NSF / NCAR Gulfstream V

INVESTIGATOR'S HANDBOOK

Research Aviation Facility, Earth Observing Laboratory
National Center for Atmospheric Research
Boulder, Colorado, USA

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Summary of Revisions

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04/18/2008	Conversion from Draft to Original document format.	All

Introduction

The Gulfstream V (GV) aircraft was selected and developed as a high performance platform to serve the environmental research needs of the National Science Foundation (NSF) for the next several decades. The capability offered by the GV to carry payloads to high altitudes (the aircraft is certified to a maximum altitude of 51,000 feet) and over large distances make it an ideal research vehicle for in-depth studies of the troposphere and lower stratosphere and for remote sensing studies of the Earth's surface.

The GV is maintained and operated for NSF by the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, USA. The Research Aviation Facility (RAF) within NCAR's Earth Observing Laboratory (EOL) manages the support and deployment of the aircraft, and the GV itself is based at the RAF at Rocky Mountain Metropolitan Airport (JeffCo) in Broomfield, Colorado.

This Investigator's Handbook is intended to serve investigators as a complete reference guide for the NSF/NCAR GV. As such, information is included on the following: basic aircraft specifications; research systems specifications, including information on structural modifications, standard instrumentation racks, the research power system, and the data system and products; aircraft performance characteristics and considerations; flight operations; integration of investigator equipment packages; NCAR/EOL standard instrumentation; and aircraft request procedures and project support services.

Investigators who are either considering requesting use of the GV or who have already been awarded project support with this facility are strongly encouraged to review this handbook in its entirety and to structure their programs and payloads to the operational guidelines and integration requirements outlined in this document. While this handbook has been designed and constructed to be as comprehensive as possible, it is anticipated and normal that other, more project specific, questions will arise as investigators make plans to utilize the GV. Investigators are invited and encouraged to work closely with NCAR/EOL staff while making preparations for research deployment of the aircraft, and a list of key contact personnel is given on Page iv of this document to aid investigators in contacting those individuals within EOL who can be of assistance with particular issues as they arise. General questions regarding the GV should be addressed to either the EOL Director's Office (303-497-2040) or the RAF (303-497-1030).

Please Note - This document contains blank back-facing pages between sections where required for the purpose of duplex printing.

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Table of Contents

Table of Contents (Cont.)

Page No.

Table of Contents (Cont.)

List of Figures

List of Figures (Cont.)

List of Tables

List of Acronyms/Definitions

ACAS	Aircraft Collision Avoidance System
ACP	Audio Control Panel
A/D	Analog to Digital
ADADS	Aircraft Data Acquisition and Display System
ADF	Automatic Direction Finder
ADS	Airborne or Aircraft Data System
AEROS	Airborne Environment Research Observing System
AFIS	Airborne Flight Information System
AGL	Above Ground Level
ALT	Altitude
ANSI	American National Standards Institute
APA	Airport Pressure Altitude
APU	Auxiliary Power Unit
ARINC	Air Radio Incorporated
ASCII	American Standard Code for Information Interchanges
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATIS	Automatic Terminal Information Service
BL	Buttline (in inches)
CDS	Computer and Data Services
CFIT	Controlled Flight Into Terrain
CG	Center of Gravity
COTS	Commercially Available Off The Shelf
CRT	Cathode Ray Tube
CW	Continuous Wave
DER	Designated Engineering Representative
DFS	Design and Fabrication Services
DME	Distance Measuring Equipment
DSM	Data Sampling Module
EDO	Extended Data Out
EIA	Electronics Industry Association
ELT	Emergency Locator Transmitter
EOL	Earth Observing Laboratory
FAA	Federal Aviation Administration
FAC	Facilities Allocation Committee
FAR	Federal Aviation Regulation
FIFO	First In First Out
FMCS	Flight Management Control System
FMS	Flight Management System
FPS	Field Project Services
GAC	Gulfstream Aerospace Corporation
GNSSU	Global Navigation System Sensor Unit

List of Acronyms/Definitions (Cont.)

GPS	Global Position Sensor, Global Positioning System
GPWS	Ground Proximity Warning System
GS	Glide Slope
GTW	Gross Takeoff Weight
GV	Gulfstream V Aircraft
GVFS	GV Fuselage Station
HDLC	High Level Data Link Control
HF	High Frequency Communications
ICP	Interphone Control Panel
ICS	Intercommunications System
IDG	Integrated Drive Generator
ILS	Instrument Landing System
I/O	Input / Output
IRIG	Inter Range Communication Group
IRS	Inertial Reference System
IRU	Inertial Reference Unit
ISA	International Standard Atmosphere
KCAS	Knots Calibrated Air Speed
KTAS	Knots True Air Speed
LAOF	Lower Atmospheric Observing Facilities
LBL	Left Buttline (in inches)
LEO	Low Earth Orbiting
LOC	Localizers
LNAV	Lateral Navigation Locallizers
MADC	Micro Air Data Computers
MMO	Maximum Operating Mach Number
MNP	Minimum Navigation Performance
MPDB	Main Power Distribution Box
MSL	Standard Atmosphere
NACA	National Advisory Committee on Aeronautics
NCAR	National Center for Atmospheric Research
NEMA	National Electrical Manufacturers Association
NM	Nautical Mile
NEXRAD	Next Generation Radar
NSF	National Science Foundation
NTP	Network Time Protocol
OFAP	Observing Facilities Advisory Panel
PCI	Peripheral Component Interconnect
PI	Principal Investigator
PIC	Pilot In Command

List of Acronyms/Definitions (Cont.)

PPS	Pulse Per Second
PSI	Passenger Service Units
RAD ALT	Radio Altimeter
RAF	Research Aviation Facility
RBL	Right Buttline (in inches)
RDP	Research Data Program
RNAV	Area Navigation
RVSM	Reduced Vertical Separation Minimum
SATCOM	Communications Satellite
SIGMETS	Significant Meteorological Conditions
SOD	Scientific Overview Document
SPDB	Secondary Power Distribution Box
SPDDB	Secondary Power Distribution Drop Box
SSDB	Secondary Signal Disbution Box
TAS	True Airspeed
TCAS	Traffic Collision Avoidance System
TWIP	Terminal Weather Information for Pilots
UDP/IP	User Datagram Protocol/Internet Protocol
UPS	Uninterruptible Power Supply
VDC	Voltage From Direct Current
VHFNAV	Very High Frequency Navigation System
VHF	Very High Frequency Communications
VME	VersaModule Eurocard Bus
VNAV	Vertical Navigation
VOR	Omnidirectional Range
VSR	Stall Reference Speed
WL	Waterline (in inches)
WOW	Weight-On-Wheels

1. Basic GV Specifications

1.1 General View

The NSF/NCAR GV aircraft, also know during its development phase as "HIAPER", is a Gulfstream Aerospace Corporation (GAC) Gulfstream V (GV) aircraft certified in the transport category and specially modified to perform environmental research missions. The aircraft is powered by two Rolls-Royce Deutschland GmbH BR710A1-10 turbofan engines.

Two views of the GV are shown in Figure 1.1 below. Dimensions of the aircraft are also given.

