SCANNING HIGH-RESOLUTION INTERFEROMETER SOUNDER (S-HIS)

Instrument Description Document

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Quick Reference Data Sheet

Instrument name and acronym	Scanning High Resolution Interferometer Sounder (S-HIS)
Principal Investigator	Joe K Taylor Email: joe.taylor@ssec.wisc.edu Phone: 608-263-4494 (work), 608-320-4607 (cell)
Instrument and/or PI website	http://shis.ssec.wisc.edu
What does the instrument measure?	The Scanning High-resolution Interferometer Sounder (S-HIS) is a cross-track scanning interferometer which measures emitted thermal radiation at high spectral resolution between 3.3 and 18 microns (specifications). S-HIS produces sounding data with 2 kilometer resolution (at nadir) across a 40 kilometer ground swath from an altitude of 20 kilometers
Dimensions of major components (inches)	Interferometer Enclosure and Calibration Module: 28.8x12x13 Electronics Enclosure : 15 x 11.5 x 11.26 Data Storage Computer : 7.9 x 5.5 x 14.7 When mounted on ER-2 centerline pod frame: 61.32 (L) x 14.44 (H) x 17.09 (W) envelope
Total weight (pounds)	Interferometer Enclosure and Calibration Module: 78.5 lbs Electronics Enclosure : 30 lbs Data Storage Computer : 8.9 lbs Frame : 16 lbs Cabling : 4.6 lbs Total, including ER-2 centerline pod frame: 138 lbs
Control method (aircrew switches, onboard researcher, fully autonomous, uplink/downlink)	2 pilot switches (Instrument power, descent mode)
Do you require real time aircraft state parameters (time, nav data, etc.)?	Time and nav data required
Telemetry/satcom requirements	
List missions flown and on which aircraft.	GOES-R PLT (ER-2), SNPP Cal Val 2015 (ER-2), HS3 (Global Hawk, 2011, 2012, 2013, 2014), SNPP Cal Val 2013 (ER-2), Railroad Valley (ER-2), TC-4 (ER-2), JAIVEx (WB-57), Tahoe 2006 (ER-2), CR-AVE (WB-57), AVE (WB-57, 2004, 2005), MPACE (Proteus), EAQUATE (Proteus), ADRIEX (Proteus), INTEX-Proteus (Proteus), Tahoe 2004 (ER-2), Atlantic THORPEx (ER-2), Pacific THORPEx (ER-2), TX-2002 (ER-2), ARM-UAV (Proteus), SMEX 2002 (DC-8), IHOP (ER-2), CLAMS (ER-2), TX-2001 (ER-2), AFWEX (DC-8), SAFARI 2000 (ER-2), WISC-T2000 (ER-2), KWAJEX (DC8), WINTEX (ER-2), AirMISR 1998 (ER-2), CAMEX-3 (DC-8)

Aircraft Power Requirements

	Power (watts)	Load name	Peak current	Run current
28V DC	280 W peak (typ)	Bus A	15 A Fused (typical peak of 10A)	9 – 10 A
28V DC	392W peak (typ)	Bus B	15 A Fused (typical peak of 14A)	3.5 - 14 A

Table of Contents

Payload Description

Overview

The Scanning High-resolution Interferometer Sounder (S-HIS) shown in Figure 1 is an advanced version of the HIS NASA ER-2 instrument. The S-HIS was initially designed to fly on an unmanned aircraft vehicle (UAV) with limited payload capacity. This drove it to be small, lightweight, and modular, with low power consumption. It was developed between 1996 and 1998 at the University of Wisconsin (UW) Space Science and Engineering Center (SSEC) with the combined support of the US DOE, NASA, and the NPOESS Integrated Program Office. Its design and calibration techniques have matured from experience with the HIS and with the ground based Atmospheric Emitted Radiance Interferometer (AERI) instruments developed for the DOE Atmospheric Radiation Measurement (ARM) program. The nadir-only spatial sampling of the original HIS has been replaced by programmable cross-track coverage with similar sized footprints. The S-HIS is also smaller, more robust, and easier to operate. Since 1998, the S-HIS has flown in several field campaigns and has proven to be very dependable and effective. It has flown on the NASA ER-2, the NASA DC-8, the Scaled Composites Proteus, the NASA WB-57, and the NASA Global Hawk. On the Proteus and WB-57 aircraft, an upward (zenith) view is available, providing a means for further calibration verification analysis and upper atmosphere studies.

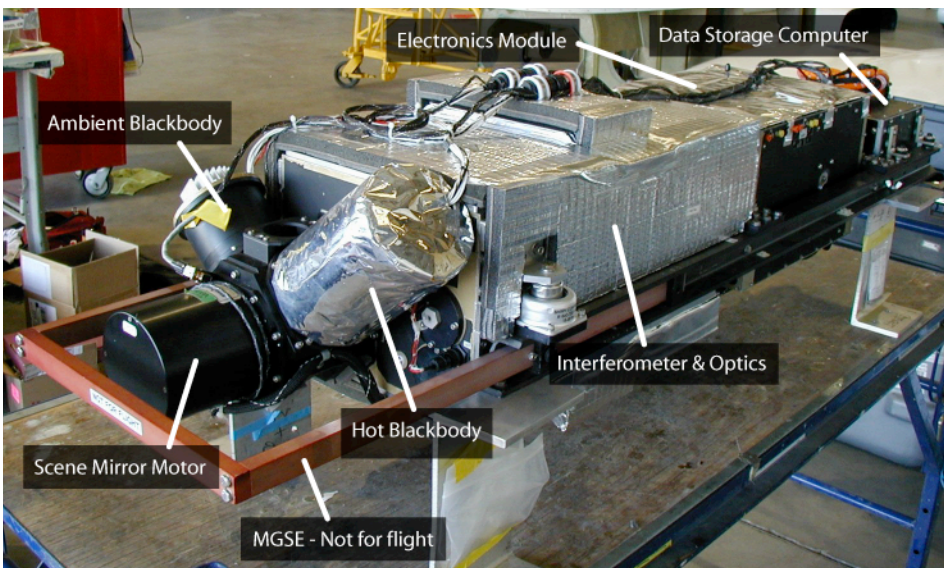

Figure 1: The Scanning High-resolution Interferometer Sounder (S-HIS); Proteus integration (with extra insulation on optical enclosure), Scaled Composites, July 2004.

Instrument Measurements and Characteristics

The basic spectral and geometrical sampling characteristics are summarized in Table 1. The optical design is very efficient, providing useful signal-to-noise performance from a single 0.5 second dwell time. This allows imaging with 2-3 km resolution to be accomplished by cross-track scanning. Onboard reference blackbodies are viewed via a rotating 45° scene mirror as part of each cross-track scan, providing updated calibration information every 20-30 seconds.

The fundamental measurement consists of one numerically filtered interferogram from each of the three spectral bands collected every 0.5 second. These interferograms are stored on a solid-state hard drive. The Level 0 data is downloaded from the instrument over an ethernet connection and processed to calibrated radiances and temperature and water vapor retrievals. This allows initial conclusions to be made in a timely way for evaluating the success of experiment objectives as the field campaign progresses. Detailed instrument health and performance data is also processed each day to assure that a healthy instrument is ready for the next flight.

Table 1. S-HIS Characteristics

Characteristic	Specification / Description	Note
Interferometer		
Interferometer type	Voice Coil Dynamically Aligned plane mirror (Custom Bomem DA-5)	
Fringe counting	¼ wave quadrature, continuous	
Optical Path Difference (OPD) sampling reference	HeNe laser w/ white light at startup	
Michelson mirror assembly	Linear bearing with voice coil	UW-SSEC design
Beamsplitter / Compensator	KBr; wedged; Antimony trisulphide and Ge coating	
Spectral resolution	0.5 cm^{-1}	Unapodized
OPD scan speed	4 cm/s	
Maximum Optical Path Difference (OPD_{MAX})	$\pm$1.037 cm	unapodized resolution = $(2 * OPD_{MAX})^{-1}$
Angular FOV	$\pm$20 mrad	
Scan time	0.5 s	
Beam diameter	4.5 cm (aperture stop)	
Mirror tilt monitoring	0 – 2 kHz	
Spectral Coverage		
Longwave (LW) band	9-17 µm, 580-1200 cm^{-1}	HgCdTe
Midwave (MW) band	5.5-9 µm, 1030-1810 cm^{-1}	HgCdTe
Shortwave (SW) band	3-5.5 µm, 1760-3000 cm^{-1}	InSb
Cooler type / Detector temperature:	0.6 W Stirling Cooler (Litton), 78 K	
Spatial sampling		
Angular Field-of-view (FOV)	100 mrad	
Beam diameter	2.85 cm (at scene mirror)	
Cross-track scan step	0.15 rad	programmable
Number of IFOV per cross-track scan	15 earth views + 10 calibration views	Typical (programmable)
Mass:	63 kg	
Onboard data processing:	64-point FIR filter	
RMS noise (per spot):	< 0.25K at 260 K	
Radiometric Uncertainty (k=3):	< 0.3K absolute (at altitude) 233-300 K brightness temp equivalent scenes	

The S-HIS employs a customized commercial interferometer (DA5 from Bomem, Inc, Quebec, Canada), with dynamically aligned plane mirrors. The moving Michelson mirror is voice coil driven and its support mechanism was designed and built at UW-SSEC to make use of a linear bearing approach to minimize tilts. The spectral characteristics of the measurements are very well known and stable because of the use of a HeNe laser to control optical delay sampling. A 1/4-wave quadrature system is used to assure that no samples are dropped or miscounted and the laser is also used to maintain alignment. Any residual misalignments are measured as a diagnostic and as the basis for corrections as needed.

The continuous spectral coverage from 3.3 to 16.7 μm at 0.5 cm^{-1} resolution is illustrated in Figure 2 by a sample spectrum from the SAFARI-2000 mission in South Africa. This coverage is divided into three bands with separate detectors (two photoconductive HgCdTe and one InSb) to achieve the required noise performance. The bands use a common field stop to ensure accurate spatial co-alignment. The longwave band provides the primary information for temperature sounding for cloud phase and particle size. The midwave band provides the primary water vapor sounding information and further cloud property information. The shortwave band provides information on cloud reflectance and augments sounding information. The detectors are cooled using a Litton 0.6W split-cycle Stirling cooler.

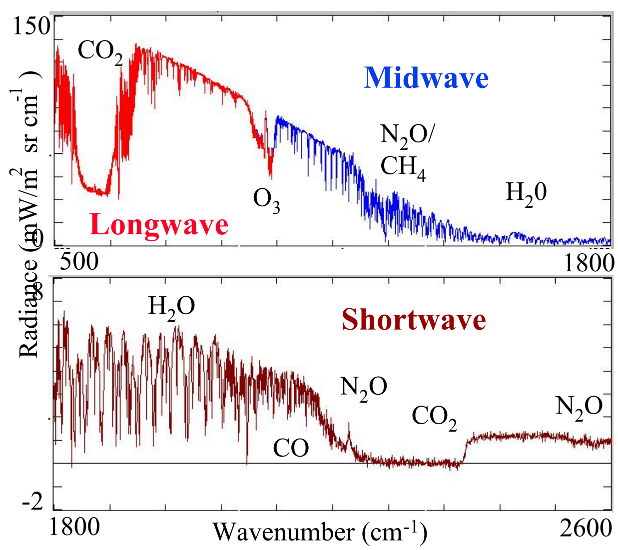

Figure 2. Sample Scanning HIS spectrum from NASA SAFARI-2000 mission. The three different spectral bands are color coded. There is overlap between the longwave and the midwave band that is useful for diagnostics.

Example of Data Products

The rapid sampling frequency of the S-HIS allows cross-track imaging at 2 km resolution with a swath width on the ground of 30-40 km. An example of how this capability can be used to build up an image of a larger area by flying a mapping pattern with the ER-2 is shown in Figure 3.

