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LAIRTS Documentation Executive Summary

Frank Regan

Systems Integration Engineering, Inc
35 Bedford Street, Suite 12
Lexington, MA 02173

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AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AIR FORCE BASE, MASSACHUSETTS 01731-5000

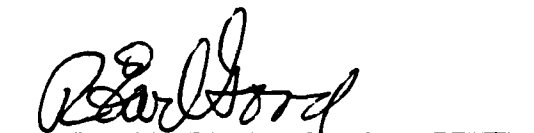
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"This technical report has been reviewed and is approved for publication"

FOR THE COMMANDER


STEPHAN D. PRICE, Chief
Celestial Backgrounds Branch


R. EARL GOOD, Director
Optical/Infrared Technology Division

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) The purpose of this document is to provide an executive summary of the available technical information on the Large Aperture Infra-Red Telescope System (LAIRTS). The program was originated and managed by the Air Force Geophysics Laboratory (AFGL) at Hanscom Air Force Base, Massachusetts. LAIRTS received limited funding in FY 84 and FY85 for program initiation and definition. Late in FY 85 the decision was made to terminate the program effective FY 86. This report briefly describes the documentation available from participating contractors, in the following format: • Purpose, • Description of LAIRTS, • Identification of Key Participants.			
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19. ABSTRACT

- 4) Summary of Key Technical Reports,
 - 3) Description of Distribution Plan, *Key points:*
- Space surveillance*

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1.0 PURPOSE

The purpose of this document is to provide an executive summary of the available technical information on the Large Aperture Infra-Red Telescope System (LAIRTS). The program was originated and managed by the Air Force Geophysics Laboratory (AFGL) at Hanscom Air Force Base, Massachusetts. LAIRTS received limited funding in FY 84 and FY 85 for program initiation and definition. Late in FY 85 the decision was made to terminate the program in FY 86.

In order to capture the technology developed for a state of the art Large Infrared Telescope Experiment, Systems Integration Engineering (SIE) Inc. was tasked to collect and create a data depository for some of the program's key engineering documentation. The documentation will be available for initial distribution and will be stored in an SIE documentation file for later use by the Government on an as required basis.

This executive summary will briefly describe the documentation available from participating contractors and will outline procedures for initial and future distribution. Organization of the summary is as follows:

- Purpose
- Description of LAIRTS Program
- Identification of Key Participants
- Summary of Key Technical Reports
- Description of Distribution Plan

2.0 LAIRTS PROGRAM

The LAIRTS experiment was designed to obtain high spatial resolution infrared data to meet the needs of the Space Surveillance and Strategic Defense Programs. The design concept allowed for operation on a large high altitude sounding rocket or in the bay of an orbiting space shuttle. This section of the Summary describes the experiment and is divided into the following subsections:

- Introduction
- Scientific Objectives
- Development Concept

2.1 Introduction

In order to address future Space Defense Initiative Surveillance Systems, two areas of technology must be addressed. First infrared background signatures must be obtained, verified and catalogued. These background measurements will describe the environment of potential targets. Therefore, the background measurements must be at the same or better sensitivities than the systems which will sort out the targets from the backgrounds.

The second area of technology to be developed is a system to detect, acquire and track potential targets against the various catalogued backgrounds. Celestial sources are the fundamental backgrounds against which space surveillance and space defense systems must operate when looking toward outer space. The celestial sources include planets, stars, and zodiacal radiation (thermal emission from particles distributed about the ecliptic plane). These particles absorb solar radiation and then radiate signals in the infrared. In addition, low flying targets must be acquired and tracked through the background of the earth's limb radiance.

High altitude sounding rockets in the Hi Star and Background Measurements Program experiments have acquired significant data on celestial and earth limb signatures. These experiments were conducted by AFGL and the reduced signatures data is contained in the AFGL Four Color Infrared Sky Catalog.

In November 1983 the International Infrared Astronomy Satellite (IRAS) completed operation. IRAS sky catalogue data will contain data at high sensitivities.