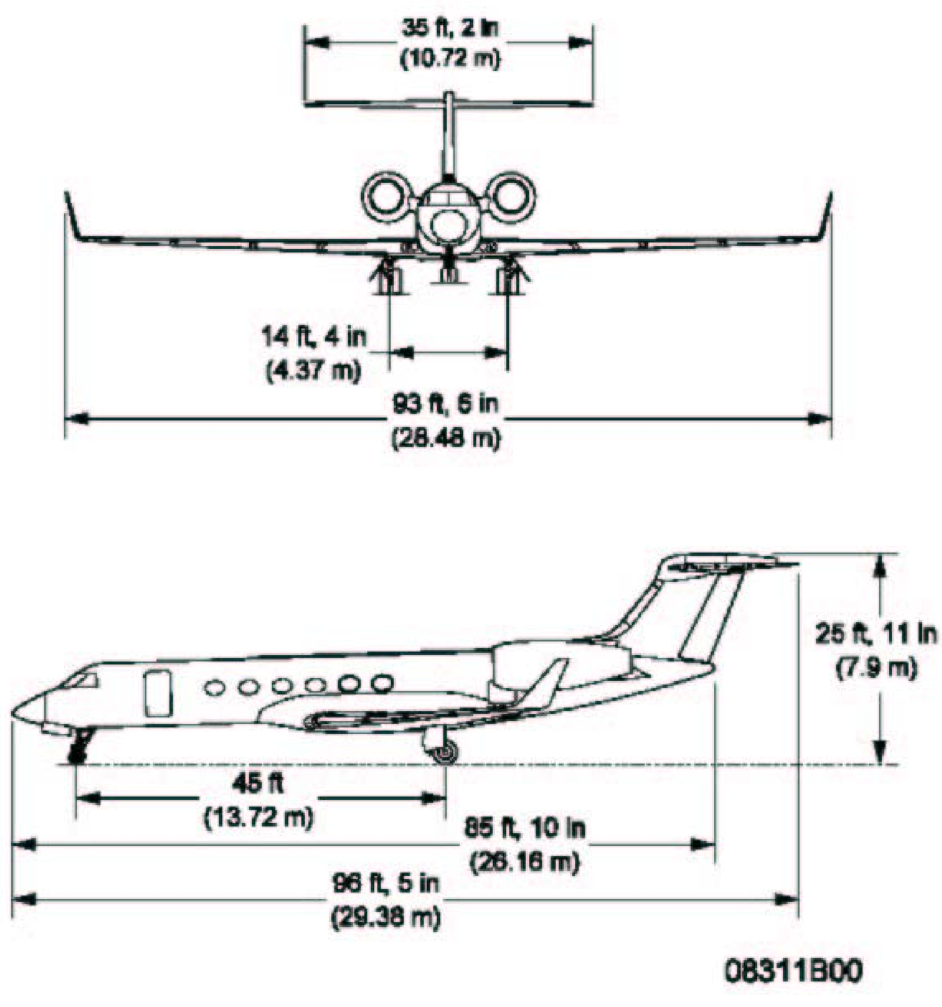

Figure 1.1 Front- and side-looking views of the GV.

1.2 Cabin Layout

The basic configuration of the GV cabin is as shown in Figure 1.1 below. The aircraft is equipped with a galley and a lavatory in the aft section of the main cabin. The research mission power rack is located in the forward section of the cabin immediately across from the main crew entry door. Locations of fire extinguishers and one of the life rafts are also shown in this diagram. (The second life raft [not shown] is stored in the galley.) The seats forward of the emergency exits can be removed and replaced with equipment racks. Four additional rack positions are also available. Two are located in front of the two forward most seats with the other two just forward of the galley and lavatory.

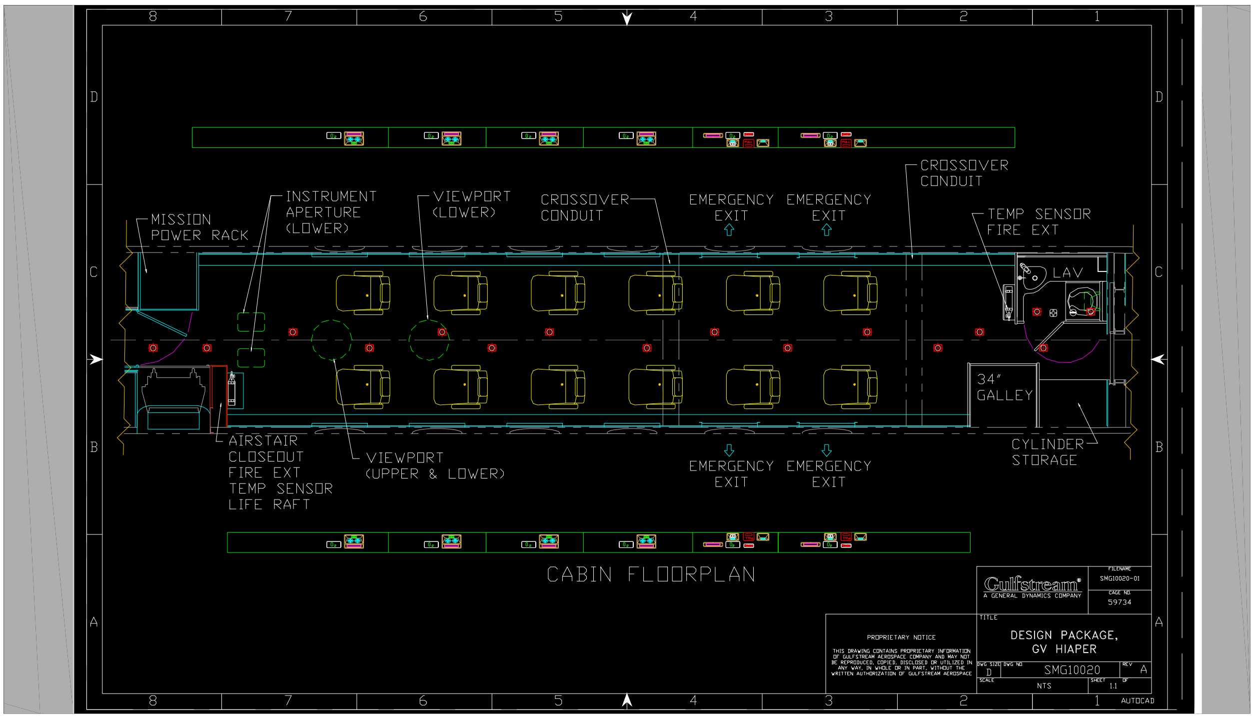

Figure 1.2 GV cabin configuration. Note that the seat positions shown are those at the time of aircraft delivery to UCAR/NCAR. Seats can be removed and/or relocated according to the needs of each specific research program.

Secondary power distribution and secondary signal distribution boxes (SPDBs and SSDBs, respectively) are located throughout the aircraft cabin for the provision of power to research equipment (see Section 2.3) and for the transmission of signals to and from instrumentation. Additionally, cabin interior attachment points have been installed on the floor and ceiling of the aircraft for the installation of equipment racks and instrumentation. Passenger service units (PSUs) situated on the upper section of the aircraft cabin walls contain reading lights, oxygen boxes, and "No Smoking/Fasten Seat Belts" signs. Figure 1.3 shows a cross section of the GV cabin, with the locations of seats relative to the power and signal wiring trays, SPDBs and SSDBs, PSUs, return air duct, and upper attachment (railing) depicted.