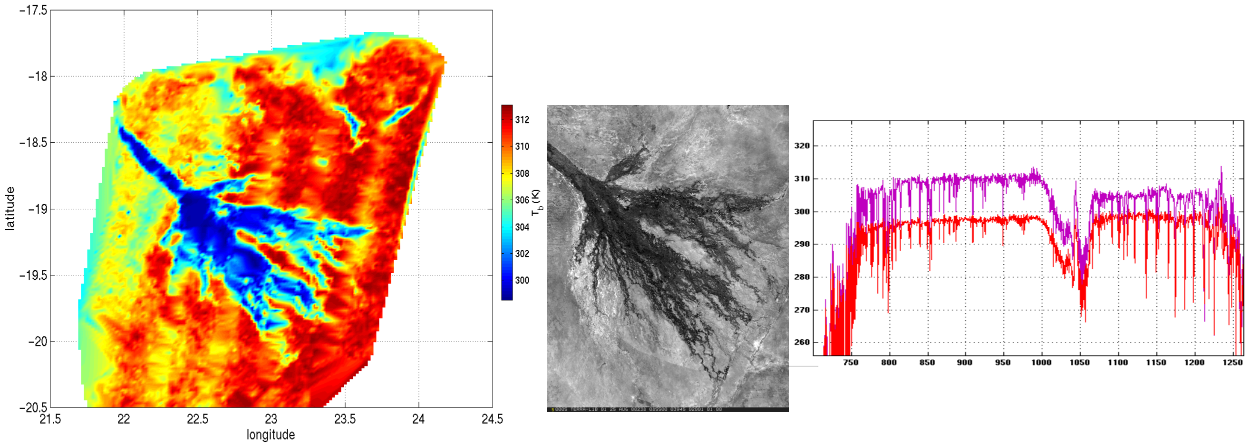

Figure 3: Scanning HIS image of the Okavanga Delta from the ER-2 during SAFARI-2000 compared to a 0.25 km MODIS image (0.65 μm). The S-HIS image is for the average of 980-985 cm-1, an example of a clean window region selection as illustrated by the water (red) and barren land (purple) example spectra shown. Images can be made from any of the nearly 5000 spectral samples of the S-HIS. For clouds, linear combinations of clean window channels will be used to investigate the spatial distribution of cloud properties.

Instrument Physical Description

The S-HIS is packaged in three enclosures each mounted to a structural frame. The three enclosures house the Interferometer Module, Electronics Module, and the Data Storage Computer (data system). The Flight Calibration Assembly is directly mounted to the front of the Interferometer Module enclosure and the S-HIS structural frame is mounted to the aircraft structural frame. The system is modular, and the three enclosures may be mounted on a different frame if required.

Flight Calibration Assembly

The flight calibration assembly consists of a 45° scene mirror, two calibration sources (Ambient Blackbody and Hot Blackbody), the scene mirror motor, and front-end hex structure. The S-HIS 45° scene mirror allows the instrument to image using cross-track scanning. It executes a sequence consisting of multiple views of the earth, a zenith view (when available), and the two calibration sources, one at ambient and another controlled to a fixed temperature (typically 300-310 K in flight and 333K in the laboratory). The S-HIS calibration techniques achieve the high radiometric accuracy needed for atmospheric state retrieval, spectroscopic applications and calibration validation activities.

Interferometer Module

The Interferometer Module (Figure 4, Figure 5) houses the interferometer and all related optical subsystems. This enclosure is provided vibration isolation from the frame by four Barry 7002 series shock mounts. The forward and aft ends of the box are machined out of 0.5-inch aluminum. The corresponding four corners of these end plates are tied together fore/aft with longeron angles that support the four remaining faces of the box. These faces are 0.25-inch aluminum, providing mass and stiffness to minimize acoustic coupling. The interferometer beamsplitter is hygroscopic and needs to be protected from moisture. The scheme employed for the interferometer box to provide this protection is to let the box breath to ambient pressure upon ascent through redundant 0.5 psig relief valves. Upon descent, incoming air enters the enclosure (through a separate 0.5 psig relief valve) and is dried as it passes through a large cylinder of molecular sieve. Upon descent, the hygroscopic elements are protected, additionally, by heating them to 40° C. At altitude during normal data collection mode, the interferometer is not thermally controlled and runs cold, typically at –20 C or cooler.

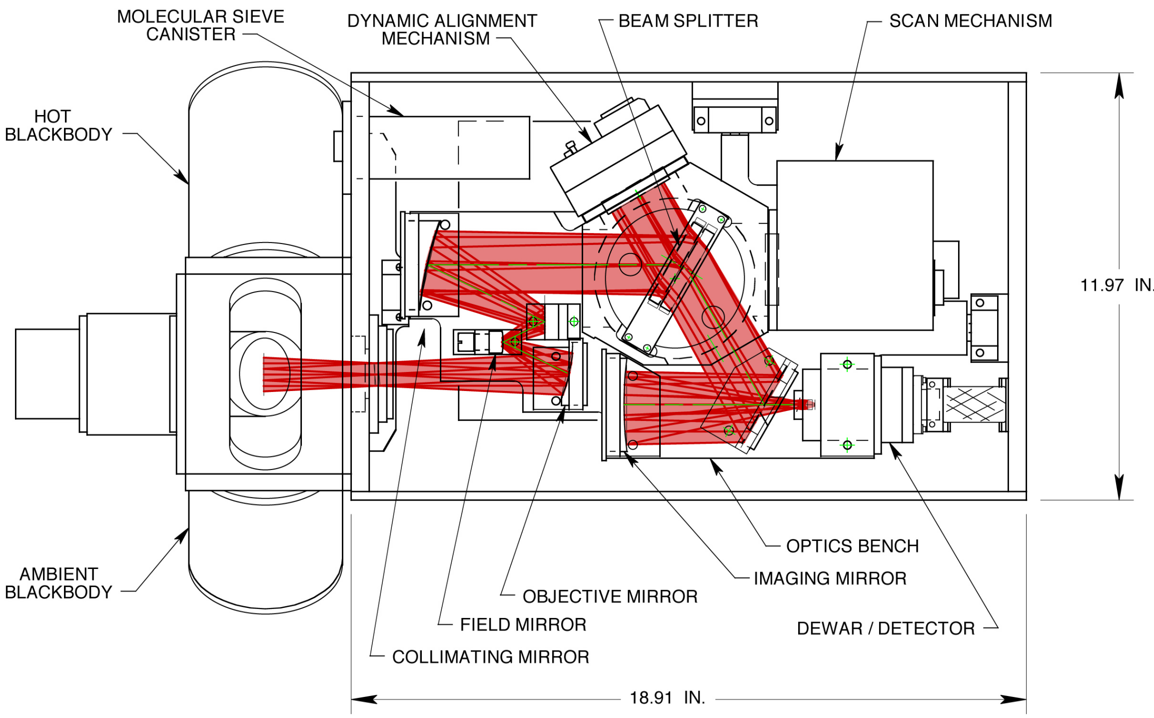

Figure 4: Diagram of the S-HIS Interferometer Module with optics path from the input window through the fore-optics, Michelson interferometer (hex structure with beamsplitter, fixed mirror, and optical path difference mirror), and on to the aft-optics and Stirling cooled detector assembly. The optical path from the beamsplitter to the moving mirror is not shown. The metrology laser is located on the underside of the optics bench.

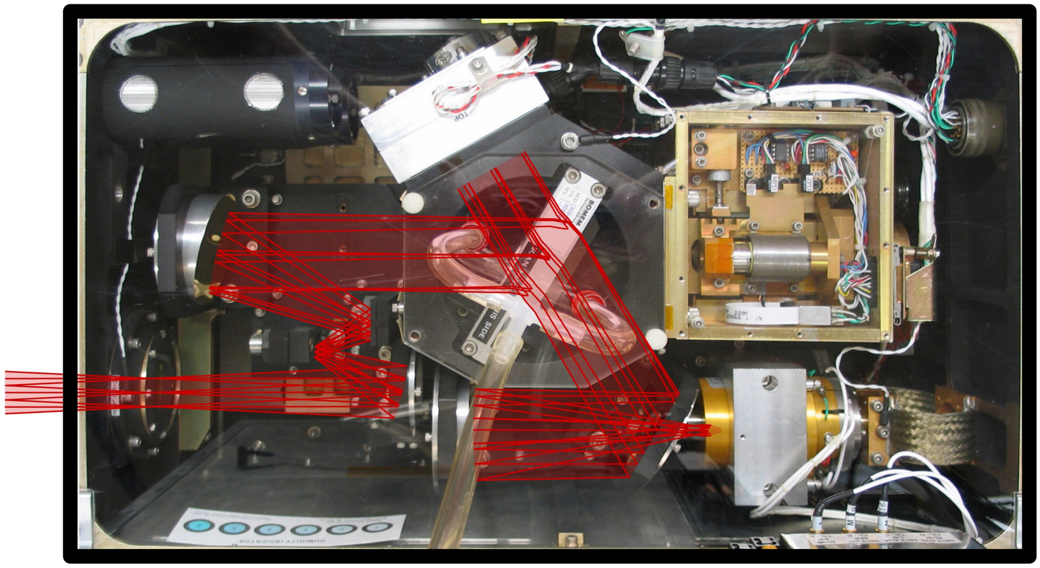

Figure 5: Photo of the S-HIS Interferometer Box with optics path from input window through the fore-optics, the Michelson interferometer (hex structure with beamsplitter, fixed mirror, and optical path difference mirror), and on to the aft-optics and Stirling cooled detector assembly. The optical path from the beamsplitter to the moving mirror is not shown. The metrology laser is located on the underside of the optics bench.

An optics bench is mounted inside the interferometer box to provide common mounting for the fore-optics, interferometer (including metrology laser), output optics, and Stirling cooled detector (3 channels). The optics bench is mounted to the interferometer box at three points. These points attach to the forward and aft bulkhead (primary load path), and the third point (that mostly reacts rotation about the forward and aft attach points) attaches to a vertical column that is supported by two longerons. Where the three attach points connect to the optics bench there is a captured 0.1 inch thickness of heated Sorbathane that is used for additional vibration isolation and damping.

The S-HIS employs a customized commercial dynamically aligned plane-mirror interferometer (DA5 from Bomem Inc, Quebec, Canada). The Michelson mirror is voice coil driven with a support mechanism that was designed and built at UW-SSEC to make use of a linear bearing approach to minimize vibration-induced tilt errors. The spectral characteristics of the measurements are very well known and stable because of the use of a HeNe laser to control optical delay sampling. A 1/4-wave quadrature system is used to assure that no samples are dropped or miscounted. The laser is also used to maintain alignment via the dynamic alignment (DA) servo. Any residual misalignments are measured as a diagnostic and used for residual tilt corrections in post processing.

To achieve the required noise performance, the spectral coverage is divided into three bands with separate detectors for each band (two photoconductive HgCdTe and one InSb). Together, the three detector bands provide continuous spectral coverage from 3.3 to 16.7 μm at 0.5

wavenumber resolution, with overlap between the adjacent bands that is useful for instrument diagnostics including nonlinearity assessment. Due to the initial design constraints on size, the S-HIS instrument uses a novel detector configuration with the shortwave detector positioned in front of the side-by-side longwave and midwave detectors that share the available aperture. The bands use a common field stop, ensuring accurate spatial co-alignment. This arrangement allows cooling to be provided by a single mechanical cooler and eliminates the need for dichroic beamsplitters. The cooler is a 0.6 W, split-cycle Stirling cooler from Litton.

Electronics Module

The electronics module (shown in Figure 6) provides all the electrical support functions for the instrument, including the power conversion and distribution, interferometer control, science and control processor, as well as scene mirror, blackbody, and heater control. The Science DSP compresses the raw interferograms for each scan in real-time using a numerical filter and decimation algorithm. The Control DSP is responsible for instrument control.