2.2 Scientific Objectives

The LAIRTS instrument was designed to validate previously acquired celestial, zodiacal and atmospheric models. To perform this mission LAIRTS was to be capable of mapping pre-selected one degree by one degree regions with a sensitivity of 10^{-21} w/cm². In addition to verifying and expanding present sky catalogues for background definition, LAIRTS was expected to provide the following:

- Development of a long life Cryogenic Cooling System
- Low Scatter Lightweight Optics and Baffles
- High Speed On Board Data Processing
- Long Wave IR Focal Plane Technology

2.3 Development Concept

The LAIRTS instrument consisted of a cryogenically cooled, high off-axis rejection, large aperture telescope which would focus infrared radiation at the detectors of two IR sensors (a staring imaging camera to measure the wavelength region between 5 and 25 μ m and a scanning Far Infrared Imaging Spectrometer operating in the 2 to 24 μ m region). In the shuttle mode LAIRTS would have been positioned by means of a three axis, astronaut/microprocessor controlled, low jitter pointing system. A low light level television camera, coaligned with the telescope and a joystick controller would allow the astronaut to position LAIRTS from the aft flight deck of the shuttle. A star tracker would maintain inertial position. When not directly controlled by the astronaut, a Master Control Unit would perform the necessary calculations to determine LAIRTS' position and provide the proper command sequences to prepare the instrument for its next observation. Data from the observations would be recorded by an on board recording system and periodically telemetered to the earth from TDRSS data channels.

3.0 IDENTIFICATION OF KEY PARTICIPANTS

Table 1 is a listing of the key participants in the LAIRTS development.

Table 1: LAIRTS PARTICIPANTS

<u>Participant</u>	<u>Address</u>	<u>Responsibility</u>
Air Force Geophysics Laboratory (AFGL)	Hanscom AFB, MA 01731	● Experiment Specifications ● Program Management ● Engineering Integration
Naval Research Laboratory (NRL) Code 4138-S	455 Overlook Ave. Washington, DC 20375	● Development of an Infrared Imaging Spectrometer for LAIRTS
Systems Integration Engineering (SIE)	35 Bedford St., Suite 12 Lexington, MA 02173	● Management Support ● System Engineering Support ● Documentation ● Work Breakdown Structure
Wentworth Institute of Technology (WIT)	550 Huntington Ave. Boston, MA 02115	● Mechanical/Electrical Design and Fabrication ● Subcontracting
SSG, Inc.	150 Bear Hill Rd. Waltham, MA 02154	● Design of the Large Aperture Cryogenic Infrared Telescope ● Preliminary Design of Infrared Camera ● Preliminary Design of LWIR Spectrometer
E. A. Botti (EAB)	60 Hickory Dr. Waltham, MA 02154	● Structural and Mechanical Analysis
RDP, Inc.	391 Totten Pond Rd. Waltham, MA 02154	● Software Design ● Star Field Stabilization and Positional References ● Encounter Scenarios ● Shuttle Vibrations
Northeastern Univ. (NU)	360 Huntington Ave. Boston, MA 02115	● Design of LAIRTS Controller

4.0 SUMMARY OF REPORTS SUBMITTED

Below is a brief abstract of the documentation available on LAIRTS. The abstracts are reprinted exactly as received from the contributing contractors. To facilitate communication regarding these documents a primary point of contact with telephone number is identified with each abstract.

4.1 Naval Research Laboratory Abstract

Point of Contact: Dr. K. Shivanandan
Telephone : (202)767-2749

The objective of this program is to develop a technology base to support Surveillance, Acquisition, Tracking, and Kill (SATKA) Assessment Programs for the Space Defense Initiative (SDI) with high sensitivity and high spatial and spectral resolution. The emission will provide unique celestial and earth limb clutter and background measurements required for re-entry vehicle and satellite detection and acquisition together with a LWIR signature data base for cold body tracking.

The NRL cryogenic imaging Fabry-Perot spectrometer on LAIRTS will detect line emission from plumes with high sensitivity, while rejecting the scintillating background. It can perform the phenomenology required by Strategic Defense Initiative (SDI) and provide rapid look away capability to protect the IR array from blinding. The program emphasizes also certain basic infrared astrophysics problems related to the kinematics and composition of extended infrared objects, their energetics, and the evolutionary states. This investigation will use high resolution spectroscopy ($\approx 3 \times 10^3$), over the wavelength interval from about 2.5 to 24 μm coupled with extended field diffraction limited imaging. The program proposes to build an Infrared Imaging Spectrometer for a Large Aperture Infrared Telescope Systems Shuttle Sortie mission to achieve these goals.