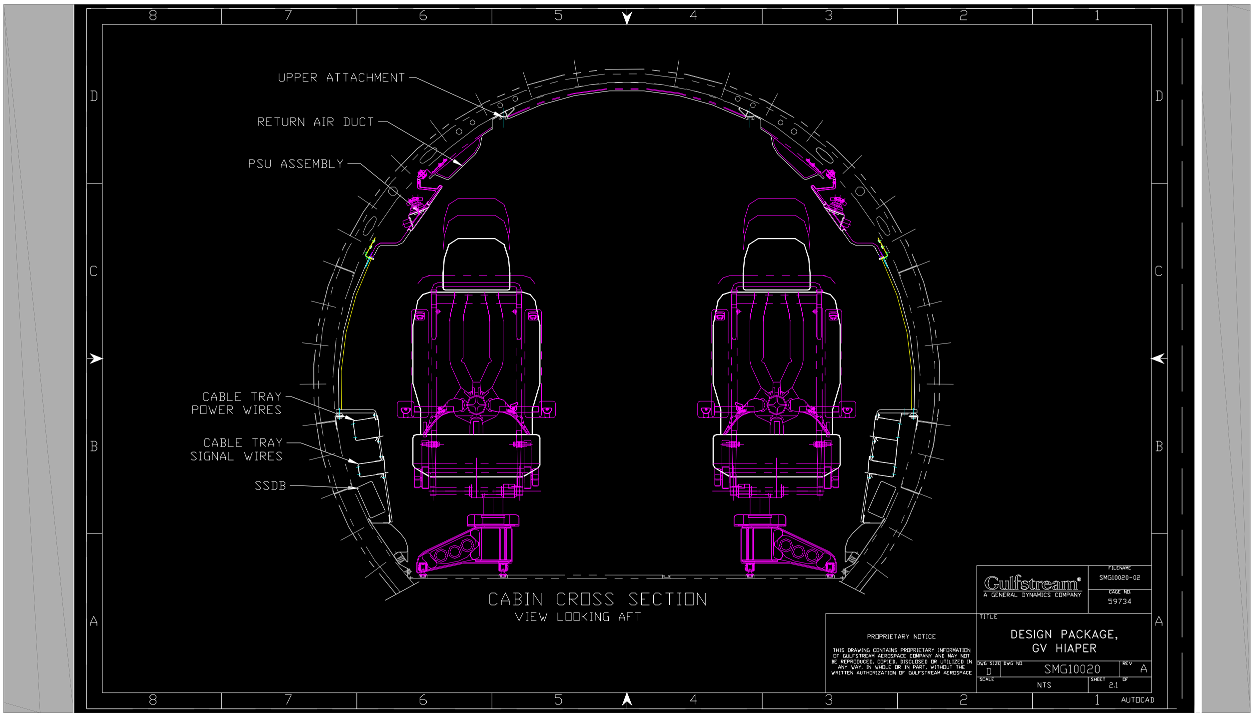

Figure 1.3 GV cabin cross section (view looking aft).

Figures 1.4 and 1.5 show the GV galley and lavatory, respectively.

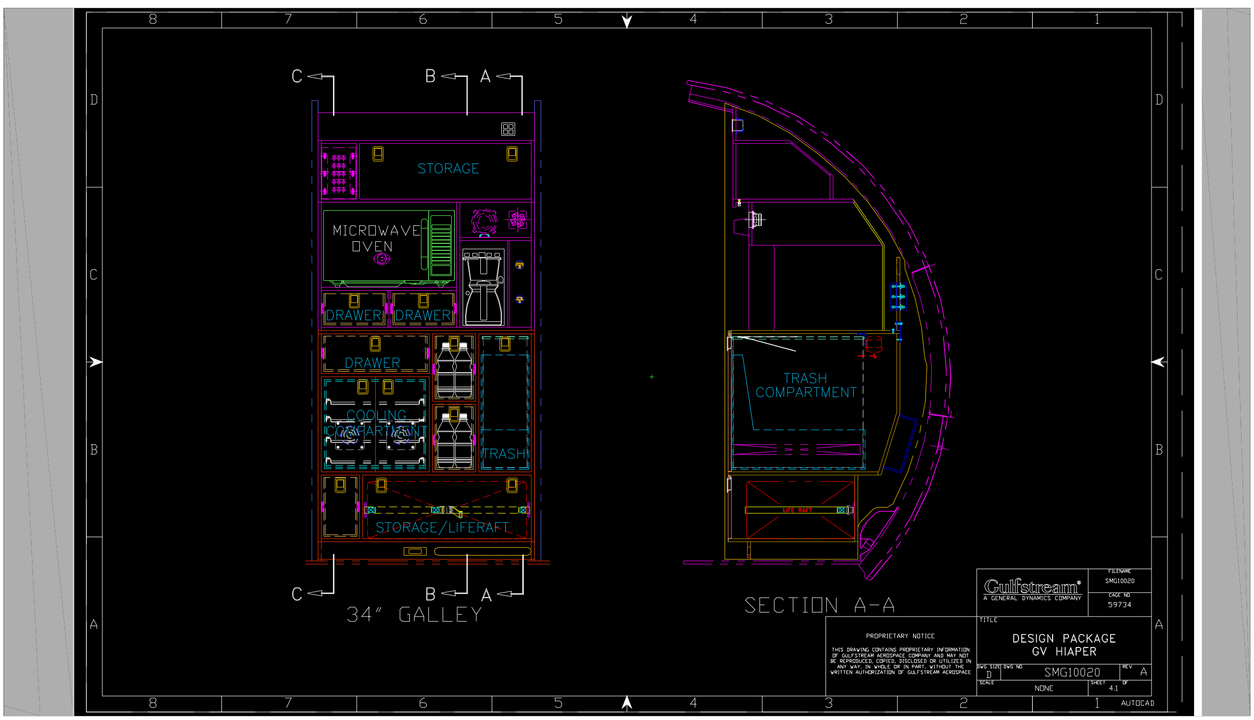

Figure 1.4 GV galley (front view).

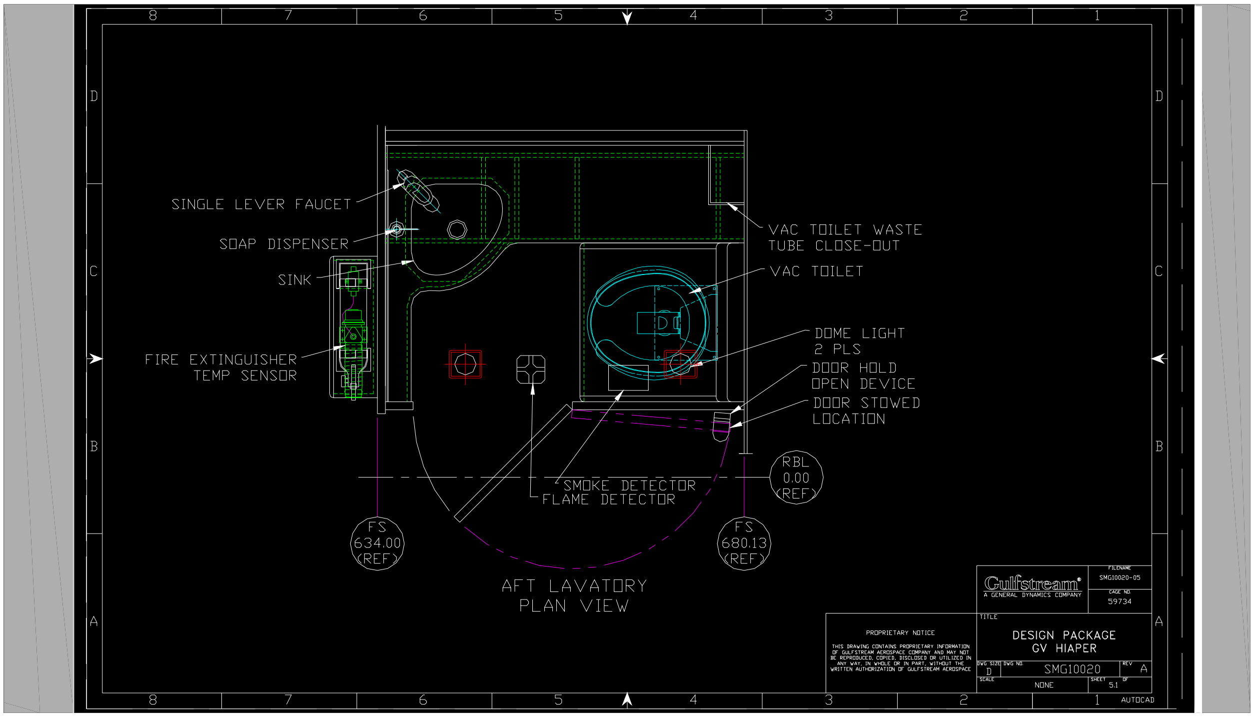

Figure 1.5 GV lavatory (plan view).

