PA-LOC-272

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

Originator: **Zaki Kudiya** Date: **7/15/02**

Subject/Title: **OPERATIONS HAZARD ANALYSES**

Description/Summary/Contents:

1. This Operations Hazard Analyses (OHA) provides planning, analyses, and documentation of potential system and personnel hazards related to the contractor operations and testing of the HIRDLS Instrument.

Keywords: Personnel Safety, Hazardous Conditions, Operations and Tasks,

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Purpose of this Document: This document constitutes CDRL #L107
(20 char max.)

Reviewed by**:** **/s/ Albert Rodriguez for/ Terry Osborn (ATC Lead)** Date (yy-mm-dd):	**/s/ Zaki Kudiya**	**/s/ Althea Mcfield**	**/s/ Tim Crews**	**/s/ Eric Johnson**

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1.0 INTRODUCTION
The document provides planning, analyses, documentation of the Operations Hazards Analyses (OHA) for the High Resolution Dynamics Limb Sounder (HIRDLS) instrument. The OHA is submitted in accordance with CDRL No. L107.

2.0 OHA OBJECTIVES
The OHA is used to identify hazardous operations and tasks, the conditions associated with the tasks, the causes of the hazardous conditions, the risks associated with the hazardous conditions, and recommendations to eliminate or reduce the effects of the hazardous conditions.

In the performance of an OHA the following are considered:
a) Planned configuration at each phase of activity.
b) Supporting tools or other equipment specified for use.
c) Operational/task sequence, concurrent task effects and limitations.
d) Biotechnological factors, regulatory or contractually specified personnel safety and health requirements.
e) Potential and unplanned events including hazards introduced by human errors.

3.0 OHA SCOPE
This OHA addresses the planning and describes the performance of the Hazards Analyses of the HIRDLS instrument.

The HIRDLS instrument is comprised of the following subsystems as defined in the instrument specification (GSFC 424-28-21-13):

a) Structure/Thermal Subsystem (STH)
b) Sunshield Subsystem (SSH)
c) Gyro Subsystem (GSS)
d) Telescope Subsystem (TSS)
e) Detector Subsystem (DSS)
f) In-Flight Calibrator Subsystem (IFC)
g) Instrument Processor Subsystem (IPS)
h) Cooler Subsystem (CSS)
i) Power Subsystem (PSS)

The TSS, DSS, IPS, and PSS are contractor supplied, while all others are to be considered GFE (supplied by UK contractor).

With the requirements stated in GSFC 424-11-13-01, the OHA is performed due to the fact that the use of a facility or the performance of an activity could result in subjecting the instrument or personnel to hazards. The OHA identifies the hazards and documents the requirements for either eliminating or adequately controlling each hazard. Operations that may require analyses include handling, transportation, functional tests, and environmental test.

Verification of the control of all hazards is accomplished by test, analysis, inspection, similarity to previously qualified hardware, or any combination of these activities.

4.0 REFERENCE DOCUMENTS

The following documents are referenced in this OHA:

LMSSC-MSO documents:

GSFC 424-28-21-13	Instrument Technical Specification (ITS)
GSFC 424-11-13-01 October 1996	Mission Assurance Requirements (MAR) for the High Resolution Dynamics Limb Sounder (HIRDLS) EOS Chemistry Mission
PA-LOC-103 October 1996	HIRDLS Instrument Integration Contamination Control Plan
TC-LOC-398A	Transportation and Handling Procedures
PM-HIR-362	Test Operation Standards

Government documents:

MIL-STD-1629A 28 November 1984	Procedures for Performing a Failure Mode, Effects and Criticality Analysis
MIL-STD-882C 19 Jan 1993	System Safety Program Requirements
EMR 127-1 (Tailored)	Eastern and Western Range Safety Requirements (As tailored for the EOS Common Spacecraft Projects)

HIRDLS Program documents:

PM-LOC-130	DSS and WFC Statement of Work
SP-HIR-037	Detector Subsystem (DSS) and Warm Filter Carrier (WFC)Specification
SP-LOC-121 Rev. A	Acceptance Test Station (ATS) Requirements
PA-LOC-072	Product Assurance Implementation Plan (PAIP)

5.0 SYSTEMS DESCRIPTION

HIRDLS System
HIRDLS is an Infrared (IR) radiometer designed to view the atmosphere at the limb from Low Earth Orbit (LEO), for the purpose of collecting thermal gradient, and selected IR band radiant data.