4.2 Wentworth Institute of Technology Abstract

Point of Contact: Mr. Mark Browne
Telephone : (617)445-0882

Wentworth Institute's technical research staff supported the preliminary development and partial design for the LAIRTS sensor and payload. The following tasks were completed by Wentworth Institute in FY 85 during this preliminary conceptual design phase:

1. Commercial vendors were contacted to examine and discuss the fabrication of particular sensor and payload elements.
2. A preliminary analysis directed towards understanding the deflections of the radiation shield and internal support structure at their expected loads and at cryogenic temperatures was done.
3. The mechanical structural elements and electrical support requirements were partially defined.
4. A work breakdown structure for both the LAIRTS shuttle and probe options was completed.

Wentworth Institute's administrative and technical staff interfaced with all LAIRTS team members and organizations to support their completion of preliminary analyses and designs. This support included participation at weekly progress meetings, quarterly technical design reviews as well as several facilities visits.

4.3 SSG, Inc. Abstract

Point of Contact: Mr. Dexter Wang
Telephone : (617)890-0204

SSG has designed a large aperture cryogenic infrared telescope for space background and target measurements. The telescope design was the result of an extensive design study, and accommodated the system, optical, structural and thermal requirements defined by the Air Force Geophysics Laboratory. The design effort also included the preliminary design of an infrared camera instrument, and an LWIR spectrometer instrument. Both these instruments were packaged in the LAIRTS and used the same main telescope.

The main optical telescope consists of a four-element, all reflective, decentered design. The system uses a spherical figure primary mirror for ease of fabrication, and a small general aspheric corrector mirror as the fourth mirror. This mirror can be easily diamond figured. The second mirror is a simple conic section, and the third mirror is again a spherical figure mirror. The system has a collecting aperture of 32 by 22 limited resolution at 5 microns wavelength. The telescope is also capable of good straylight rejection with the use of superfinished optics. The structure and optics are all composed of aluminum to eliminate thermal problems, and are designed to operate at 15 Kelvin absolute temperature. The telescope is 39 inches in diameter and 96 inches long, including the two instruments. The telescope and instruments weigh less than 550 pounds. A layout of the telescope is shown in Figure 1.

A technology demonstration program was conducted to establish the feasibility of the LAIRTS concept. A prototype optical system was developed in the laboratory and proved to be easy to manufacture and align. A computer aided alignment scheme was developed to help in the alignment process. A lightweight mirror program was started to develop the techniques necessary to fabricate a light primary mirror. The main issue in this program was to evaluate the bimetal effects of the nickel plating on the aluminum mirror substrate. Various tests were conducted on a two-thirds size primary test mirror and results agreed well with computer stress models. Projecting the measured effects to the full size mirror indicated that the design would work. These technology steps established the feasibility of the LAIRTS telescope concept.

The LWIR camera optics use a three-mirror relay with a demagnification of four. The focal plane array covers a one-degree square field, and has a 24 position filter wheel for color. The LWIR spectrometer has two channels, each with a blocking filter wheel and a tuned etalon for color.

4.4 E. A. Botti Abstract

Point of Contact: Mr. Anthony DeLuzzio
Telephone : (617)890-2222

As of this date E. A. Botti, Inc. has completed a structural and mechanical conceptual design which accomodates the latest optical design. Structural and thermal analyses have been performed which indicate that an all-aluminum telescope will satisfy the performance requirements at cryogenic temperatures. Significant light-weighting of the mirror and supporting structures must be accomplished since alignment and test must be performed with the telescope in a vertical position in order to avoid distortions due to gravitational effects.