1.3 Weight and Balance

The NSF/NCAR GV aircraft is certified for operation at the following gross weights:

Category	Weight, lbs
Maximum Ramp Gross Weight	90,900
Maximum Takeoff Gross Weight	90,500
Maximum Landing Gross Weight	75,300
Maximum Zero Fuel Weight	54,500

Table 1.1. GV operational gross weights.

The following table provides loading information for the aircraft:

Category	Weight, lbs
Operating Weight Empty	46,200
Fuel Capacity, Maximum	41,300
Payload w/ Maximum Fuel	3,400
Fuel Capacity w/ Maximum Payload	36,400
Payload, Maximum	8,300

Table 1.2. GV loading information.

NCAR will determine the aircraft zero fuel center of gravity (either by weighing the aircraft or by numerical computation of the configuration) prior to each mission to ensure the aircraft center of gravity is within the approved GV envelope.

1.4 Cabin Pressurization

The aircraft pressurization system can automatically maintain a cabin altitude of sea level at an aircraft altitude of 11,000 feet to a cabin altitude of 6,000 feet at an aircraft altitude of 51,000 feet. The system can also be operated manually. A warning is displayed if cabin altitude exceeds 8,000 feet. The pressure safety relief valve is set for a +10.48 psi and -0.25 psi pressure differential.

1.5 Communication and Navigation

1.5.1 Integrated Flight Management System (FMS)

The GV is equipped with a FMS that integrates flight instrument displays and flight planning, navigation, and performance management utilities. The FMS consists of integrated displays and navigation, performance, guidance, and sensor systems. Equipment includes dual flight and navigation display cathode ray tube (CRT) systems, dual integrated avionics computers, dual flight guidance computers, a single Data Loader, and a PC Data Loader Port. Primary sensors consist of three (3) Micro Air Data Computers (MADC) and three (3) Inertial Reference Systems (IRS).

The FMS provides interfaces to the following:

- Navigation systems
- Inertial Reference Systems (IRS)
- Lateral Navigation (LNAV)
- Vertical Navigation (VNAV)
- Area Navigation (RNAV)
- Flight Planning
- Navigation Data Base Storage
- Autopilot
- Auto-throttle
- Stability Augmentation
- Performance Management
- Air Data
- Guidance

1.5.2 Communication and Navigation Systems

The aircraft is equipped with the following communications and navigation equipment. These systems meet the latest requirements for high density air traffic and all weather operations, including Minimum Navigation Performance (MNP) and Reduced Vertical

Separation Minimums (RVSM). Controls for the equipment are provided on the flight deck.

Note: *The frequency ranges of the navigation, radio, and radar units are also given in the following sections. Investigators are cautioned to engineer their equipment to utilize frequencies other than those specified for the various GV systems in order to prevent interference with aircraft equipment.*

1.5.3 High Frequency (HF) Communications

Dual HF transceivers provide 99 user-programmable preset channels and 280,000 discrete operating frequencies covering the 2.0000 – 29.9999 MHz range in 100 Hz increments.

1.5.4 Very High Frequency (VHF) Communications

Dual VHF Communications transceivers provide AM voice communication in the frequency range of 118.0 – 136.975 MHz in 8.33 kHz increments for a total of 1360 separate channels.

Note: *The use of frequencies for scientific purposes (i.e., other than routine contact with the Federal Aviation Administration [FAA]) requires that NCAR apply for authorization in advance of the project. It is important that needs for radio communications are clearly defined by investigators in the HIAPER Facility Request Form (see Chapter 7 of this handbook).*

1.5.5 VHF Navigation (VHFNAV), Instrument Landing System (ILS), and Marker Beacon

Dual VHFNAV systems provide Omni-directional Range (VOR) and ILS capabilities for the crew. The ILS is made up of the Localizer, Glide Slope, and Marker Beacon. The ILS functions are used to provide range, azimuth, and vertical input to align the aircraft with the landing runway. Both Navigation receivers operate in a frequency range of 108.0 MHz – 117.95 MHz spaced 50 kHz apart. The Localizers (LOC) operate in the frequency range of 108 – 112 MHz, and the Glide Slope (GS) receivers operate in the frequency range of 329.3 – 335.0 MHz. These frequency ranges provide 200 VOR channels and 40 Localizer channels. The Marker Beacon antenna is optimally tuned to receive signals at 75 MHz at an input impedance of 50 ohms.

1.5.6 Automatic Direction Finder (ADF)

Dual solid state ADF's provide bearing and audio output information that pertain to a selected ground station. The bearing and audio information are routed to the aircraft's navigation and intercommunication systems, respectively. The ADF can also be used for reception of voice or continuous wave (CW) transmissions. Both ADF receivers operate in frequency ranges of 190.0 – 1799.0 kHz and 2179.0 – 2185.0 kHz, tunable in 0.5 kHz increments.

1.5.7 Global Positioning System (GPS)

The GPS consists of two (2) identical Global Navigation System Sensor Units (GNSSUs) and a single antenna for each sensor. Data from these sensors are provided to the Flight Management Control System (FMCS) for very accurate worldwide navigation capabilities. The GPS uses the Department of Defense (DOD) space-based satellite system to determine a three-dimensional aircraft position that consists of longitude, latitude, and altitude. The GNSSU is a twelve-channel GPS receiver that receives L1 transmissions (centered at 1575.42 +/-10 MHz) from the NAVSTAR GPS satellite constellation.

1.5.8 Distance Measuring Equipment (DME)

The DME system consists of two (2) complete, independent and redundant systems. These units provide distance, time to station, ground speed, and station identification information for use by other aircraft systems. Each DME can track as many as three (3) ground stations at the same time. Channel 1 of either DME is normally paired with the on-side VOR (manually tuned), and the data are directly displayed to the flight crew. Channels 2 and 3 are used by the Flight Management System (FMS) for multi-sensor navigation and are automatically tuned. Both DME receiver functions operate in the L-band frequency range of 962 – 1213 MHz, and the transmitter functions operate in a frequency range of 1025 – 1150 MHz. The DME receiver operates 63 MHz above or below the transmitter frequency.

1.5.9 Air Traffic Control (ATC)

Dual solid state ATC systems provide Mode A and Mode C identification replies to Air Traffic Control Radar Beacon System (ATCRBS) interrogators for tracking, identification, and altitude reporting. Mode A provides coded aircraft identification and Mode C provides aircraft altitude information. The ATC transducers receive interrogation pulses on a frequency of 1030 MHz and, in response to all valid interrogations, transmit coded replies on a frequency of 1090 MHz.

1.5.10 Traffic Collision Avoidance System (TCAS)

One (1) TCAS 2000 (ACAS II/Change7) system and controls is installed in the GV to provide the flight crew with notifications of the presence of other transponder equipped traffic in the vicinity that may present a collision hazard. The TCAS/ACAS can track up to 50 airplanes simultaneously. The system provides aural alerts in the cockpit to the presence of traffic and visual plots on cockpit displays of the relative location of other airplanes and visual cues for evasive maneuvers are provided to the flight crew if collision is imminent. If both converging airplanes are equipped with TCAS/ACAS and mode S transponders, the systems mutually coordinate evasive maneuvers to ensure diverging flight paths. Both TCAS antennae on the GV operate at a transmit frequency of 1030 MHz and a receive frequency of 1090 MHz. The antennae have a nominal impedance of 50 Ohms.