The HIRDLS Detector Subsystem (DSS) converts chopped IR radiation collected by the HIRDLS Telescope Subsystem into ac voltages. The DSS consists of 21 HgCdTe Photoconductive IR detectors and one quad-cell alignment detector, with associated optical filters of the Cold Filter Assembly (FPA), contained in a hermetically sealed vacuum dewar and provided with individual preamplifiers. These 21 preamps are located inside of the HIRDLS Signal Processor Unit (SPU) while the alignment detector preamplifier is located in the Ground Support Equipment, as it will be operated only during ground testing and not during the HIRDLS mission. Analog filtering and digitizing occur in the SPU of the Instrument Processor subsystem, and are not part of the DSS. The FPA is cooled through a flexible link by a closed cycle refrigerator, which is part of the Cooler Subsystem (CSS). The Alignment Detector will be used to measure vertical line-of-sight (LOS) jitter using a thermal source, e.g. a black body operating at 600 degrees K.
The HIRDLS instrument is comprised of the following subsystems as defined in the instrument specification (GSFC 424-28-21-13):

Structure/Thermal Subsystem (STH)
Sunshield Subsystem (SSH)
Gyro Subsystem (GSS)
Telescope Subsystem (TSS)
Detector Subsystem (DSS)
In-Flight Calibrator Subsystem (IFC)
Instrument Processor Subsystem (IPS)
Cooler Subsystem (CSS)
Power Subsystem (PSS)

The TSS, DSS, IPS, and CSS are contractor supplied, while all others are to be considered GFE (supplied by UK contractor).

Telescope Subsystem (TSS)
The TSS consists of optical components, and Optical Bench (OB) mounted to the Baseplate, that holds the optical components in rigid alignment, and the necessary electronics to control and monitor scanning, chopping and temperature control functions. The optical components form a telescope that focuses IR radiation from the atmosphere at the limb onto a cooled focal plane. The LOS of the telescope is determined by the attitude of the Optical Bench, and the setting of a 2-axis scan mirror. A light chopper provides the detectors with alternating views of the atmospheric scene and a stable reference.

Detector Subsystem (DSS)
The DSS consists of 21 HgCdTe IR detectors contained in a vacuum dewar and cooled to 60-65 degrees K by the Cooler Subsystem. Each detector element views the atmosphere through a separate cooled bandpass filter element of the Focal Plane Filter Assembly (FPFA) and has an Instantaneous Field Of View (IFOV) in the atmosphere that extends 1 km vertically (tangent height) and 10 km horizontally. The DSS is mounted on the OBA. A cable connects the DSS to the instrument’s Signal

Processing Unit (SPU). This cable is made of AWG 28 Gauge Wire, Cu Braid and MU-metal Foil Shield, Textile Braid Jacket, NASA and MICRO D Plugs, and Keyed Connectors The DSS is mounted on the OBA.

Instrument Processor Subsystem (IPS)

The IPS serves as the logical single point of contact between the Instrument and the Spacecraft. It manages the Instrument side of the Command and Telemetry (C&T) interface, controls and coordinates other subsystems, performs detector data processing, and gathers housekeeping data. The IPS weighs 22 kg. It interfaces with the Spacecraft (S/C), Power Subsystem (PSS), Telescope Subsystem (TSS), Gyro Subsystem (GSS), In Flight Calibrator (IFC), Cooler Subsystem (CSS), Sunshield (SSH), Detector Subsystem (DSS), and temperature sensors and operational heaters. The Instrument Processing Unit (IPU) has a redundant system of Side A and Side B. Each side is on when their quiet bus (A and B) are on. Each side has a power supply of DC-DC converters, control computer, and subsystem interfaces and control logic. The IPS has an independent power system that provides isolation from subsystem faults. It has 28V Driver Printed Wiring Board.

Power Subsystem (PSS)

The PSS is installed within the Instrument enclosure and includes power converters, mounting backplane, packaging components, and associated interconnects. The function of the PSS is to supply secondary regulated and conditioned power at a variety of voltages to the other Instrument subsystems. Its design is based on a Standby Redundancy Concept. The PSS has Redundant DC-DC Converters (DESC SMD approved), Redundant Relays (MIL 39016; MIL-R-83536; MIL6016), and Redundant Logic (Harris RH typically).The system is limited to 28 V and is not addressed in the hazard worksheets.