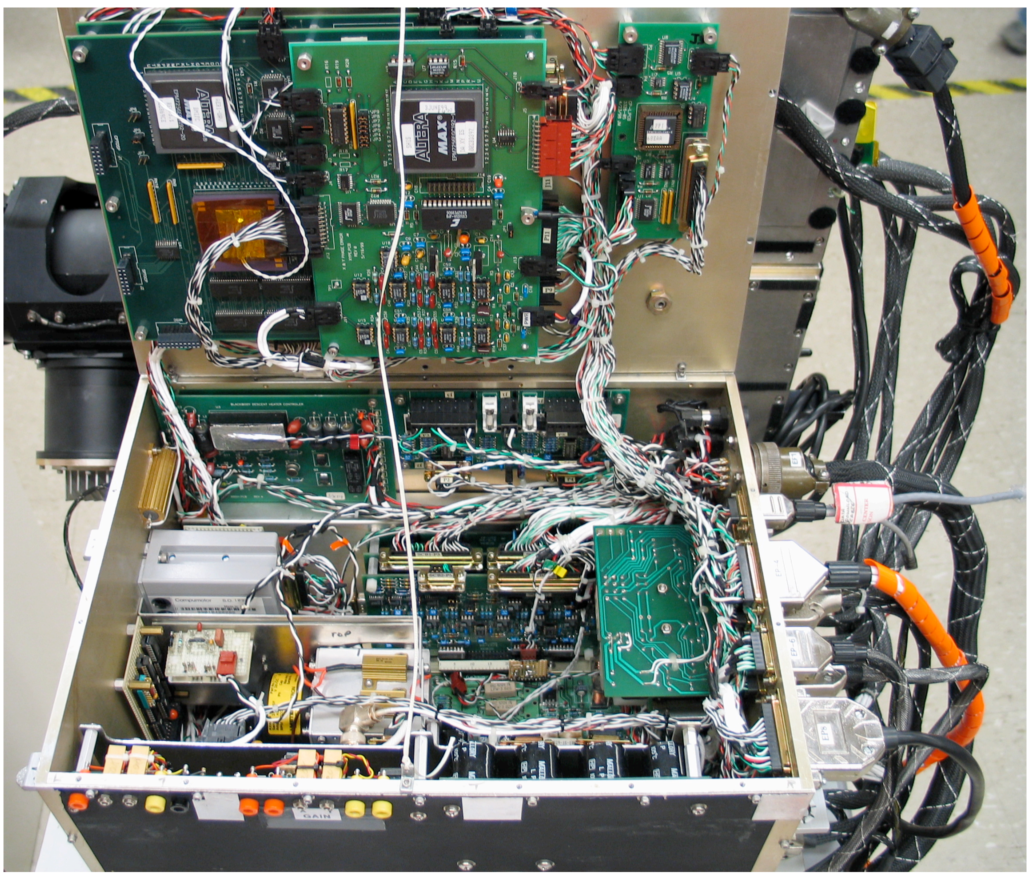

Figure 6: S-HIS electronics module.

The forward and aft sides of the Electronics box are machined out of aluminum (0.25 inch thick). The longerons are square aluminum bars, and the remaining skins are 0.063 aluminum. The Electronics box is liberally vented to ambient pressure through numerous holes. It is heated via self-dissipation and by temperature-controlled heaters. High altitude fans mix the air within the box to eliminate local hot spots and distribute the heater power that is thermally coupled to a heat sink containing fins. The Electronics box is vibration isolated from the S-HIS structural frame by EAR D-1110 Isodamp bushings at the four box mount points.

Data Storage Computer

The original S-HIS data storage computer (DSC) was an environmentally hardened laptop enclosed in a pressurized enclosure. This concept resulted in an overly massive design that needed additional vibration isolation to operate. The current data storage computer (Figure 7) is based on an industrial single board computer (EBX form factor, low-power fanless Celeron 566 MHz processor) with a PC-104+ bus for expansion cards. The design requires no enclosure pressurization and uses a solid-state drive (SSD) for data storage. The unit has operated effectively and dependently on the ER-2, the Proteus, WB-57, and the Global Hawk. It has not yet been integrated or operated on a DC-8 mission.

The Data Storage Computer module (shown in Figure 7) contains the data storage computer and solid-state drive used to collect both S-HIS science and engineering data. This box is constructed with angles and 0.050 inch aluminum skins. The Data Storage Computer box is also liberally vented and uses the same thermal scheme as the electronics box. Also, this box is vibration isolated from the S-HIS structural frame by EAR D-1110 Isodamp bushings at the four box mount points.

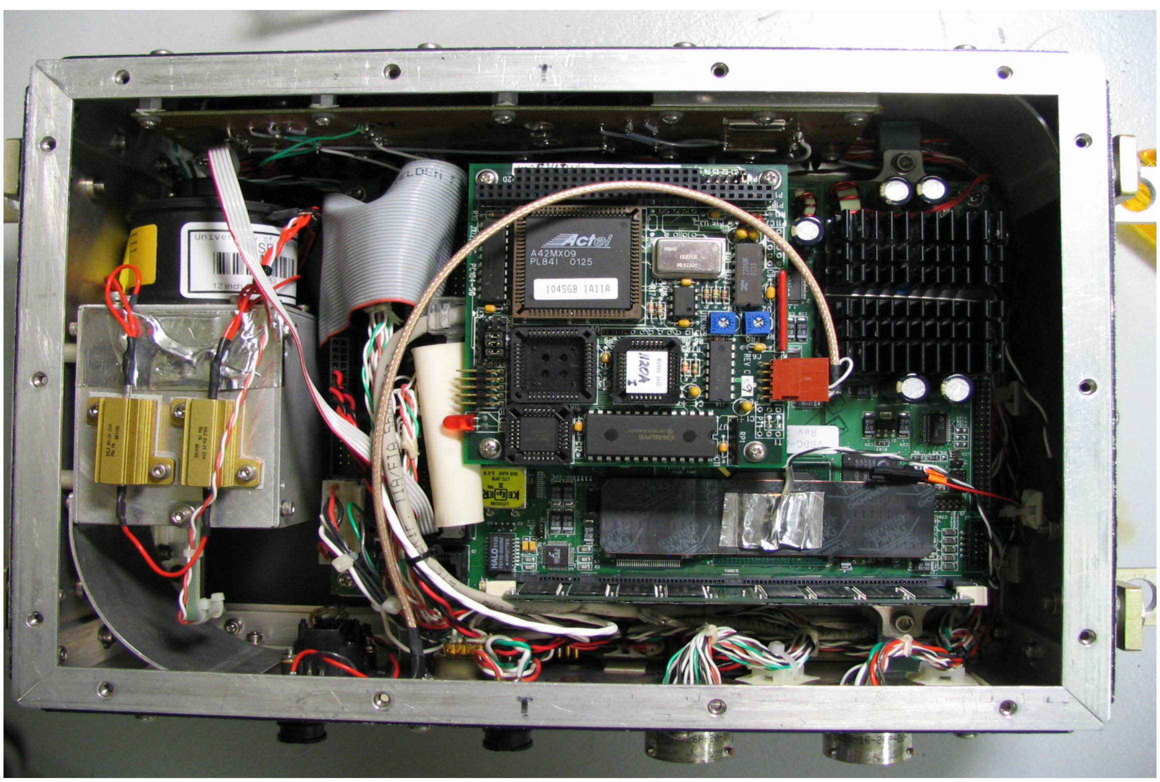

Figure 7: S-HIS Data Storage Computer (DSC) module..

Thermal environment monitoring and control

S-HIS uses several temperature-controlled heaters for thermal control. Figure 8 presents the locations of these heaters, and the thermistors used for feedback control and housekeeping temperature reporting.

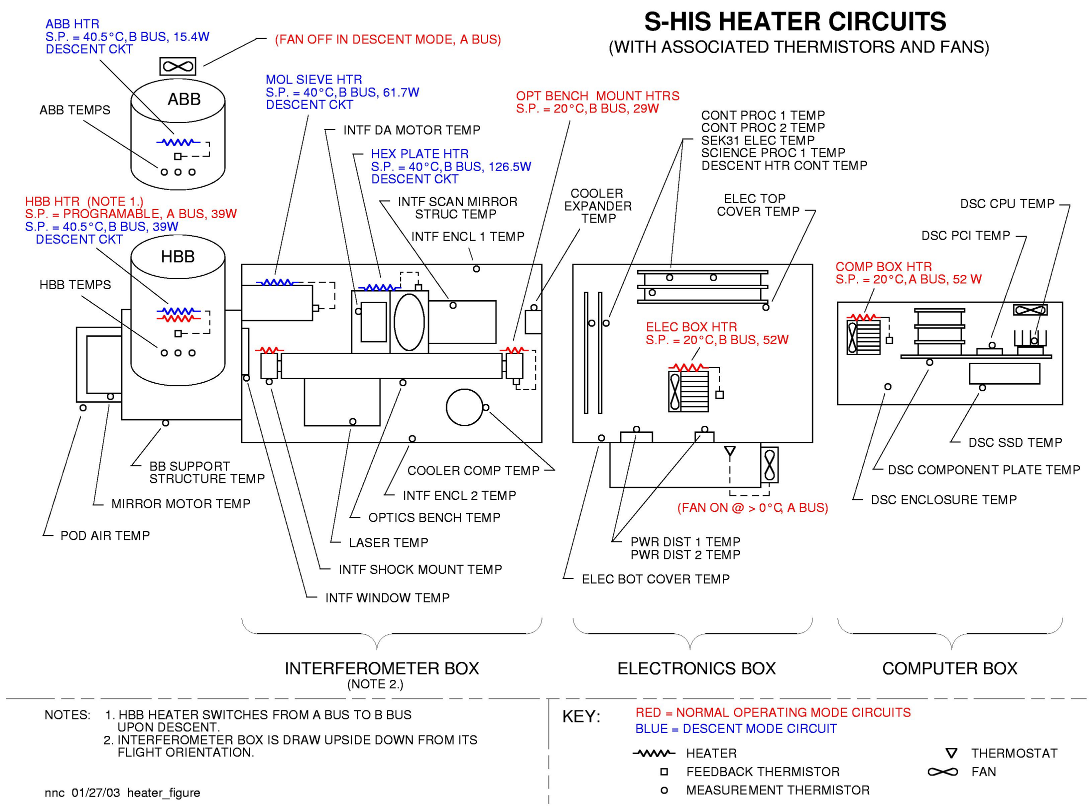

Figure 8: S-HIS heater circuits and temperature sensors.

Simplified Assembly Drawings (For reference only)

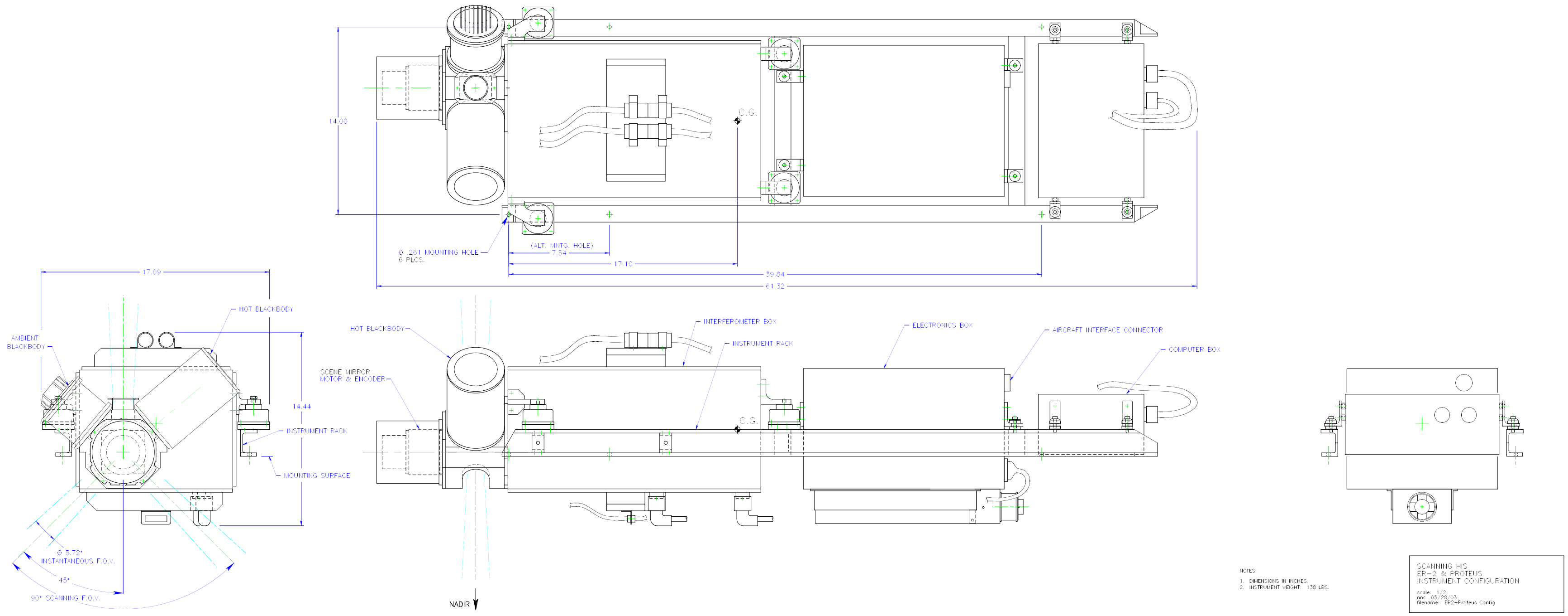

Figure 9: S-HIS simplified assembly drawing (for reference only).