1.5.11 Color Weather Radar

The Primus Weather Radar system installed in the GV is a lightweight X-band digital radar designed for weather detection and ground mapping. The primary purpose of the system is to detect storms along the flight path and to give the pilot a visual color indication of the storms' rainfall and turbulence content. After proper evaluation of radar images, the pilot can chart a course to avoid storm areas. In the weather detection mode, target returns are displayed as one (1) of five (5) video levels (0, 1, 2, 3, & 4). Level 0 is shown as a black screen which indicates weak or no returns. Levels 1, 2, 3, and 4 are shown as green, yellow, red and magenta, respectively, with increasing number indicating progressively stronger returns. Areas of potentially hazardous turbulence are shown as gray white. In the ground-mapping mode, video levels of increasing reflectivity are displayed as black, cyan (sky blue), yellow, and magenta. The weather radar system transmits and receives on a frequency of 9375 (+/-25) MHz (X-band radio frequency).

1.5.12 Radio Altimeter (RAD ALT)

The RAD ALT system consists of two (2) complete and separate systems. The purpose of the RAD ALT system is to provide the flight crew with an accurate above ground level (AGL) altitude indication during low level flight. The range of the RAD ALT system is -20 to +2500 feet AGL. The radio altimeter antennae have an input impedance of 50 Ohms and operate within a low frequency range of 4200 – 4400 MHz.

1.5.13 Emergency Locator Transmitter (ELT)

One (1) ELT System is installed in the aircraft. This system, an Artex C406-2 series ELT, is a third generation ELT that transmits at 121.5, 243.0, and 406 MHz. The system is capable of transmitting both aircraft position and aircraft identification.

1.5.14 Enhanced Ground Proximity Warning System (GPWS)

The GPWS provides wind shear detection and alerting. GPWS also provides advanced ground proximity warning with increased terrain-ahead awareness. These features help prevent accidents caused by Controlled Flight into Terrain (CFIT). The GPWS monitors the various sensor inputs for deviations that exceed predetermined parameters. The GPWS produces visual and audible warnings to notify the flight crew when any of the parameters are exceeded. The major feature of the enhanced GPWS is the incorporation of terrain awareness and display functions. The terrain awareness alerting algorithms in the GPWS computer continuously compute an advisory level and a warning level clearance envelope ahead of the aircraft. If the boundaries of these envelopes conflict with terrain elevation data in the terrain database, an alert or warning is issued.

1.5.15 Intercommunications System (ICS)

The cockpit ICS delivered with the GV was modified and expanded prior to delivery of the aircraft to UCAR/NCAR to provide communications capabilities for crew members in the main cabin. The GV ICS consists of hardware components manufactured by ATS Orbitz and includes three (3) Audio Control Panels (ACPs) in the cockpit (for the two pilots and one flight observer) and five (5) ACPs and three (3) Interphone Control Panels (ICPs) in the main cabin. Additionally, one (1) ICP is located in the aircraft baggage compartment. One (1) intercommunications jack is provided in the fuselage nose exterior, and one (1) is also provided in the tail compartment. Each of the ACPs in the GV main cabin provides investigators with the capability to communicate with other members of the flight crew (including the pilots) and to communicate outside of the aircraft using either one of the GV VHF radios (selected by the pilots) or the SATCOM systems. ICPs provide investigators with the capability to communicate with flight crew members in the main cabin only.

Instruction in the use of the GV ICS is provided to investigators by RAF personnel during preparation for aircraft field deployments.

1.5.16 Satellite Communications (SATCOM) Systems

Iridium and Inmarsat SATCOM systems are both available on the NSF/NCAR GV. An AirCell ST 3100 Iridium system is installed on the aircraft. The Inmarsat system is a Thrane & Thrane Aero-H+/Swift 64 SATCOM system. The operating frequency range for the Iridium system is 1621.35 – 1626.5 MHz. The Inmarsat system transmits in a frequency range of 1626.5 – 1660.5 MHz and receives in a frequency range of 1530 – 1559 MHz.

Using a network of 66 low-earth orbiting (LEO) satellites, the AirCell SATCOM system provides worldwide voice and data communications. RS-232 support built into the AirCell cabin-mounted equipment supplies the capability for Internet dial-up connection at a maximum data transmission rate of 2.4 kilobits per second (kbps). The Thrane & Thrane Inmarsat system provides global voice, fax, and PC modem data capabilities using the Inmarsat Aero-H+ service. High speed data transfers at rates up to 128 kbps are possible using the Inmarsat Swift64 aeronautical High Speed Data (HSD) service.

Instruction in the use of the GV SATCOM systems – and additional materials describing the capabilities of the two systems – is provided to investigators by RAF personnel during preparation for aircraft field deployments. A copy of basic operating instructions for the GV SATCOM systems is included in Appendix B of this handbook.

1.5.17 Airborne Flight Information System (AFIS)

The Honeywell AFIS installed on the GV is a tool for the communication of necessary flight information to the pilots using a VHF datalink. Information transmitted to the aircraft is displayed for the flight crew on the cockpit displays of the FMS. The AFIS may be used to access Automatic Terminal Information Service (ATIS) products and the digital version of an Air Traffic Control (ATC) clearance. Additionally, AFIS can be used to have a previously computed flight plan transmitted directly to the GV FMS. In flight, the AFIS can be utilized to gain access to such information as the latest terminal weather, ATC flow reports, Significant Meteorological Conditions (SIGMETS), NEXRAD graphical images, and Terminal Weather Information for Pilots (TWIP). The GV pilots can also use the AFIS to transmit messages.

2. Research Systems Descriptions

2.1 Structural Modifications

2.1.1 Aperture Pads and Plates

Six (6) inlet aperture pads have been installed on the upper fuselage of the GV. Each of these pads is 10 inches long and 7 inches wide, and a drawing showing the inlet aperture pad design is shown in Figure 2.1, below.