GFE Subsystems

Structure/Thermal Subsystem (STH)

The Instrument is contained in a roughly cubical, 1.3-meter-size box attached to the earth-facing side of the spacecraft. The structure is made graphite epoxy (CFRP) faceskins with an aluminum honeycomb. A baseplate to which the other subsystems and components of the Instrument are attached, either directly or indirectly, serves as the mechanical interface to the spacecraft. The baseplate has an Optical cube on it for alignment. The Spacecraft Interface consists of 7 Ti Mounting Feet (KM Mounts).There are Radiator panels, perpendicular to the Baseplate, carry the components of the Cooler Subsystem and some of the electronics modules; the remaining electronic units being located in the –X end of the instrument. These radiator panels form the outer wall of the Instrument on the anti-sun side and radiate heat to space. The rest of the Instrument enclosure consists of panels, externally covered with multi-layer insulation (MLI) on the non-radiator surfaces.

Sunshield Subsystem (SSH) and Space View Aperture (SVA)

The Instrument views the limb along a line-of-sight inclined downward at an angle of approximately 25° below horizontal. This view is via a Sun Shield (SSH) that allows a small elevation scan range and a large azimuth scan range while shading the interior of the Instrument enclosure from sunlight and through the Space View Aperture (SVA) an inclined rectangular tunnel that provides a reference view to cold space. The aperture door is latched closed to protect the interior of the Instrument from contamination during launch. The aperture door also serves as an adaptive sunshield that it partially closes the aperture once per orbit near local sunset to prevent direct sunlight entering the aperture. The Sunshield door is made of CFRP(Graphite Epoxy) with an Aluminum Honeycomb. The Hold-down and release Mechanism (HRM) holds the sunshield door in a latched condition during launch, and releases the door on command from the IPS when on orbit. The HRM can be manually latched without the use of special tools and without power. The deployment mechanism is a drive actuator consisting of a 3 phase stepper motor & gearhead. The hinge axis support has independent spherical bearings and has position microswitches.

Gyro Subsystem (GSS)

The GSS provides independent knowledge of changes of attitude of the optical bench for use during ground data processing. The GSS consists of the GMU (Gyro Mechanical Unit), GEU (Gyro Electronics Unit) and U26 Harness. The GSS weighs 9.85 kg. The operating temperature of the gyroscopes is 70°C. The GMU contains 4 type 125 Ferranti gyroscopes. The Gyro Electronics Unit GEU has four Ferranti frames with each holding a Gyro Interface Circuit Board and an External Interface Board. The U26 harness connects the GMU to the GEU.

In-Flight Calibrator Subsystem (IFC)

The IFC consists of a small-area blackbody with control electronics (BEU) and an off-axis parabolic mirror, controlled to the same temperature and accurately monitored. The subsystem provides an effective large-area blackbody within the Instrument enclosure to which the LOS may be directed for the hot calibration view at a temperature of approximately 300 degrees K. It concentrates the effective emitting surface in a small area with the highest thermal conductance. The IFC weighs 3.53 kg. The mirror is also used to position the optical view of the instruments sensors to cold space.

Cooler Subsystem (CSS)

The Cooler Subsystem weighs 28.17 kg and consists of a pair of split-cycle Sterling cryocoolers which are mounted on a radiator panel that dissipate power to cold space. The cold-tips of the coolers are connected to the Detector Subsystem by a vacuum-jacketed flexible thermal link. The Split-Stirling Cycle CSS provides the cooling for the Detector Array, Cold Filter Assembly and Cold Shield, which are located in the Detector Subsystem (DSS) Dewar Unit, which is in turn mounted on the TSS Optical Bench. The CSS must be capable of cooling the Detector Array, via the Cold Link, while in both ground and flight environments. The maximum operating of the CSS is 133 psid at room temperature. The CSS uses helium for cooling. The CSS consists of six elements, the Cooler Mechanical Unit (CMU), Cooler Control Unit (CCU), Cryovac Housing (CVH), Cold Link & Flexible Vacuum Enclosure, Cooler Software, and the Cooler Radiator Panel. The compressor and displacer were proof pressure tested and leak checked.