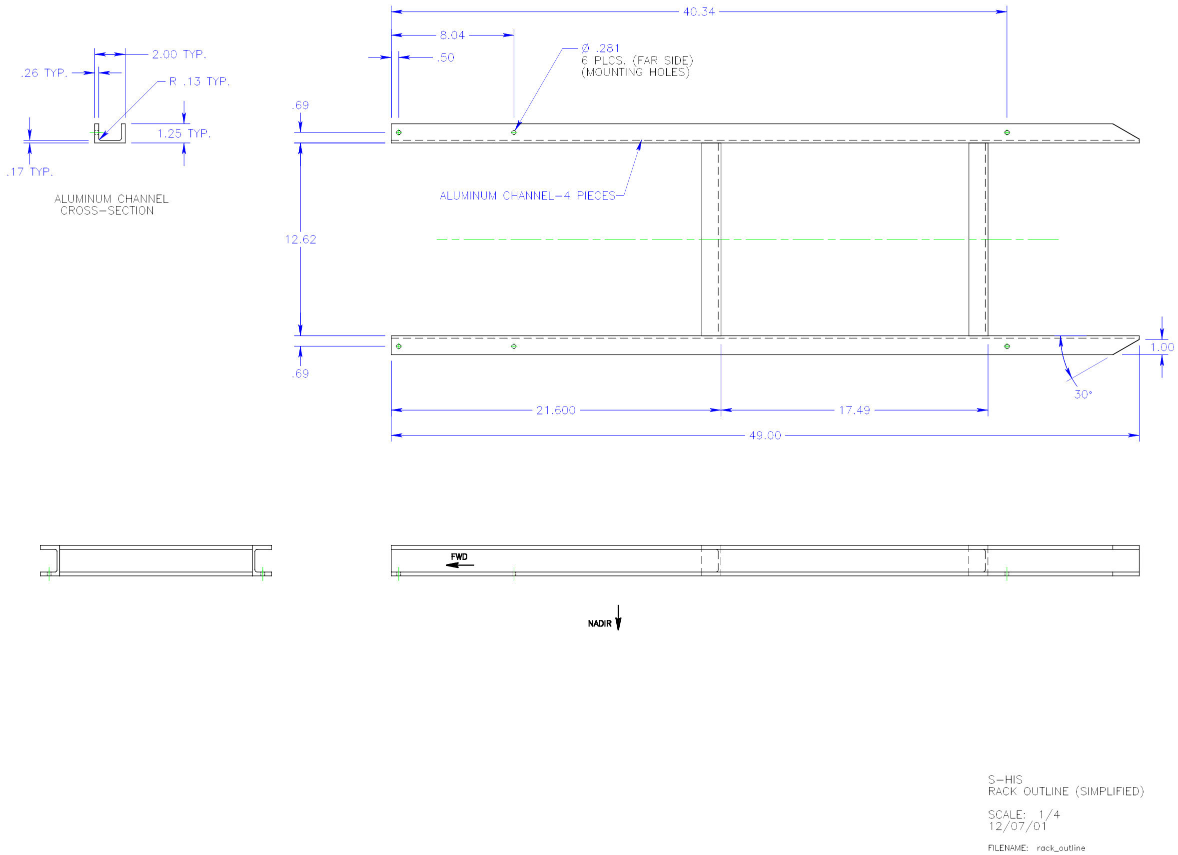

Figure 10: S-HIS ER-2 instrument rack outline (used on ER-2, WB-57, Proteus, Global Hawk), simplified drawing (for reference only). The S-HIS instrument modules mount on the instrument rack and the instrument rack mounts to the aircraft rack (rack to rail slide, 6 mounting holes).

S-HIS on the ER-2

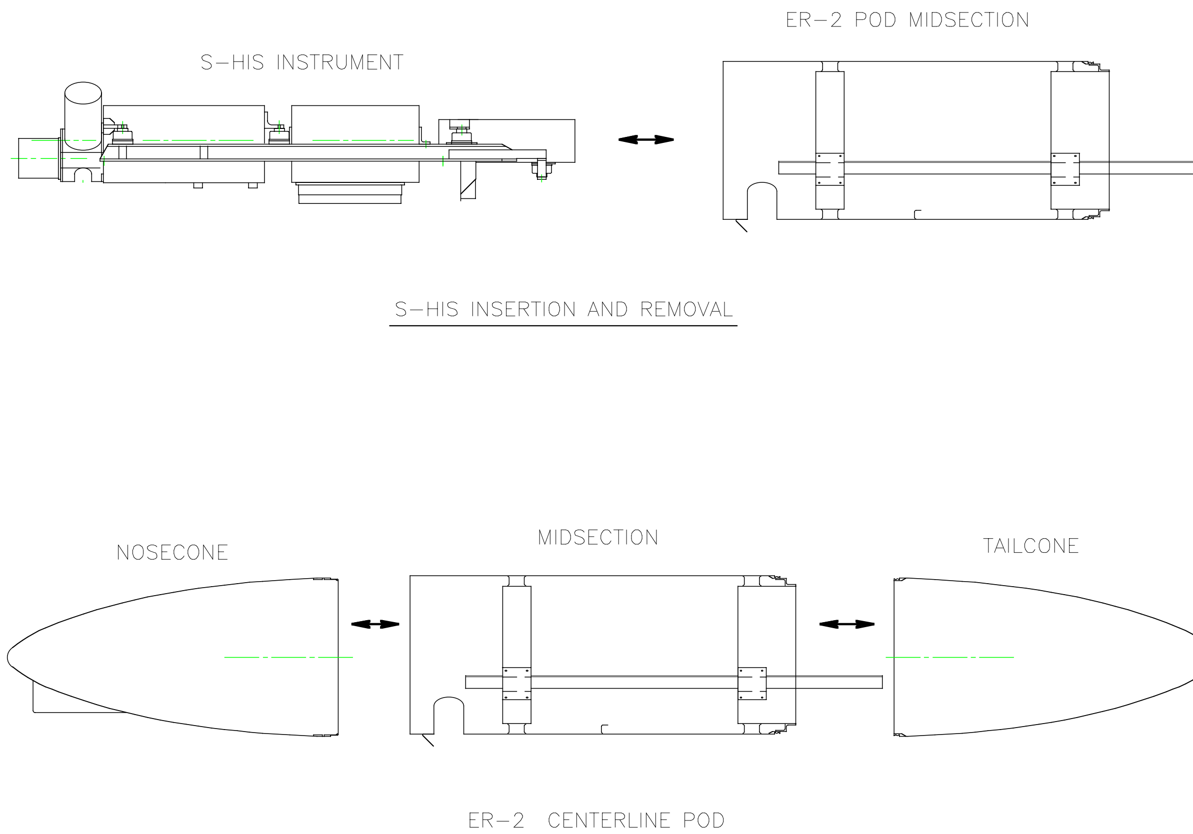

Figure 11: Insertion and removal from ER-2 centerline pod.

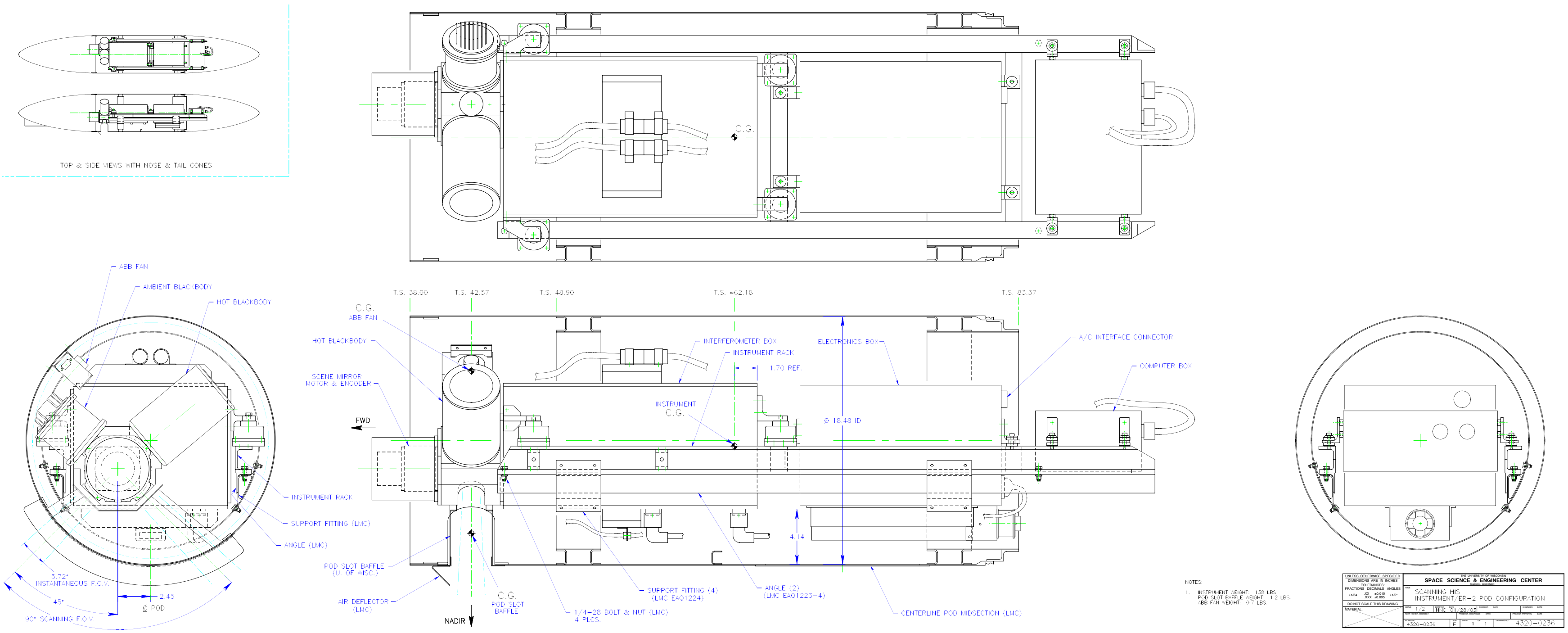

Figure 12: S-HIS ER-2 Centerline Pod configuration.

Figure 13: S-HIS mounted in ER-2 centerline pod.

Figure 14: S-HIS mounted in ER-2 centerline pod.

S-HIS on the WB-57

On the WB-57, the S-HIS is mounted in the Wing Pod. Figure 15 illustrates the positioning of the instrument within the pod envelope.