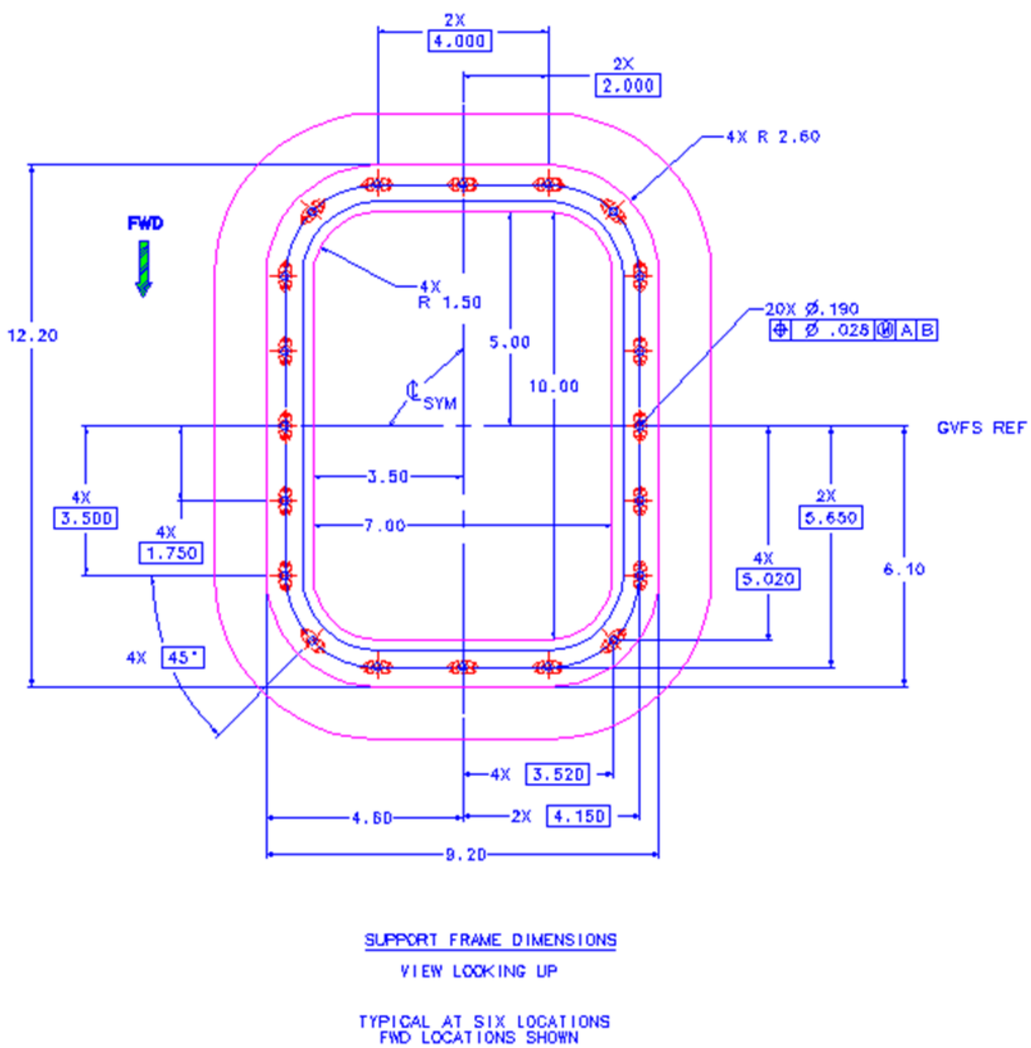

Figure 2.1. Drawing of GV inlet aperture pad.

Specific locations of the pads on the upper fuselage are as follows:

Pad #1: GVFS 255.5, LBL 13.91
Pad #2: GVFS 255.5, RBL 13.91

Pad #3: GVFS 328.5, BL 0.0
Pad #4: GVFS 434.0, LBL 14.84
Pad #5: GVFS 498.0, RBL 14.84
Pad #6: GVFS 532.0, LBL 21.7

Figure 2.2, below, shows the locations on the aircraft of the six inlet aperture pads.

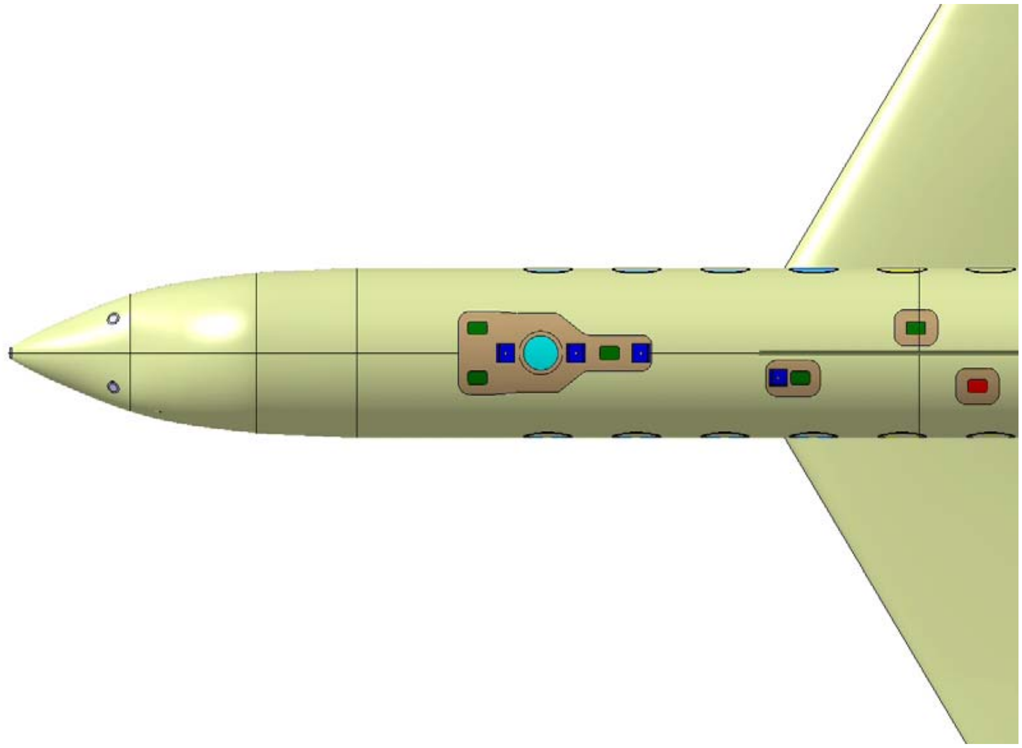

Figure 2.2. View of GV upper fuselage, showing inlet aperture pads (green and red), optical view port (light blue), fuselage mounts (dark blue), and two (2) forward fuselage pads below windscreen (grey circles). *Drawing courtesy of Lockheed Martin.*

In addition to the inlet aperture pads installed on the upper fuselage, two (2) instrument aperture plates are installed on the lower fuselage at the following locations:

Plate #1: GVFS 250.0, LBL 9.0
Plate #2: GVFS 250.0, RBL 9.0

The instrument aperture plates are similar in design to the inlet aperture depicted in Figure 2.1, above. Figure 2.3 below shows the locations of the two (2) lower fuselage instrument aperture plates.

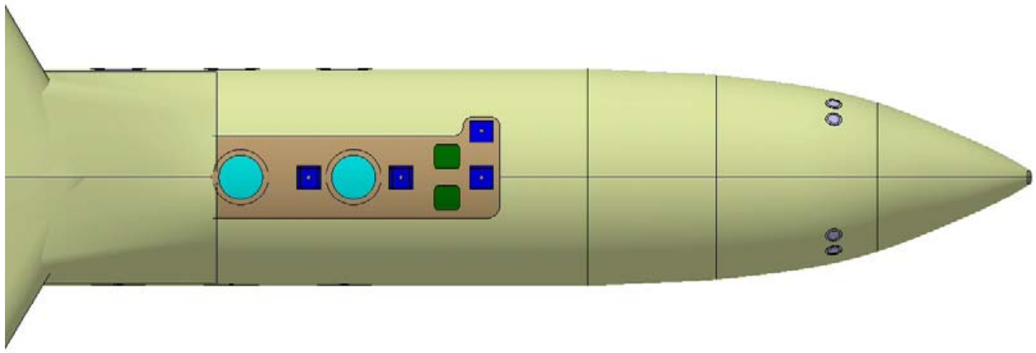

Figure 2.3. View of GV lower fuselage, showing instrument aperture plates (green), optical view ports (light blue), fuselage mounts (dark blue), and four (4) forward fuselage pads (grey circles). *Drawing courtesy of Lockheed Martin.*

2.1.2 Fuselage Mounts

Eight (8) fuselage mounts are installed on the GV fuselage, with four (4) on the upper fuselage and four (4) on the lower. Six (6) of the upper and lower mounts are installed at various locations on the aircraft centerline, and one (1) each of the upper and lower mounts are installed off of the centerline. Each of the mounts is 4.25 inches long and 3.0 inches wide and has a 1.75-inch diameter hole in the center of the mount to which a second plate can be mounted externally to attach inlets, bulkhead feed-through connectors, or lugs for securing fairings. Figures 2.4 and 2.5 show a fuselage mount and a second (instrument attachment) plate, respectively.