Contamination Control Plan (CCP)

The HIRDLS instrument is sensitive to both molecular and particulate contamination; and will require contamination control to meet defined performance requirements in addition to the contamination requirements of the other EOS Payload instruments and Spacecraft requirements. The Contamination Control Plan (CCP) meets the requirements of CDRL 007 (see reference PA-LOC-103). The objective of the CCP is to develop and implement design features and ground-operations procedures to ensure mission success without failures due to contamination-induced effects. The scope of the CCP is to establish contamination control requirements and define their implementation to assure that the HIRDLS instrument program performance objectives are met. This end-to-end plan begins with the development of particle and molecular contamination requirements from performance requirements which then influence the development of the instrument design, fabrication, integration, testing, storage, transportation, and satellite integration operations.

Introduction of ATS Requirements Testing

This Acceptance Test Station (ATS) Requirements involve two distinct “stations”, the Line of Sight (LOS) Acceptance Test Station and the Radiometric Acceptance Test Station. The LOS ATS will consist of a stable platform capable of supporting the HIRDLS instrument and the goniometric metrology test equipment required to characterize the instrument’s LOS performance. The LOS ATS is located in the same class 100 cleanroom as the building 202 HIRDLS instrument integration facility at the Lockheed Martin Advanced Technology Center in Palo Alto California, also known as the Lockheed Martin Palo Research Laboratories (LMATC). The Radiometric Acceptance Test Station consists of a vacuum-compatible vibrationally isolated optical table capable of supporting the HIRDLS instrument and the infrared sources, collimator and related test support equipment for characterization of the instrument's radiometric performance. The Radiometric Acceptance Test Station will reside in the SEARCH chamber in building 205 of the Palo Alto facility.

Line of Sight ATS

The LOS Acceptance Test Station concept takes advantage of an easily accessible (no vacuum chamber) testbed. All of the requirements of ITS section 3.5 except for jitter are verifiable outside of a vacuum chamber. The key elements of the LOS ATS are:

(1) A large optical bench platform capable of establishing a stable mechanical reference between the instrument and the test equipment. (2) A "vertical" optical bench to contain the test equipment. (3) A collimated IR test source. (4) A precision 2-axis scanning mirror drive system. (5) A "rotate and lock" platform for the instrument. (6) A system of test isolators and shakers. Figure 1 is a schematic diagram of the LOS ATS concept.

The LOS ATS allows characterization of the two aspects of LOS verification, pointing knowledge and pointing control.

(1) Pointing Knowledge Verification

- Independent of Control Loop (within sensor/telemetry bandwidth)
- Uses full accuracy of Calibrated feedback sensor
- Accuracy confined to telemetry sample rate
- Makes use of additional sensors (Gyros and "Wobble" sensors), which are not part of the control system

(2) Pointing Control Verification

- Dependent upon Control Loop accuracies
- Dependent upon Real time accuracy of feedback sensors
- Utilizes full bandwidth of feedback sensors

