IV. Relation of SAFIR to NASA Strategic Plans

Linkages to the Roadmaps

As detailed in Section II, SAFIR addresses multiple research areas that have been identified as strategic priorities for the agency. In doing so, SAFIR helps develop technologies that are enabling for high priorities in other research areas. While this strategic planning is ongoing, and evolves to keep up with new science questions and promising technological developments, the SAFIR mission has, from its conception, been motivated by science questions that are regularly at the forefront of strategic objectives for the agency. With dramatic advances in infrared sensor technology and cooling architectures, as well as the new far infrared science perspectives coming out of Spitzer, SAFIR represents critical science need being met by the technological capability to fulfill that need.

The last cycle of strategic planning for the Office of Space Science articulated specific research focus areas that serve high priority strategic objectives. The Space Science Enterprise Strategy (2003) maps these objectives directly to agency strategic goals, proving a sound foundation for investment planning. This document is based on strategic roadmaps from the Origins theme and the Structure and Evolution of the Universe theme, in which the SAFIR mission appears prominently in research focus areas (RFAs) that address these objectives.

Objective 5.8 Learn how galaxies, stars, and planetary systems form and evolve.

RFA: Learn how the cosmic web of matter organized into the first stars and galaxies and how these evolved into the stars and galaxies that we see today.

SAFIR will map star formation and nucleosynthesis in the earliest galaxies. It will penetrate the dust that obscures this star formation, and trace stellar energy generation across the eons.

RFA: Understand how different galactic ecosystems of stars and gas formed, and which ones might support the existence of planets and life.

SAFIR will reveal the detailed systematics of large scale star formation in galaxies. Within our own galaxy it will follow the distribution and chemical evolution of biogenic constituents such as hydrocarbons and water.

RFA: Learn how gas and dust becomes stars and planets.

SAFIR will track the collapse of interstellar clouds into protostars, peering directly into otherwise opaque cores to watch accretion and spinup happen.

RFA: Observe planetary systems around other stars and compare their architectures and evolution with our own.

SAFIR will map debris disks around nearby stars, looking for telltale spectral and morphological markers caused by planetary systems. Far infrared studies of these debris disks will characterize zodiacal composition, and will reflect on habitability of such planets by constraining bombardment scenarios.

Objective 5.9 Understand the development of structure and the cycles of matter and energy in the evolving universe.

RFA: Determine how, where, and when the chemical elements were made, and trace the flows of energy and magnetic fields that exchange them between stars, dust, and gas.

SAFIR will use fine structure lines to map the enrichment of heavy elements across the galaxy, developing a clear picture of galactic enrichment of light elements. With sensitive measurements of ionization states in light ions, SAFIR will accurately measure the luminosity and color temperature of massive embedded stars.

In addition to explicit connections with high priority agency goals and objective, SAFIR will answer to similar science goals laid out in the Aldridge Report on the Presidents Vision for Space Exploration. In the last Decadal Report for Astronomy of the National Research Council (2001) *Astronomy and Astrophysics in the New Millennium*, SAFIR was identified as a high scientific priority for which investment should begin within this decade.

SAFIR in the Context of NASA Space IR Astronomy

Space infrared astronomy has had a rich history, and we wish to place the notional SAFIR concept in the context of these efforts. The 0.6 m diameter US-Dutch-British Infrared Astronomical Satellite (IRAS) was a pioneering cryogenic infrared mission that did the first all sky scan survey in the thermal infrared. It offered far infrared point source sensitivity of order 1 Jy, and spatial resolution of order 2 arcminutes at 100 μm, mapping 250,000 cosmic infrared sources and large areas of extended emission. The Infrared Astronomical Observatory (ISO), a cryogenic observatory also with 0.6 m aperture offered low resolution spectroscopy as well as array imaging, with diffraction limited

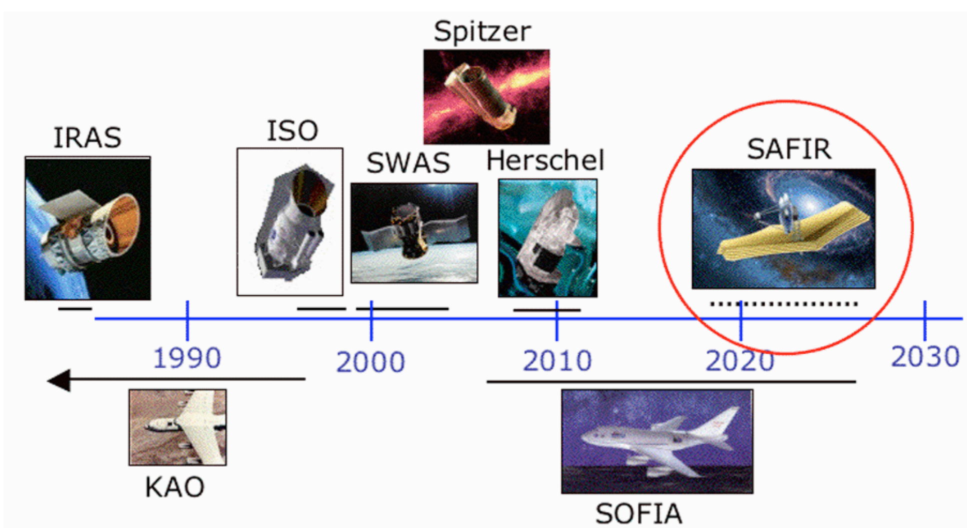

Figure IV-1: A contextual timeline for SAFIR, showing relevance to other agency far infrared and submillimeter investments. Not shown on this plot for convenience are scientifically relevant missions at other wavelengths, such as JWST, Con X, and TPF.