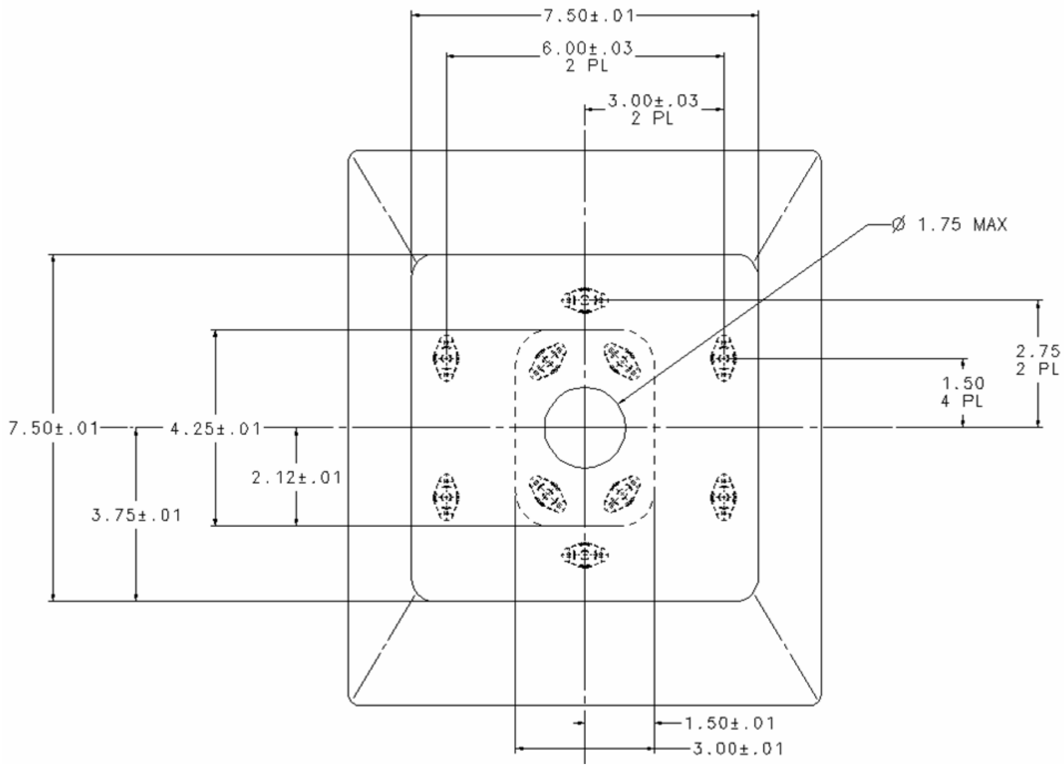

Figure 2.4. Drawing of GV fuselage mount.

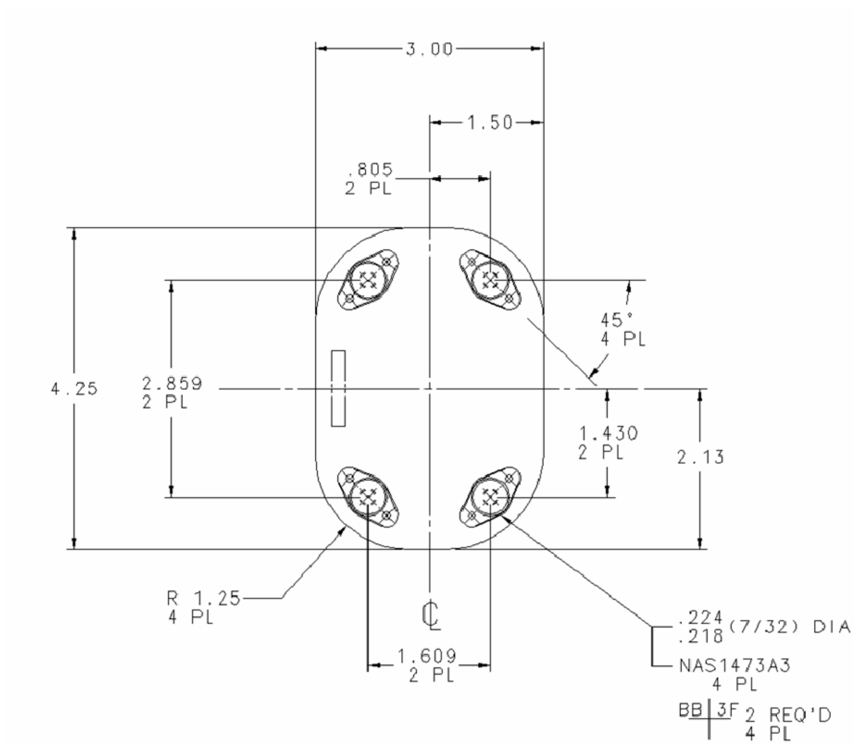

Figure 2.5. Drawing of GV fuselage mount connector plate.

Locations of the fuselage mounts are as follows:

Upper mount #1: GVFS 271.0, BL 0.0
Upper mount #2: GVFS 310.0, BL 0.0
Upper mount #3: GVFS 346.0, BL 0.0
Upper mount #4: GVFS 421.8, LBL 14.8
Lower mount #1: GVFS 235.0, BL 0.0
Lower mount #2: GVFS 235.0, LBL 19.97
Lower mount #3: GVFS 270.91, BL 0.0
Lower mount #4: GVFS 310.23, BL 0.0

Positions of the upper and lower fuselage mounts are shown in Figures 2.1 and 2.2, respectively.

2.1.3 Forward Fuselage Pads

Six (6) forward fuselage (nose) pads have been installed on the NSF/NCAR GV. Four (4) of the pads (two [2] on each side) are located on the sides of the forward fuselage, and the remaining two (2) are located on the upper section of the forward fuselage directly below the aircraft windscreen. Each forward fuselage pad is a mounting plate 4.75 inches by 4.5 inches that has a 2.0-inch diameter hole in the center of the pad to allow for the mounting/internal clearance of a cylinder 2.0 inches in diameter and 4.0 inches in length. Each pad is attached to the aircraft fuselage with eight (8) screws. Figure 2.6, below, shows one of the forward fuselage pads.

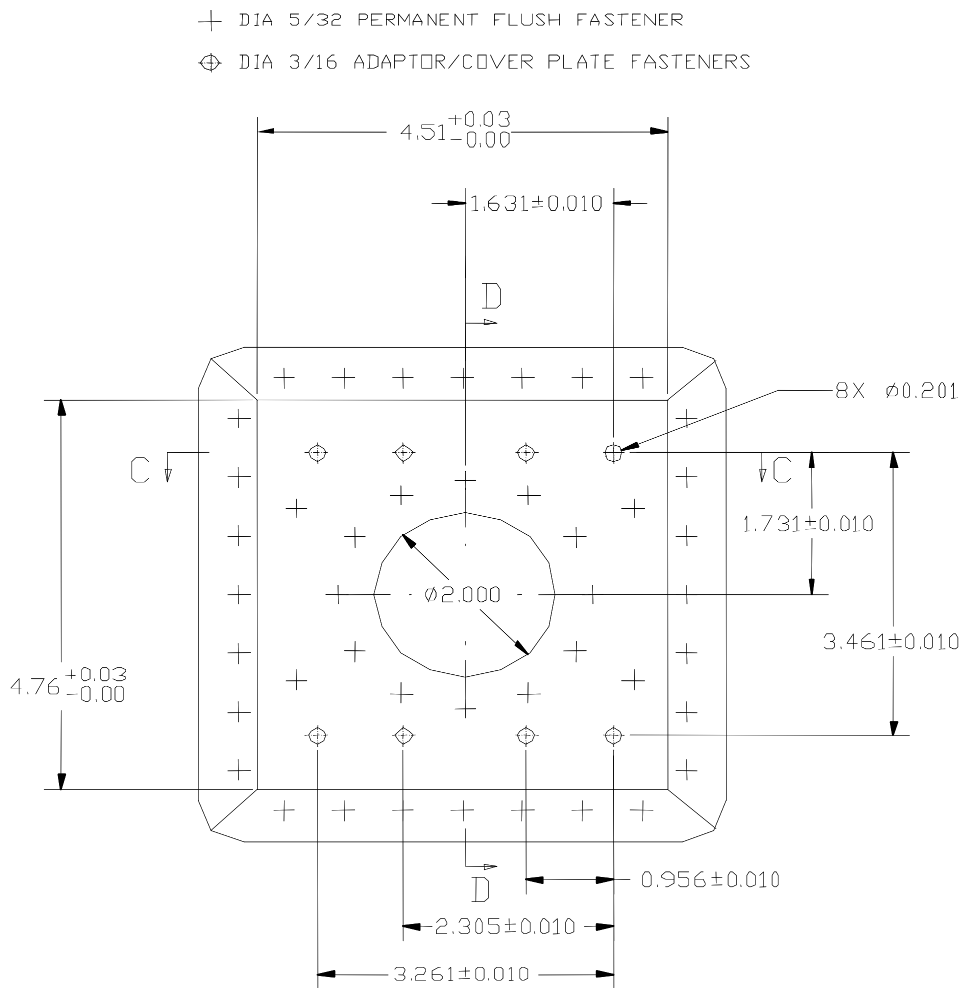

Figure 2.6. Drawing of GV forward fuselage pad.