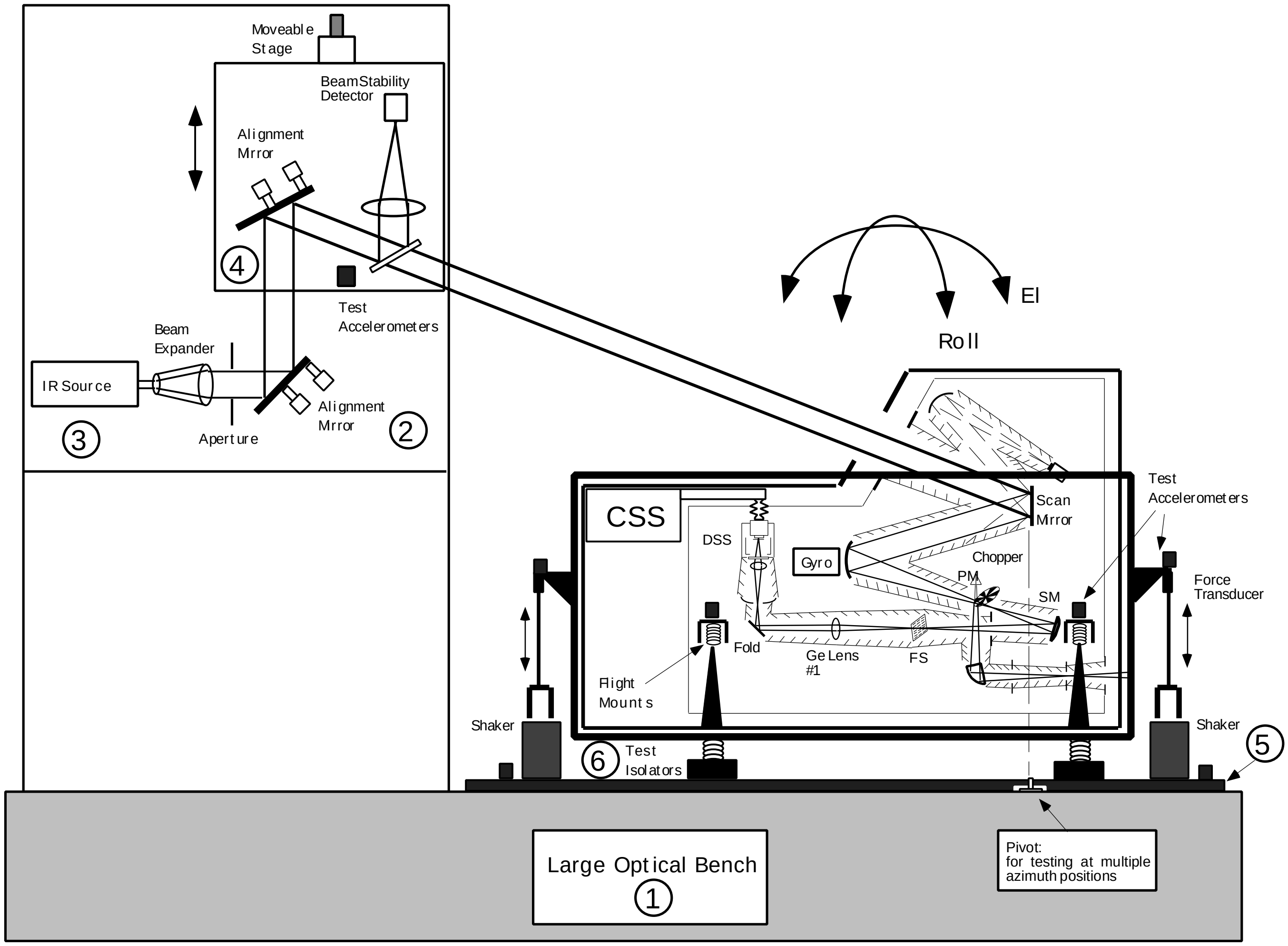


Figure 1-Line of Sight Testbed

Radiometric ATS

The Radiometric Acceptance Test Station consists of:

(1) A one (1) meter by four (4) meter vacuum compatible vibrationally isolated optical table. (2) A radiometrically stable IR full field flood source. (3) An IR line source. (4) An IR point source. (5) A jitter test source, possibly the same source as item 4. (6) A full field IR collimator. (7) A vertical translation stage for item 2. (8) A rotating mount for presenting item 3 to the collimator either vertically or horizontally. (9) A source selection mechanism for presenting items 3, 4 and 5 to the collimator input. (10) A full mission azimuth range rotary platform for the instrument. (11) IR source controllers, mechanism controllers, chamber control and monitoring equipment rack. (12) Vacuum chamber, 2.4m diameter by 4.5 meters long. (13) Three (3) meter by five (5) meter portable cleanroom. Figure 2 is an overview of the radiometric ATS facility.