(~50" at 100 μm) pixels. ISO was an ESA mission, but with participation from ISAS and NASA. With more modern detectors, ISO achieved photometric sensitivity of tens of mJy in the far infrared. These observatories, with the supporting role of the 0.9 m Kuiper Airborne Observatory for pointed observations of bright sources with higher spatial resolution, have largely defined thermal far infrared astronomy to date. It is these efforts, together with more specialized missions like the Submillimeter

Wave Astronomy Satellite (SWAS), which provided high resolution spectroscopy of sources in discrete spectral bands unavailable to ground-based telescopes, that help set the stage for SAFIR. The most important far infrared mission to date is the Spitzer Space Telescope, launched in 2003. With its large detector arrays and cold telescope, Spitzer is 2–3 orders of magnitude more sensitive from 3.5–160 µm than any previous experiment.

In the future, the Stratospheric Observatory for Infrared Astronomy (SOFIA), at ambient temperature with a 2.5 m aperture, will offer routine access to large parts of the infrared spectrum with challenging new instrumentation. The Herschel telescope, with a 3.5 m aperture, will expand far infrared capabilities dramatically, offering a clear view with sensitive arrays and spectrographs throughout the far infrared and submillimeter spectrum. The James Webb Space Telescope, with a 6.5 m aperture cooled passively to 35 K, will offer dramatic increases in spatial resolution and sensitivity out to a wavelength of 30 µm. While this does not overlap in wavelength with SAFIR, it addresses many of the same science topics in different ways. The SOFIA and Herschel telescopes are not cold enough to enable background-limited performance in the far infrared, will not offer the spatial resolution now achievable in the ground-based submillimeter, and will not achieve the ambitious science goals that our community has posed for SAFIR. These missions will, however, leave a scientific legacy that SAFIR will be well poised to build on.

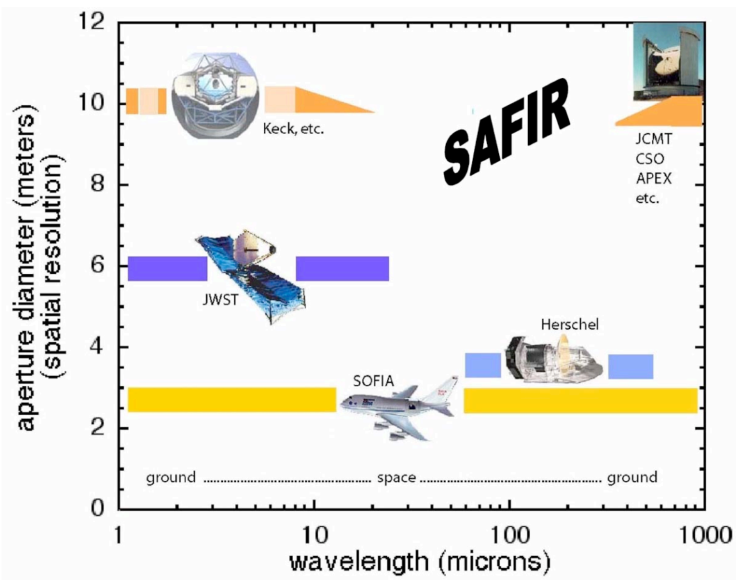

Figure IV-2: The notional SAFIR mission is compared by wavelength and aperture diameter (which, in the thermal IR defines spatial resolution) with agency missions now in development. This figure illustrates the large capability niche that SAFIR will fill, and puts it in context with other investments.

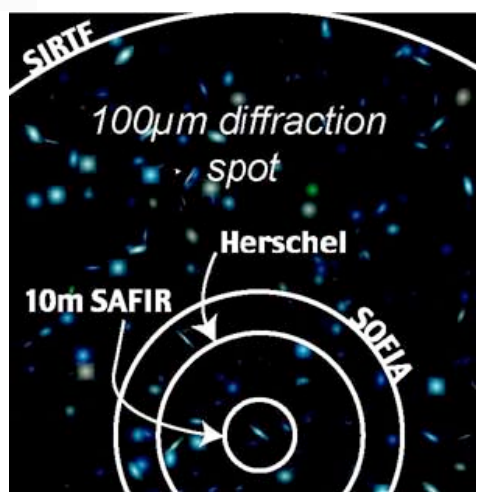

Figure IV-3: The spatial resolution offered by a 10m SAFIR at 100 µm is compared with other infrared missions. The background graphic is a simulation of the extragalactic sky at flux levels appropriate to deep imaging with SAFIR.