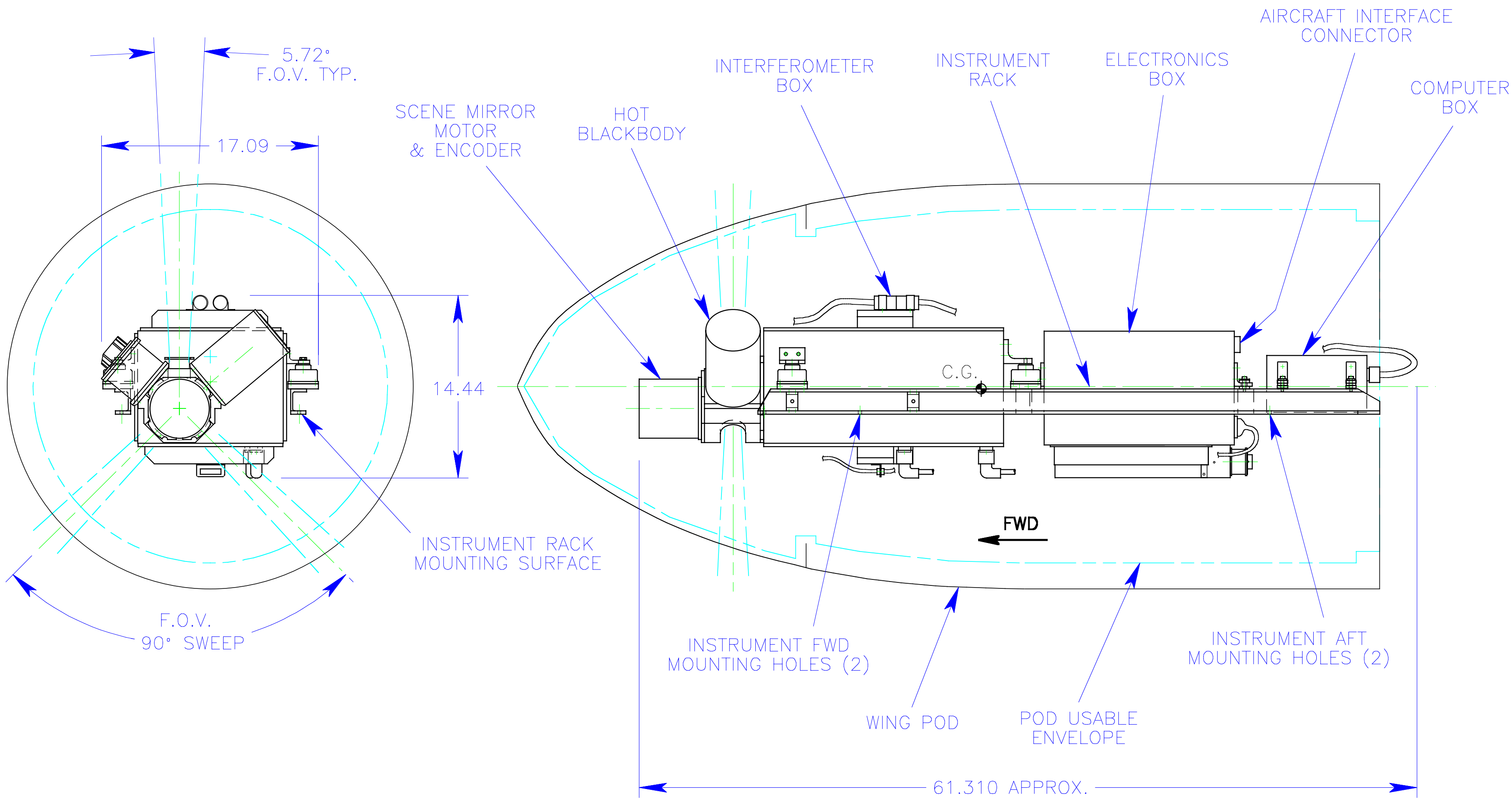

Figure 15: S-HIS installed in the WB-57 wing pod. The S-HIS instrument rack is structurally mounted at four points to the standard WB-57 pod rack (not shown). The instrument views through a slot (nadir) and hole (zenith) in the pod nosecone.

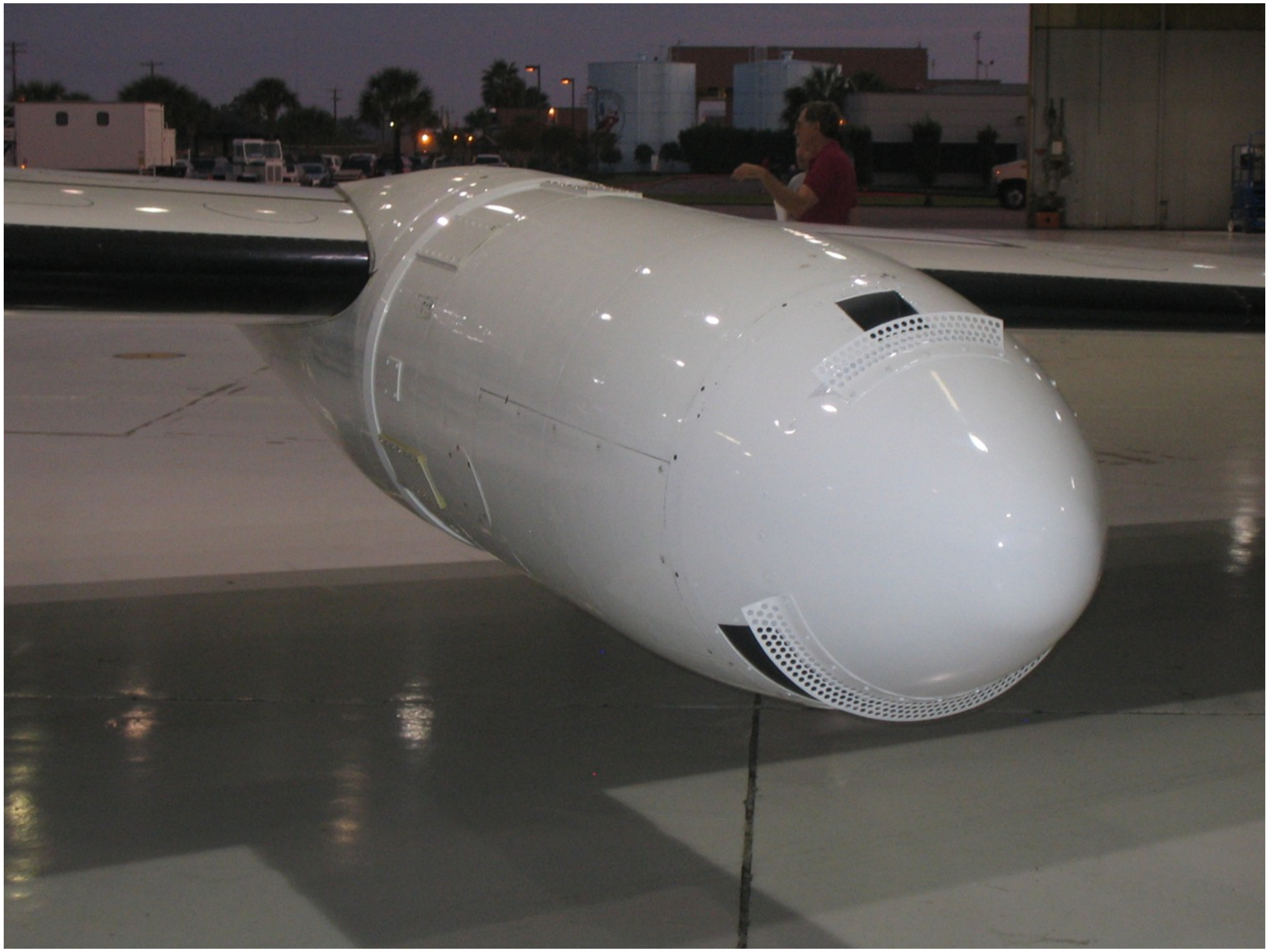

Figure 16: WB-57 Wing pod with S-HIS nose-cone installed. Zenith cross track ports and air dams are visible.

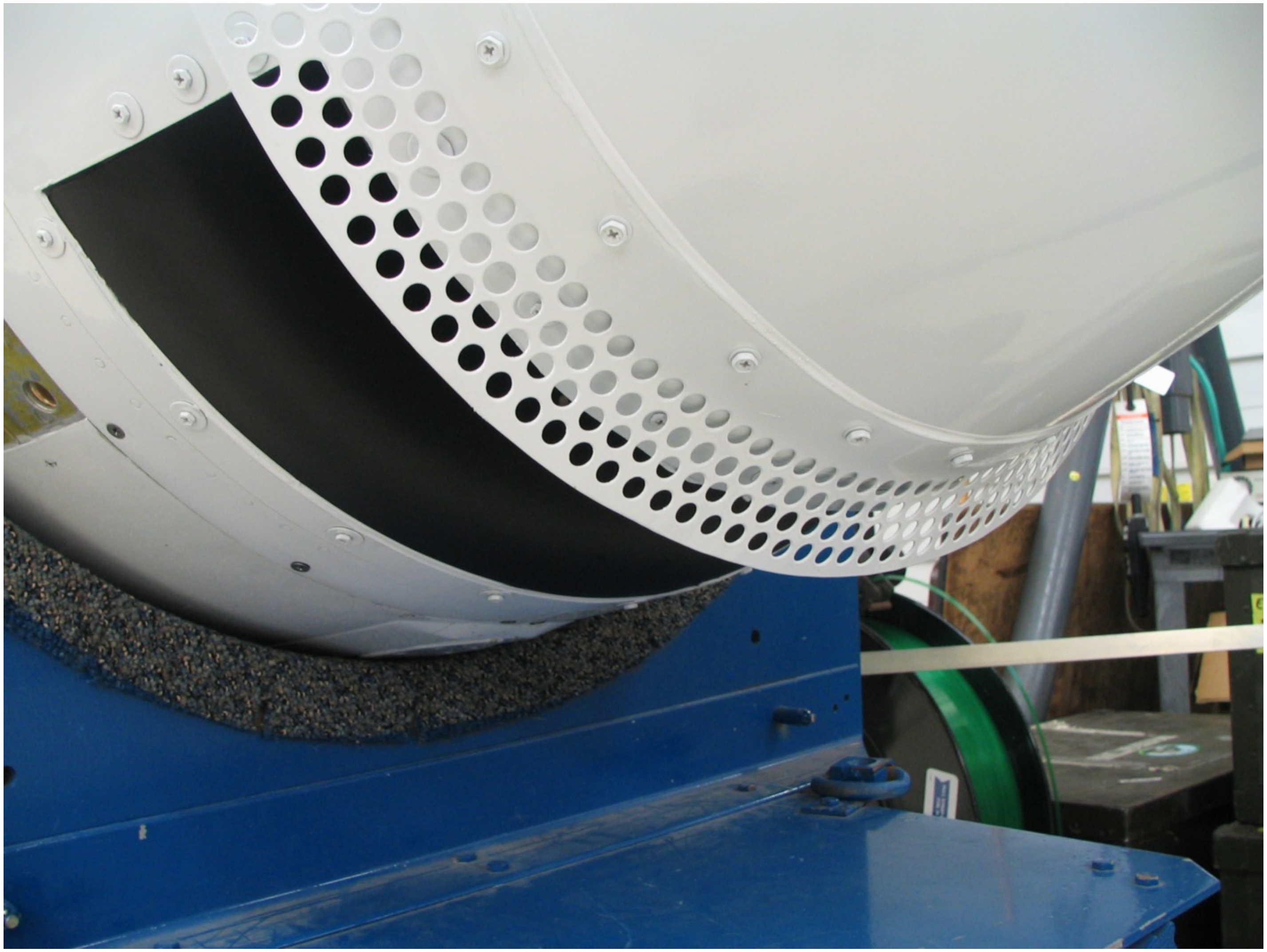

Figure 17: Close-up view of cross-track port and air dam.