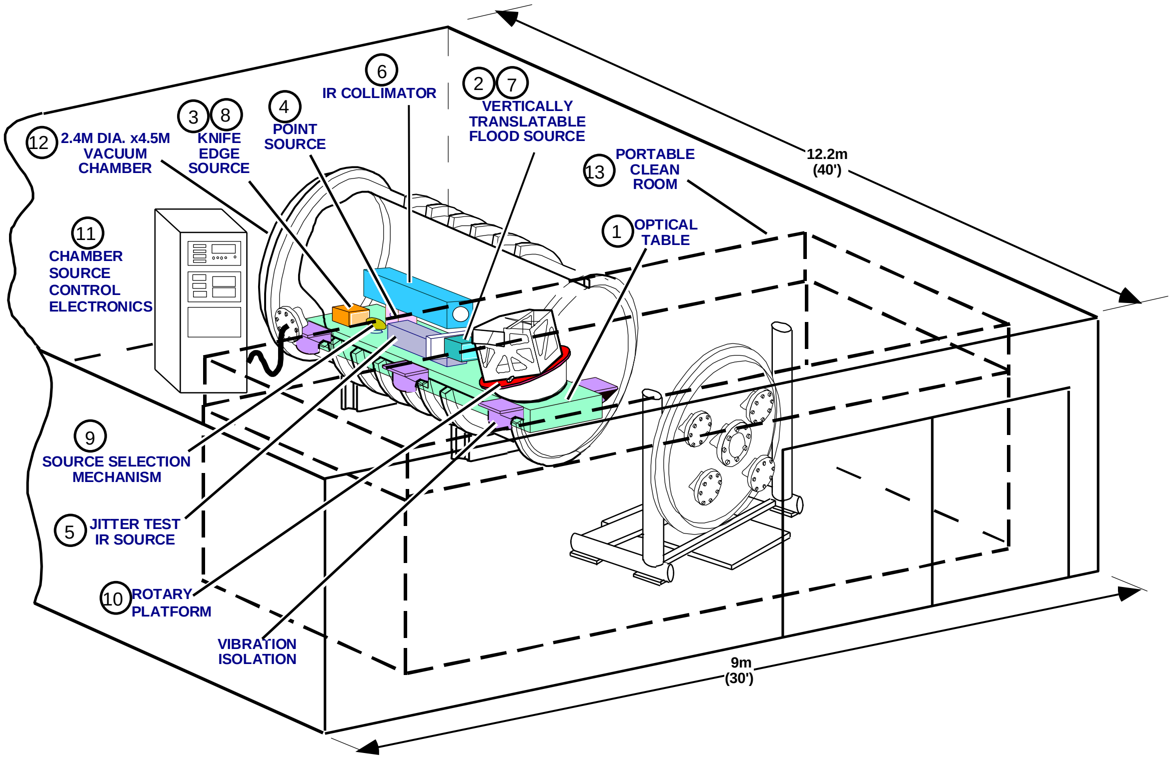


Figure 2-SEARCH Chamber facility at LMATC

LOCATION:
The SEARCH Chamber facility is located in building 205, adjacent to Lockheed's LMATC receiving dock. It is just down the hall from the HIRDLS cleanroom instrument assembly area.

ACCESS:
The SEARCH Chamber facility is a controlled access area for high value space payloads.

6.0 OHA Hazard Analysis and Approach

The ATC Systems Safety Engineer (SSE) uses standard system safety methods and techniques to evaluate the risks presented by identified hazards. Ranking of risks presented by identified hazards will be used to allocate effort and resources to corrective action. The ranking is based upon worst-case severity and likelihood of occurrence of an accident. Accident severity categories to be used for the HIRDLS program are defined in the table below. These categories provide a qualitative assessment of the worst potential consequences of accidents resulting from identified hazards.

The risk presented by a particular accident is obtained by multiplying its severity by its likelihood of occurrence. The ranking obtained is a guide to allocating effort and resources for eliminating the hazard or controlling the risk it presents to an acceptable level.

Table 1 ACCIDENT SEVERITY DEFINITIONS

Description	**Category**	**Accident Consequences**
Catastrophic	I	Death. System loss.
Critical	II	Severe injury. Severe occupational illness. Major system damage.
Marginal	III	Minor injury. Minor occupational illness. Minor system damage
Negligible	IV	No injury or illness. No system damage

Table 2 ACCIDENT LIKELIHOOD DEFINITIONS

Descriptive Word	Definition	Level
Frequent	Likely to occur frequently.	A
Probable	Will occur several times in life of the system.	B
Occasional	Likely to occur sometime in life of the system.	C
Remote	So unlikely to occur that it can be assumed that this accident won't occur in life of system.	D
Improbable	Probability of occurrence is essentially zero.	E

Table 3 RISK LEVEL MATRIX

Level	Likelihood of Occurrence	I Catastrophic	II Critical	III Marginal	IV Negligible
A	Frequent	1	3	7	13
B	Probable	2	5	9	16
C	Occasional	4	6	11	18
D	Remote	8	10	14	19
E	Improbable	12	15	17	20

The levels of risk a hazard may present are categorized or grouped by level using the above matrix, as follows:

Unacceptable - Numbers 1 through 5
Undesirable - Numbers 6 through 9
Acceptable With Review - Numbers 10 through 17
Acceptable Without Review - Numbers 18 through 20.