It is important to understand that SAFIR builds scientifically on the greater mission investment portfolio of the Universe Division in its pursuit of priority agency goals. In fact, SAFIR is complementary to most major missions preceding it that would operate both in the infrared and in other spectral regions. A simple mapping of near term mission science through to SAFIR is illustrated in the sketch below.

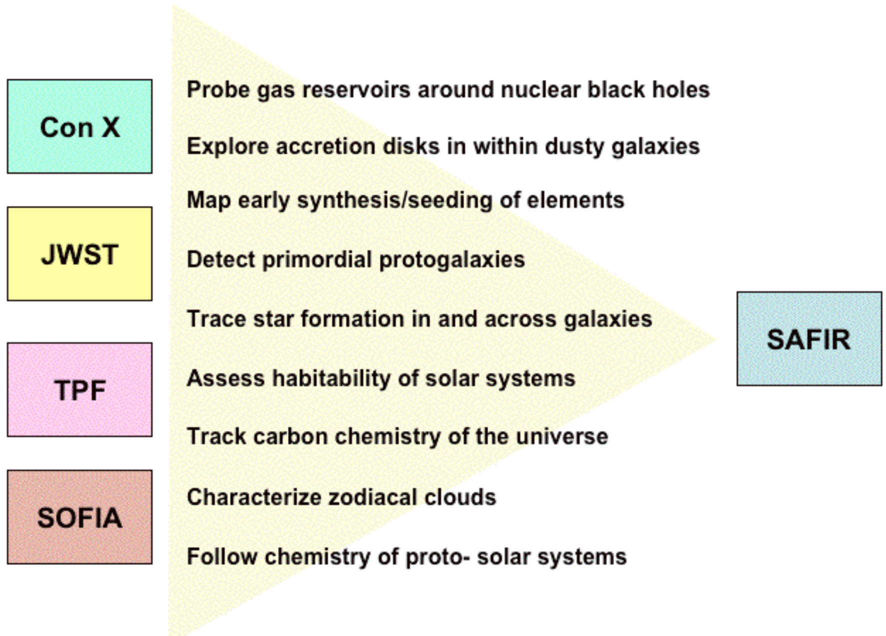

Figure IV-4: The relationship of key near-term major space astronomy missions in the NASA strategic plan to SAFIR in the contact of strategic planning goals. SAFIR builds on the science that these missions produce.

SAFIR in the Context of International Partnership: European Status

While not an explicit element of NASA strategic planning, it is recognized that a major mission like SAFIR could benefit strongly from close international collaboration. The European Space Agency has made important investments in far infrared astronomy, and is currently defining the long-term plan for its science programme for the 2015-2025 timeframe through a community consultation process entitled Cosmic Vision, which began with a call for science themes in April 2004. This included two proposals, each subscribed to by over 130 European scientists, on the themes of “Galaxy Formation and Evolution” and “Star and Planetary System Formation”, both making the case for a future far infrared mission. These themes were endorsed by ESA’s Astronomy Working Group (AWG) and selected for presentation at the Cosmic Vision community workshop in September 2004. Subsequently, the AWG has recommended that a far infrared mission be included in ESA’s future programme.

The ESA AWG has recommended that initial studies should be carried out by ESA of both single dish and interferometer concepts, and the first steps are now being taken. The ESA Advanced Studies Division will carry out an internal study between now and mid-2006, in consultation with the core group of scientists who proposed FIRM in the Cosmic Vision exercise. It is anticipated that this will pave the way for an industrial study.

There is a large community of European astronomers active in FIR/submillimetre-based research. This community has access to, and has flourished through use of, ground-based facilities including JCMT, SEST, and IRAM and satellite missions such as IRAS and ISO - with Herschel, Planck, and involvement in Astro-F coming next. The advances which Herschel will bring are eagerly awaited, but its inevitable limitations (imposed by the size and temperature of the telescope) are also recognised. Key examples of these limitations are the need for a cold telescope to achieve the sensitivity required for spectroscopy of distant galaxies, and the need to access the 25-100 μm region with high angular and spectral resolution in order to study the formation and evolution of planetary systems.

The heritage of ISO, Herschel, Planck, and JWST-MIRI means that European laboratories and institutes have a wealth of instrumentation expertise that will be important to future far infrared space instruments, and, for the same reasons, European industry has developed much relevant expertise on the spacecraft side. Experience gained in building ISO, Herschel, and Planck instruments is likely to prove invaluable in designing spectroscopic and imaging instruments for future cold-aperture space telescopes, and this is therefore an area in which European laboratories will be well placed to contribute. It is notable that four of the five Herschel and Planck instruments involve significant participation from US institutes under NASA support, and that Europe has strong involvement in two of the three JWST instruments; so a tradition of fruitful collaboration on FIR space instrumentation has already been established between the US and Europe, which has been of great mutual benefit.