http://sirtf.caltech.edu>

## 6. ACKNOWLEDGEMENTS

The work described in this paper is being carried out by a team consisting of the Jet Propulsion Laboratory, the California Institute of Technology, Lockheed Martin Space Systems Company, Ball Aerospace and Technologies Corporation, the University of Arizona, Cornell University, and the Smithsonian Astrophysical Observatory under contract to the National Aeronautics and Space Administration.

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