In performing the OHA, a number of worksheets are generated to give specific information about an identified hazard (see below for the worksheet format). No more than one (1) hazard is described on each worksheet. The specific information found on the formatted analysis worksheets analyzes each identified hazard or operation of the HIRDLS test.

It is the objective of this OHA to support the HIRDLS program during the testing that are conducted in ATC. Below are some of the objectives:

1. Identify combinations of equipment failure modes, and environmental issues that may result in personnel hazards.

2. Provide a hazard category.

3. Provide recommendations for cost effective control of identified hazards.

4. Determine level of conformance with safety requirements.

7.0 Hazard Worksheets

The OSH Hazard Analysis Worksheets are presented on the next page. The Hazards are:

- Lifting of the HIRDLS Instrument
- Transportation

Both of the Hazards are Category III. Both Hazards have scores higher than 10. This means that both Hazards are closed. Both operations have been repeated successfully during the life of the HIRDLS program and are considered safe.

OPERATIONAL HAZARD ANALYSIS **SHEET:** 1
PROGRAM: HIRDLS
SUBSYSTEM:
PREPARED BY: Zaki Kudiya
DATE:

Operational Component: HIRDLS Instrument

Function/Task: Lifting of the Instrument

Operation: Lifting of the Instrument. The HIRDLS Instrument is typically lifted a few feet off the ground to either place on blocks below it for alignment or for movement.

Failure Mode/Failure Hazard Effect: There is collision potential from there not being any control of the Instrument while in movement. This can occur from improper personnel or not having a proper handle on the Instrument.

Preventive Actions: Test Operation Standards (PM-HIR-362) call out that only essential personnel are allowed to be involved in the movement of the HIRDLS instrument. Test Operations Standards also say that only certified personnel are allowed to operate hoisting equipment. A NASA representative is always present during hazardous operations. System Safety is notified by I&T (Integration and Testing) for safety concerns and is involved in monitoring these operations. Quality Assurance Personnel are also involved in lifting operations. Since the HIRDLS instrument in not very high off the ground (4-5 ft), I&T personnel guide it themselves to avoid collision. This also allows for the Instrument to be easily controlled during mechanical movements.

Risk Assessment: **Category** III, **Probability** D, **Criticality** 14

Remarks: Closed. System Safety has monitored lifting operations of the HIRDLS instrument. Collision potential is mitigated by proper personnel being involved. Since the HIRDLS instrument is not lifted very high off the optical bench, proper control is insured.

OPERATIONAL HAZARD ANALYSIS **SHEET:** 2
PROGRAM: HIRDLS
SUBSYSTEM:
PREPARED BY: Zaki Kudiya
DATE:

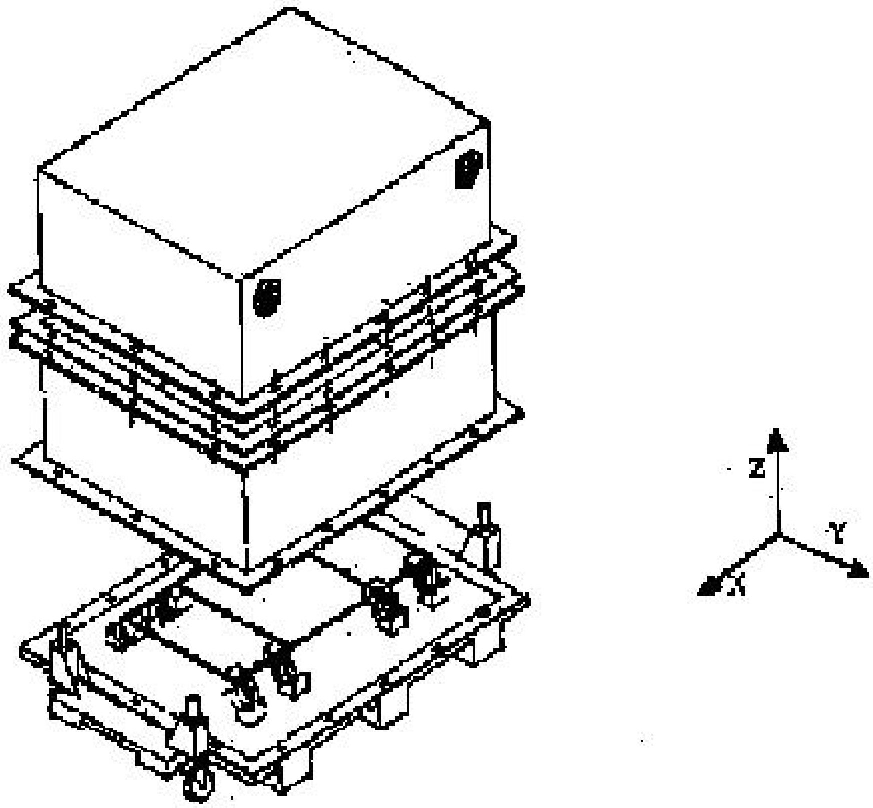
Operational Component: HIRDLS Instrument