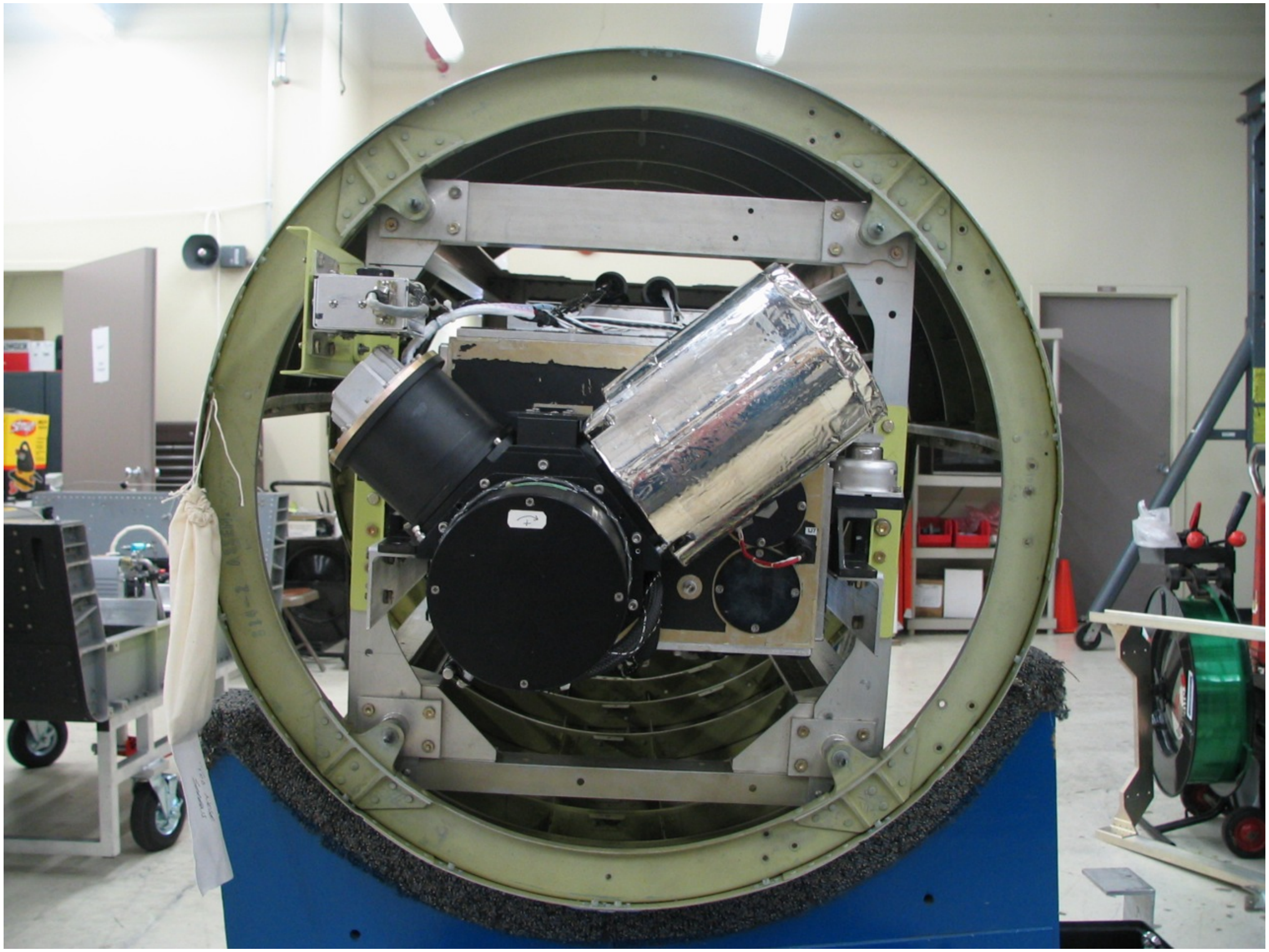

Figure 18: S-HIS mounted in WB-57 wing pod.

S-HIS on the Global Hawk

The S-HIS is mounted in Zone 25 on the NASA Global Hawk (). Since Zone 25 is controlled to a warmer than ideal temperature for S-HIS operation and calibration at altitude, a cooling duct is routed through the zone and coupled to the S-HIS ambient blackbody and other instrument points via heat sink strapping ().

Figure 19: S-HIS mounted in Zone 25 on the NASA Global Hawk with fairing removed. The cooling tube is not installed in this photo.

Figure 20: S-HIS in zone 25. The cooling tube is not installed in this photo.

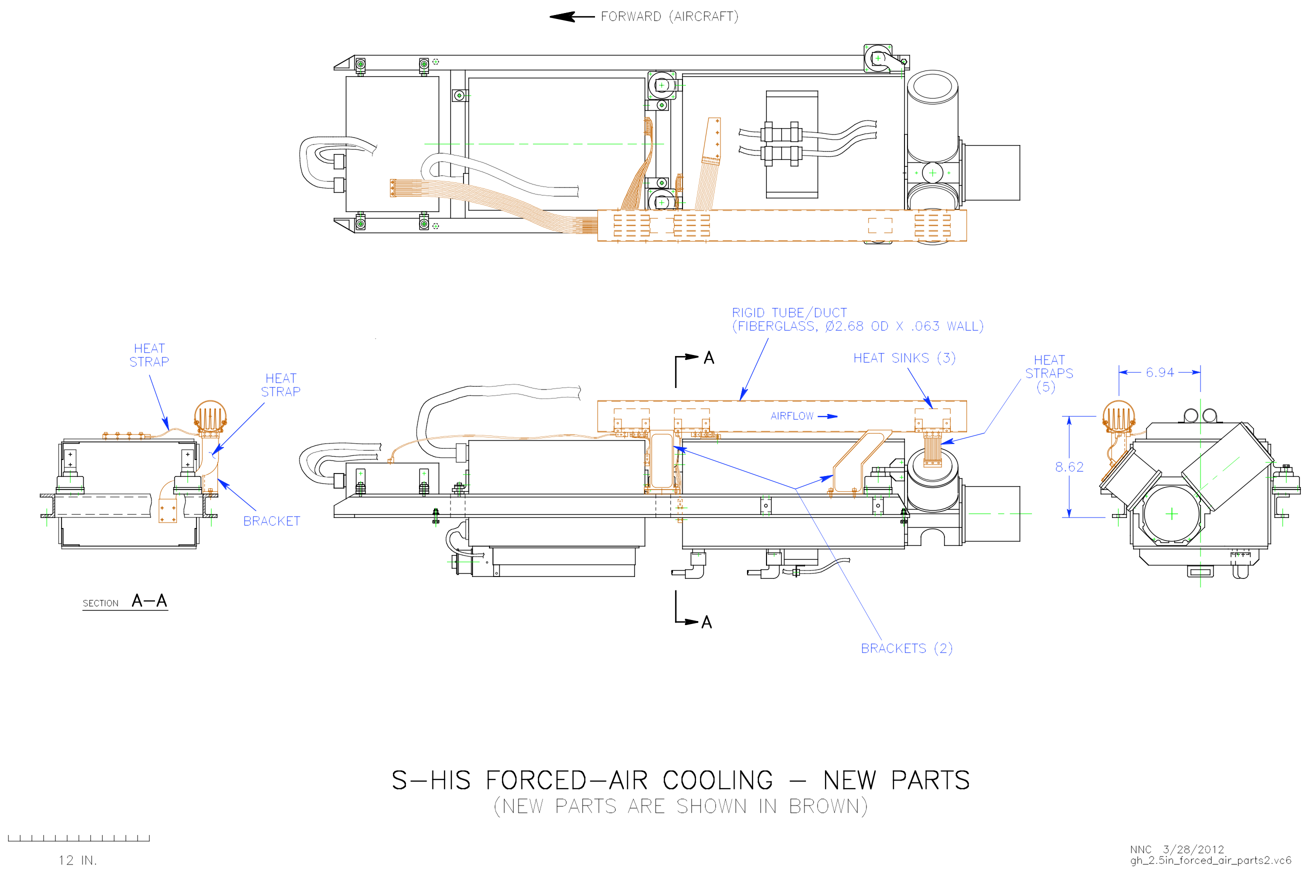

Figure 21: S-HIS forced air-cooling ducting and parts for Zone 25 installation.

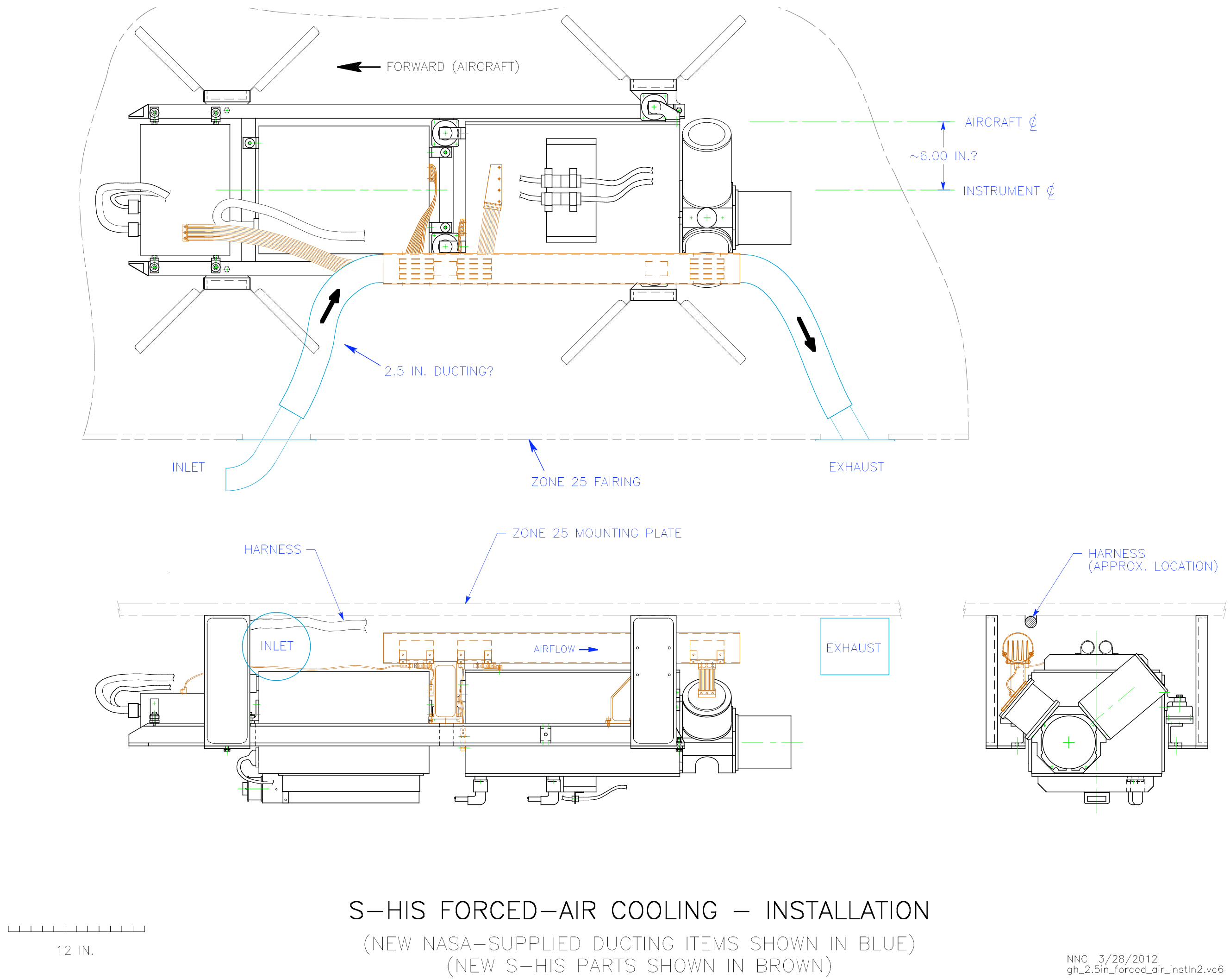

Figure 22: S-HIS forced air-cooling for Zone 25 installation.