4.5 RDP Abstract

Point of Contact: Mr. Andrew Mazzella
Telephone : (617)890-5353

A variety of topics were considered as part of the software development and evaluation analysis. In addition to the fundamental process of developing the software design program, with its associated quality and schedule requirements, certain specific topics were investigated as being critical in influencing instrument design considerations and mission requirements. These topics were:

- A) Star Field Stabilization and Positional Referencing
- B) Encounter Scenarios
- C) Shuttle Vibrations

4.6 Northeastern University Abstract

Point of Contact: Mr. Lawrence O'Connor
Telephone : (617)437-3052

The LAIRTS controller is a microprocessor based system capable of pre-programmed test sequences or individual function control and monitor. Test parameters are stored in EEPROM's, programmable through a serial communication link. A processor independent timer circuit has a range of over an hour-and-a-half with a resolution of 0.1 seconds. Other timing combinations can be incorporated if necessary. Efforts during FY 85 included design of processor, input/output and power supply circuits; investigation of packaging concepts; and fabrication of a prototype.

A Prototype unit, with 64 function capability, was tested using an RS232 serial link to a computer terminal. Features of the prototype system include:

- Busboard configuration - expandable for multiple plug-in cards with standard power and signal distribution system.
- Power supply card - includes converters, self-test circuits and monitor circuits for operating parameters.
- Processor card - accomodates the 8751 microcontroller, memory, event timer, address latch, control signal buffers, card select logic, serial channel transceiver and master reset logic.
- Output cards: each output card contains eight latched-relay-drivers, providing 64 control lines through dedicated output connectors.
- Digital input cards: each card provides 64 inputs for monitoring relay contact positions or any other bi-level devices.

Software was developed for several test routines using the prototype assembly. Further definition of payload requirements will allow hardware and software development to continue.

For the probe option a modular version of the prototype unit, incorporating printed circuit boards in place of wire-wrap, is contemplated. The busboard structure allows for additional output cards, input cards, or special interface cards as required. Duplicate units, operating in parallel, will provide redundancy.

A similar package would be incorporated in the shuttle option with the additional constraint of certified components and acceptable card-edge connectors. Also an interface card will be required to provide status monitors, a test menu and control capability to the mission specialist. A backup controller is included, and the mission specialist would have the option of switching to the redundant unit if problems developed.

5.0 INITIAL DISTRIBUTION

Initial planning calls for the distribution of 12 copies of all contractor LAIRTS final reports. SIE has been tasked to collect each contractor report. In addition, SIE is providing this Executive Summary which will catalogue the information available for initial and subsequent distribution. Contractor submissions are due as soon as possible after 1 Dec. 1985 and should be sent to:

Systems Integration Engineering, Inc.
35 Bedford Street, Suite 12
Lexington, MA 02173

Figure 1 outlines the documentation flow for the initial distribution, according to Table 1. Initial distribution will begin as soon as contractor reports are available.