Function/Task: Transportation

Operation: When the HIRDLS instrument is being moved to different locations for testing, it is transported in a container.

Failure Mode/Failure Hazard Effect: During transportation collision of the instrument could occur with walls and doors. This could happen from lack of operational procedures and an improper container.

Preventive Actions: TP-LOC 398 Rev. A –Transportation and Handling Procedures has been released to cover proper transportation and storing of the HIRDLS instrument. The procedure contains an appendix detailing the proper steps taken in the storing of the vehicle. The container used in this procedure is shown below:



The transportation container has deployable wheels and lifting slots for forklifts during transport, and lifting points for cranes to remove the cover. Within buildings, wheels are used to transport the container and the forklift is used to load on the truck. It consists of a midsection and a top section. The HIRDLS instrument is also required by this procedure to be placed in an ESD bag and purged with GN2. A zipper-locking bag is used for transport to Oxford. The instrument is placed on an isolation sub-chassis for protection from the container, and secured using mounting hardware. Shock, temperature and relative humidity are called out in the procedure for continuous monitoring. The procedure calls out that the truck will have an air-ride trailer to prevent shock being delivered to the instrument. Test Operation Standards (PM-HIR-362) calls out that only essential personnel shall be involved in the movement of the satellite and the procedure states that the crane operator must be certified.

Risk Assessment: **Category** III, **Probability** C, **Criticality** 11

Remarks: Closed. System Safety has monitored transportation operations. The transportation container protects the HIRDLS instrument. The procedure is followed and proper care is taken in the transportation of the Instrument. Proper personnel are able to move the container with the Instrument in it in a safe manner.

8.0 ACRONYMS

ATC	Advanced Technology Center
BEU	Blackbody Electronics Unit
CCU	Cooler Control Unit
CMU	Cooler Mechanical Unit
CSS	Cooler Subsystem
CVH	Cryovac Housing
DSS	Detector Subsystem
EEA	Encoder Electronics Assembly
EOS	Earth Observing System
ESD	Electrostatic Discharge
EWR	Eastern And Western Range
FMEA	Failure Mode And Effects Analysis
FPA	Cold Filter Assembly
FPFA	Focal Plane Filter Assembly
GEU	Gyro Electronics Unit
GFE	Government Furnished Equipment
GIRD	General Interface Requirements Document
GMU	Gyro Mechanical Unit
GSFC	Goddard Space Flight Center
GSS	Gyro Subsystem
HIRDLS	High Resolution Dynamics Limb Sounder
HRM	Hold-Down and Release Mechanism
ICD	Interface Control Document
IFC	In Flight Calibrator
IFOV	Instantaneous Field of View
IPS	Instrument Processor Subsystem

IPU	Instrument Processing Unit
IR	Infrared
ITS	Instrument Technical Specification
K	Kelvin
LEO	Low Earth Orbit
LMSSC-MSO	Lockheed Martin Space Systems Company Missiles and Space Operations
LOS	Line of sight
MAR	Mission Assurance Requirements
MLI	Multi-Layer Insulation
OBA	Optical Bench Assembly
OHA	Operational Hazard Analysis
OS&H	Occupational Safety And Health
PIE	Product Integrity Engineer
PPL	Preferred Parts List
PSS	Power Subsystem
RO	Responsible Organization
SHA	Systems Hazard Analysis
SPU	Signal Processor Unit
SSE	System Safety Engineering
SSG	Sensor Systems Group
SSH	Sunshield Subsystem
STH	Structural/Thermal Subsystem
TEU	Telescope Engineering Unit
TSS	Telescope Subsystem
UK	United Kingdom
WSEA	Wobble Sensor Electronic Assembly