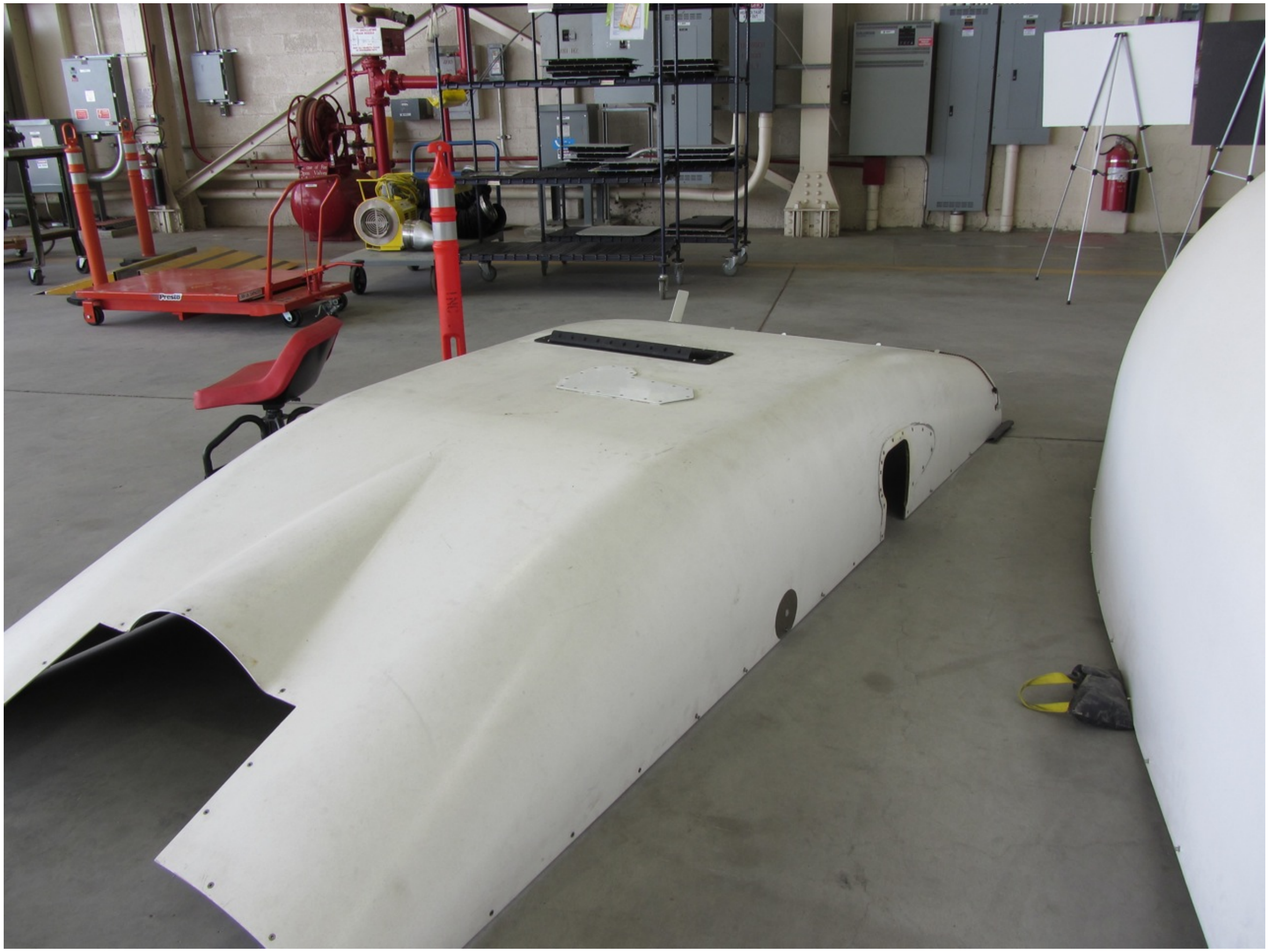

Figure 23: Global Hawk Zone 25 fairing with S-HIS cross-track viewing slot installed.

Figure 24: Close-up of S-HIS cross-track viewport and air dam (fairing removed from aircraft).

S-HIS on the Proteus

On the Proteus, the S-HIS is mounted in the Wing Boom.

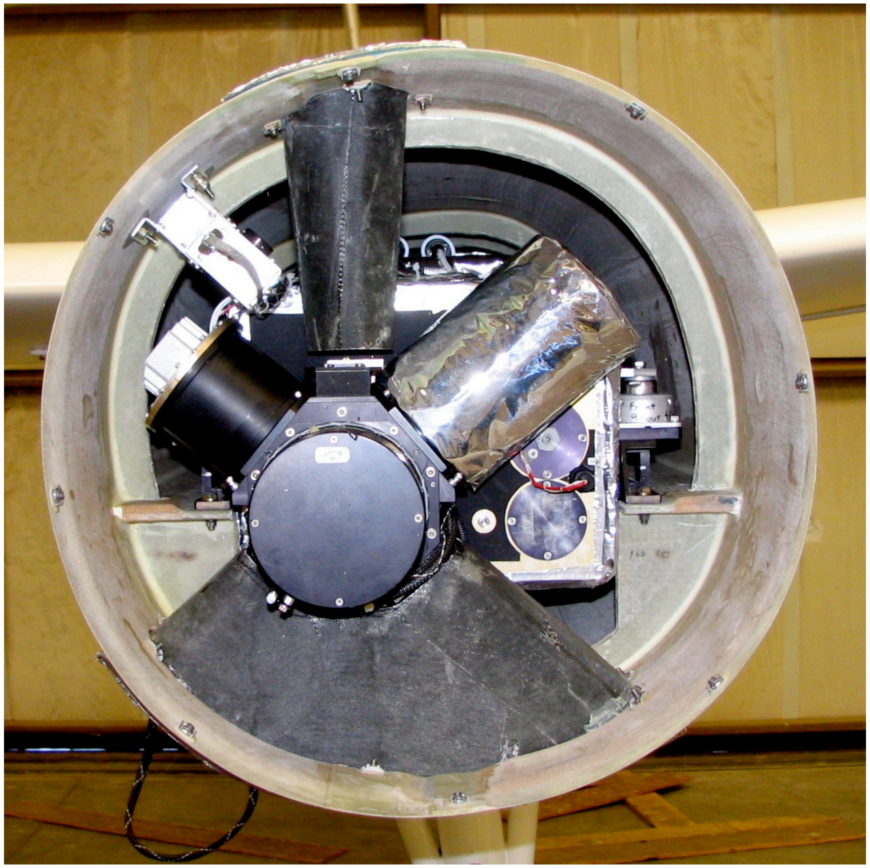

Figure 25

Figure 26

S-HIS on the DC-8

In the WB-57, ER-2, Proteus, and Global Hawk the entire S-HIS instrument is mounted in an unpressurized area of the aircraft (centerline pod on ER-2, wing pod on WB-57 and Proteus, and Zone 25 on the Global Hawk) and operates at at-altitude ambient temperature and pressure.

In the DC-8 the S-HIS Optics, Electronics, and Data Storage Computer Modules are mounted in the pressurized cargo area. The front-end assembly (scene select mirror assembly and blackbody references) are mounted in ambient pressure and separated from the rest of the instrument via the S-HIS DC-8 Adapter Cap assembly which includes a ZnSe window. Phots of the DC-8 install are included below.

Figure 27

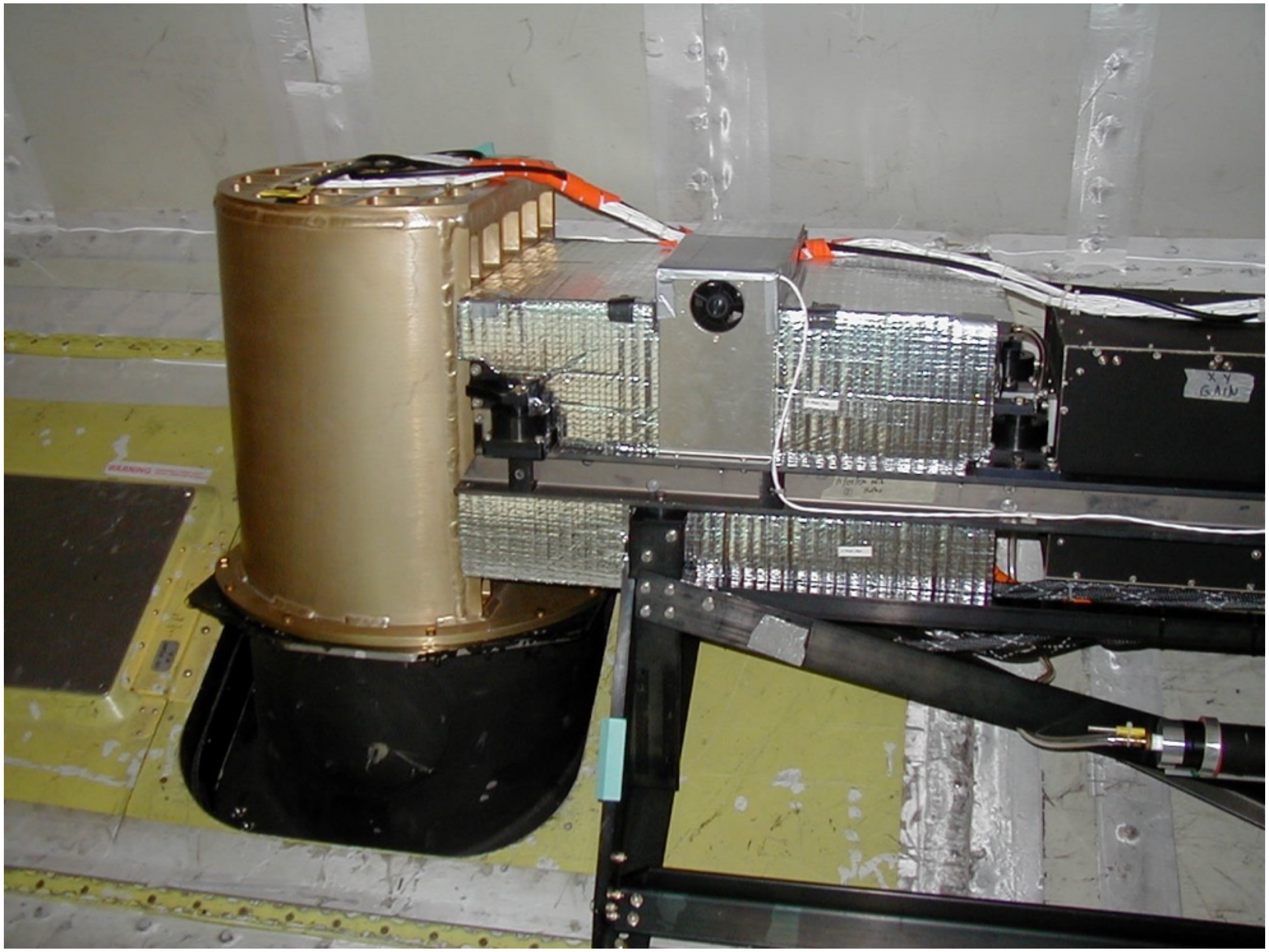

Figure 28

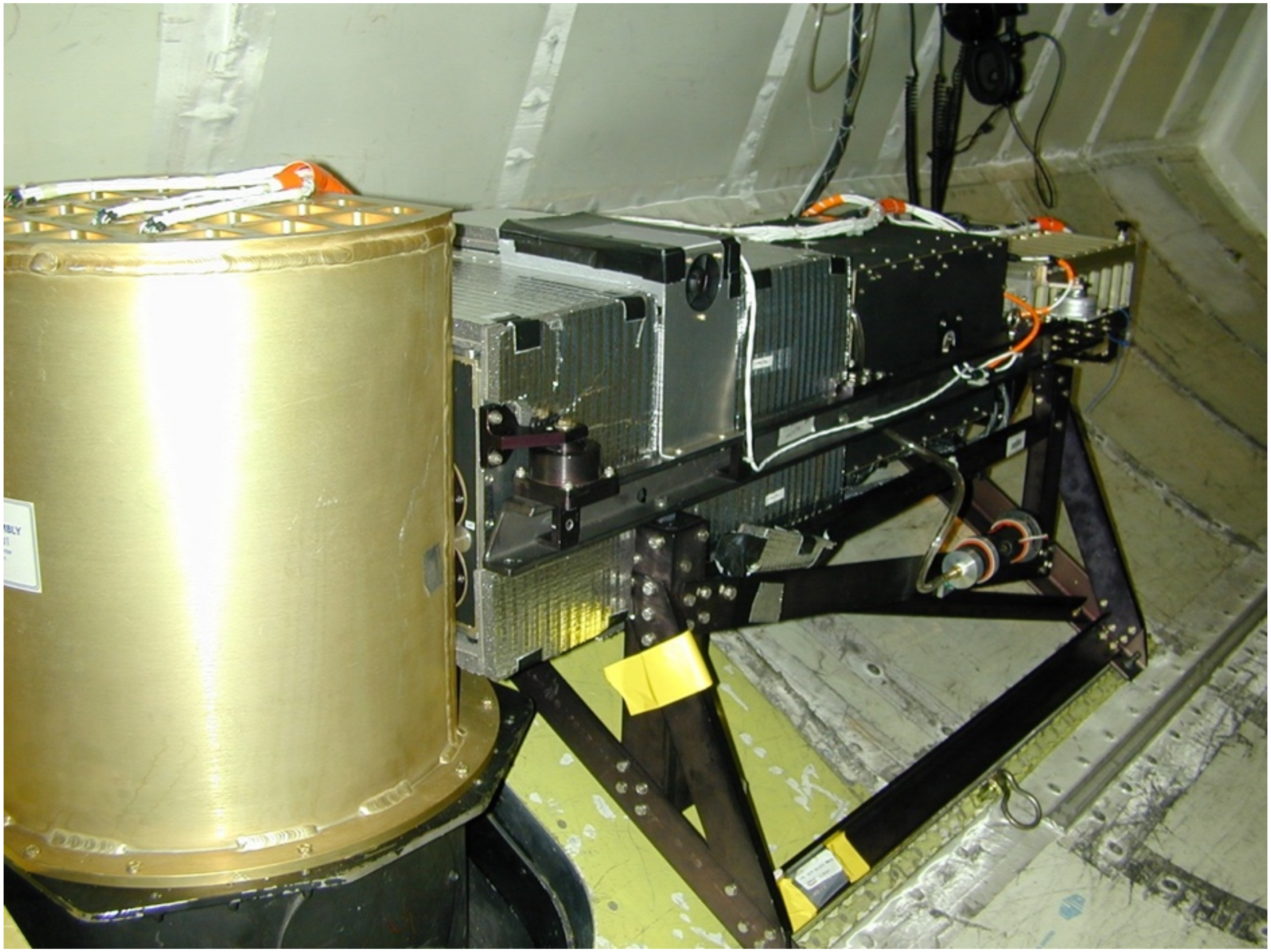

Figure 29

Figure 30

Electrical Interface and Requirements

This section describes the S-HIS Electrical characteristics.