Figure 1: FLOW DIAGRAM OF INITIAL DISTRIBUTION

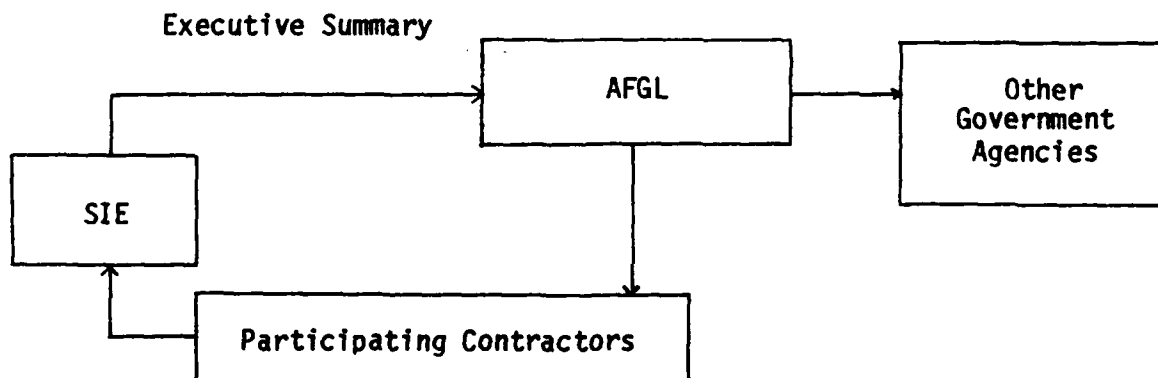


Table 2: INITIAL DISTRIBUTION

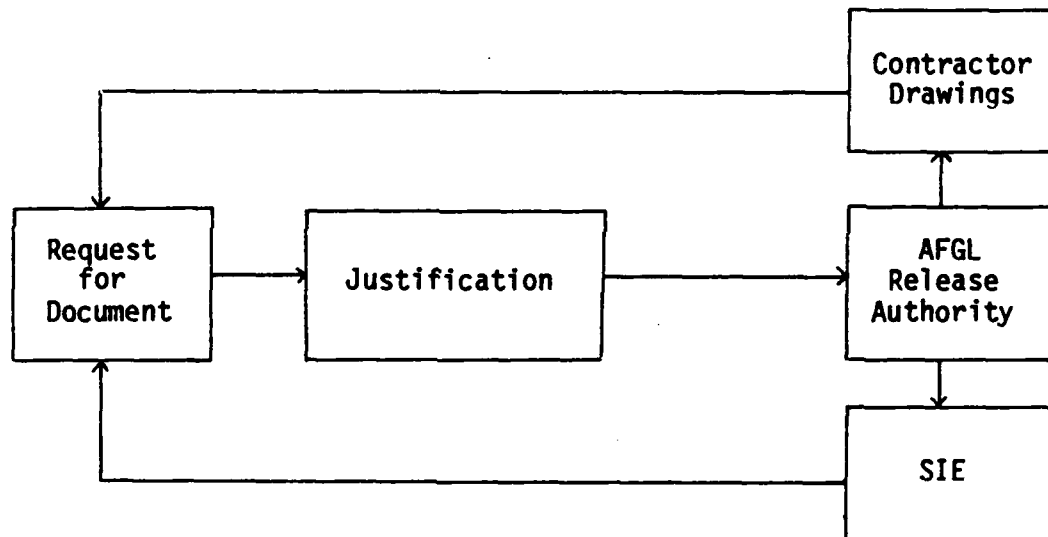
<u>Distribution</u>	<u>Executive Summary</u>	<u>Other Reports</u>
AFGL	5	5
NRL	1	1
SIE	1	1
WIT	1	1
SSG	1	1
EAB	1	1
RDP	1	1
NU	1	1

As shown in Table 2, AFGL will initially have 3 complete documentation packages for immediate distribution to qualified agencies. These three packages are in addition to those two retained by the LAIRTS PROJECT SCIENTIST and the LAIRTS CHIEF SYSTEMS ENGINEER.

6.0 SUBSEQUENT DISTRIBUTION

SIE will maintain a limited number of copies of the LAIRTS report package, but will not have reproducible copies of engineering drawings. The documents will be maintained in a separate documentation file and will be available for rapid response to AFGL distribution requirements. The documents will be kept for an indefinite period. They will be available for distribution at any future time that the requirement exists to review previous efforts to develop a Large Infrared Telescope. The documents will be distributed to authorized Government agencies when distribution approval is obtained from the LAIRTS PROJECT SCIENTIST or the LAIRTS CHIEF SYSTEMS ENGINEER. Figure 2 shows the flow for subsequent distribution of the LAIRTS documents.

Figure 2: SUBSEQUENT REPORT DISTRIBUTION



Government agencies will submit distribution requests to the LAIRTS
PROJECT SCIENTIST:

Dr. Paul LeVan, OPI
Air Force Geophysics Laboratory
Hanscom Air Force Base, MA

or to the LAIRTS CHIEF SYSTEMS ENGINEER:

Mr. Roy Walters, LCI
Air Force Geophysics Laboratory
Hanscom Air Force Base, MA

Requests should contain justification to support the distribution and should specify the reports and drawings required. The AFGL release authority will direct SIE to distribute the required reports and will request copies of required engineering drawings from the contractor maintaining the original drawings. AFGL will be advised when each distribution is completed.

7.0 SUMMARY

This executive summary is limited in that it contains only a brief description of the technical information available on LAIRTS. Its primary use is to allow Government agencies to rapidly scan the documentation available. Furthermore, it provides details on how an interested agency can acquire more information through a specific contractor's technical report.