- The S-HIS uses only 28V DC.
- The S-HIS requires two 28 VDC busses (Bus A & Bus B)
- S-HIS fuses each bus with a 15A fuse.
- Turn-on in-rush current is limited to 19A for 5 ms
- The S-HIS requires two switches (Sounding and Descent Heaters)
- The Peak current listed for Bus 1 for the Flight mode occurs at startup when the S-HIS Stirling cooler is working hard to get the detector to operational temperature. Once the cooler has reached operational temperature the Bus 1 peak current for Flight mode drops.

Aircraft Power Requirements

	Power (watts)	Load name	Peak current	Run current
28V DC	280 W peak (typ)	Bus A	15 A Fused (typical peak of 10A)	9 – 10 A
28V DC	392W peak (typ)	Bus B	15 A Fused (typical peak of 14A)	3.5 - 14 A

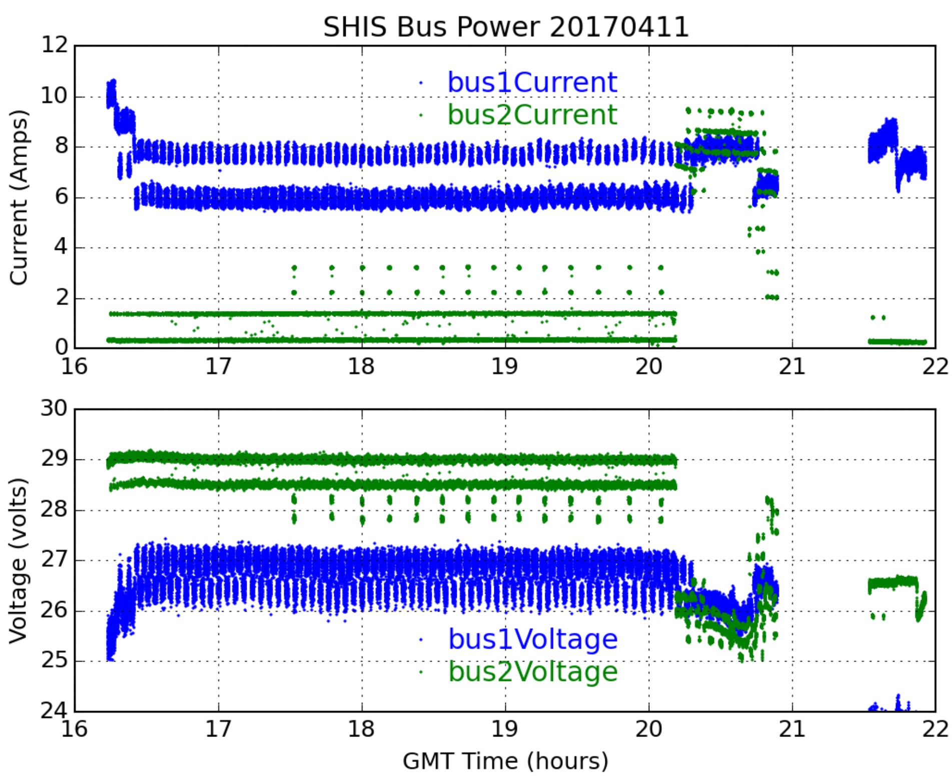

Figure 31: Typical S-HIS Bus 1 and Bus 2 voltage and current versus time for a typical ER-2 flight.

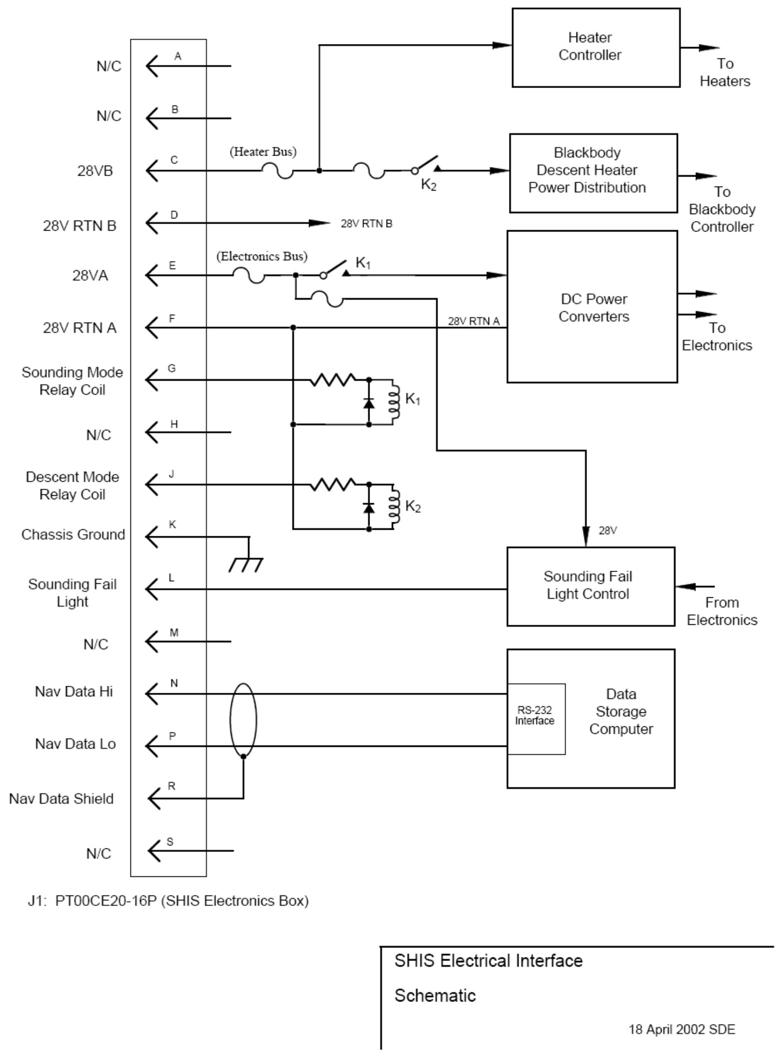

Figure 32: S-HIS WB-57 Electrical Interface.

Pressure/Vacuum Systems

The S-HIS has a pressurized box located inside the Interferometer box that houses its HeNe laser, used for the interferometer traveling mirror positioning. This laser box has a volume of 40 in^3, and is pressurized on the ground prior to the field campaign to approximately 20 psia. There is a 20 psig pressure relief valve located on this box.

LASER SYSTEMS

The S-HIS uses a Melles Griot Class II CW laser, model number 05-LHP-900. The laser has a peak power of 1 mW. This laser is internal to the S-HIS instrument (located inside the laser box which is located inside the interferometer box) and used for precise interferometer traveling mirror positioning (metrology). Most of the laser energy falls on detectors inside the Interferometer box - only a diffuse, reduced energy beam from the laser exits the instrument via the ZnSe interferometer window. The beam diameter that exits the instrument has a diameter of 19 mm. Prior to exiting the instrument, the laser beam intensity has been attenuated by 80% during transmission through the instrument KBr beamsplitter (multiple passes) and the instrument fore-optics.

A “Laser/Optical Device Hazard Evaluation Data: form has been previously submitted to JSC.

Ground Support Requirements

- Type of ground power needed for testing/operating research equipment.

  For Ground Power, the S-HIS requires 115 VAC, 60 Hz, single phase, 20 A for EGSE power.

- The need for any pressurized gas or cryogenics. State how much is needed of each to assess storage space.

  For Ground operations, the S-HIS requires about 200 scf of lab grade nitrogen gas. The gas is used for instrument purge if maintenance of the optical box is required.

- State whether or not you will be mixing or storing any chemicals that are toxic, corrosive, and/or explosive. If so, what type of material handling procedures will be required?

  N/A

- Laboratory space requested. Working and storage.

  S-HIS typically requests 250 ft^2 of working space (including storage space).

- Computer network access requested.

  S-HIS requires wideband internet access for data transfer.

Mission Procedures

Equipment Shipment

The S-HIS and associated support equipment is typically delivered to US integration sites by a UW-Madison Space Science and Engineering Center employee via a UW fleet vehicle (SSEC sprinter van).

A detailed S-HIS shipper with ECCN info is available on request.

Ground Operations

After the S-HIS instrument and associated equipment are brought to the assigned work area, all equipment will be unpacked, checked for any damage, and then assembled on its handling cart. The instrument has an Electrical Ground Support unit that allows operation on the ground. A functional test will be conducted as soon as possible. The S-HIS operates in a lab environment with no other special equipment. For extended operation in warm environments, a portable air conditioner is used to keep the instrument at nominal operating temperature.

Integration to Aircraft

When access to the aircraft is granted, S-HIS has a safe-to-mate box with associated procedure that allows the electrical interface to be checked prior to completing electrical integration of the S-HIS to the aircraft.

The Safe-to-Mate procedure and Safe-to-Mate box schematic are available on request.

Mechanical integration procedures for each aircraft are available on request.

Hazardous Materials

The S-HIS contains the following potentially hazardous materials:

Polyester tape [possible flammable material]. This tape is used as an outer covering for the ceramic fiber sheet thermal blanket that surrounds our calibration blackbody. A quantity of 2 ft^2 of this material is used. It has a NFPA Hazard classification / Flamability of 1. US Federal Regulation 311/313 states that there is no fire hazard).

Ceramic fiber sheet [possible carcinogenic material]. This material is used in a thermal blanket for the calibration blackbody. It possesses a possible cancer hazard by inhalation. A quantity of approximately 1 ft^2 x 1/8" of this material is used. For our application, this material is completely wrapped and contained with a polyester tape.

Potentially hazardous materials used in servicing the instrument:

Ethyl Alcohol is used periodically to clean the instrument scene mirror and window. A 250 ml plastic squeeze bottle is used for application and a 500 ml plastic bottle is used for storage. During each application less than 5 ml is used. Standard laboratory practices will be followed when this material is used.

Isopropyl Alcohol is used periodically to clean various parts of the instrument. A 250 ml plastic squeeze bottle is used for application and a 500 ml plastic bottle is used for storage. Standard laboratory practices will be followed when this material is used.

Material Safety Data Sheets

PDFs of the following MSDS sheets are available on request.

Materials used in S-HIS instrument:

- G-10 Fiberglass (used for thermal isolation)
- GE Noryl Plastic (used for thermal isolation)
- Sorbathane elastomer (used for shock mount material)
- EAR D-1110 elastomer (used for shock mount material)
- Ceramic fiber Sheet (used in a small thermal blanket)
- Polyester Film Tape (used as a protective covering for the thermal blanket listed above)
- Molecular Sieve (used for drying interferometer box air)
- Silica Gel (no longer used for desiccating interferometer box)

Materials used to service S-HIS instrument on the ground:

- Ethyl Alcohol (used for periodic cleaning of instrument optics)
- Isopropyl Alcohol (used for periodic cleaning of the instrument)