Fuselage locations of the forward fuselage pads are as follows:

Left Side Pad #1: GVFS 54.0, WL 105.54, LBL 19.0
Left Side Pad #2: GVFS 82.0, WL 65.8, LBL 27.95
Left Side Pad #3: GVFS 82.0, WL 60.4, LBL 21.93
Right Side Pad #1: GVFS 54.0, WL 105.54, RBL 19.0
Right Side Pad #2: GVFS 82.0, WL 65.8, RBL 27.95
Right Side Pad #3: GVFS 82.0, WL 60.4, RBL 21.93

Positions of the upper and side fuselage pads are shown in Figures 2.2 and 2.3, respectively.

It should be noted that NCAR personnel have used five of the six forward fuselage pads (the four [4] located on the sides of the forward fuselage and the left pad below the windscreen) for the permanent installation of temperature, dew point, and pitot sensors on the aircraft. As of this writing, only the right pad below the windscreen is available for the installation of equipment.

2.1.4 Optical View Ports

Three (3) 20.5-inch diameter optical view ports are installed on the aircraft centerline in the forward section of the GV fuselage. Two (2) of the view ports are down-looking and one is up-looking. The forward down-looking and up looking-ports are aligned vertically. Additionally, this pair of view ports overlaps with the forward-most window on each side of the aircraft, thereby providing users with the opportunity to perform remote sensing measurements in the up-, down-, and side-looking directions from one instrument mount location. The view ports are designed to provide an unobstructed view from within the GV cabin to the exterior of the aircraft and to accommodate flat user supplied optical glass windows. Specific locations for the three (3) optical view ports are as follows:

Up-looking view port:	GVFS 290.5, BL 0.0, WL 142.5 for internal mounting surface
Forward down-looking view port:	GVFS 290.5, BL 0.0, WL 58.25 for internal mounting surface
Aft down-looking view port:	GVFS 339.5, BL 0.0, WL 58.25 for internal mounting surface

Figures 2.2 and 2.3 show the positions of the three (3) view ports.

2.1.5 Wing Hard Points, Pylons, and Pods

Six (6) under wing hard points (three [3] underneath each wing) have been added to the NSF/NCAR GV. The locations for each hard point are as follows:

Inboard, each wing: BL 123.017, canted 0.22 degrees
Middle, each wing: BL 192.787, canted 1.25 degrees
Outboard, each wing: BL 264.133, canted 2.08 degrees

Figure 2.7, below, shows these hard point locations with notional wing stores depicted at each hard point.

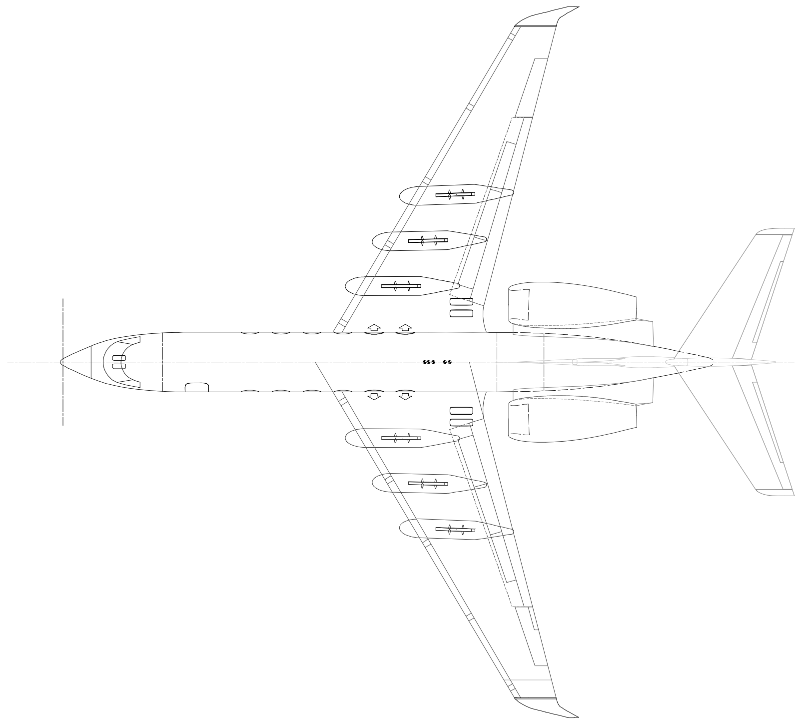

Figure 2.7. View of GV from above showing locations of six (6) under-wing hard points with notional wing stores mounted at each hard point.

Each hard point can carry a maximum static load of 1,500 pounds. This load includes the weight of the wing pod, fairing, and rack mount hardware. Installed hard points are compatible with USAF/NATO rack mount specifications, and each hard point can accommodate either 14-inch or 30-inch rack mount hardware. Power and signal wiring is provided to each wing hard point (see Section 2.3.2 of this chapter for wing power and signal wiring information).

Currently, the aircraft can only be equipped with pylons that adapt to dual canister wing stores. Each pylon is capable of mounting two standard PMS/DMT style instrumentation cans per pylon. Certified configurations allow for one such pylon at each outboard hard point or a full set of six pylons. Wing configurations must be symmetrical about the longitudinal axis of the aircraft with individual pylon weight limits of 100 lbs static load.

Additionally, GAC has performed some initial airflow and aerodynamic load studies for some larger candidate wing pods (one per pylon) being considered for deployment on the NSF/NCAR GV. See Sections 5.1 and 5.4 of this document for additional information regarding the types of airflow and aerodynamics data available from NCAR for the possible wing pods under consideration.

2.1.6 Window Blanks

As of this writing, NCAR/EOL personnel are pursuing the design and fabrication of window blanks for the GV. As delivered, the unmodified window frames of the aircraft can each support a modest equipment load (approximately 900 inch-pounds). GAC has informed NCAR that instruments mounted on the exterior surface of installed window blanks will require an FAA approved icing analysis to investigate the potential for engine ingestion of ice shed from said instrumentation.

Potential users of the GV are advised that only the forward-most four windows on each side of the aircraft can be removed for the installation of window blanks. The two rearward-most windows on each side of the aircraft are emergency exits and, as such, cannot be modified.

2.1.7 Tail Deck

The tail deck of the GV (see Figure 2.8 for a picture of this area) will be available for the installation of scientific equipment. While the tail deck had not been modified for such installations at the time of aircraft delivery to UCAR/NCAR in March 2005, EOL staff intend to make provisions for the installation of instrumentation at a later date. These provisions will include the modification of tail deck mount structures and/or the GV tail fairings as needed.

Figure 2.8. View of the GV tail deck area available for the mounting of scientific equipment.

The area available on the tail deck for instrumentation installation is approximately 12 inches high, 12 inches wide, and 6 feet long. Approximately 100 pounds total equipment can be supported in this area. However, users are advised that basic GV equipment takes up about 30 pounds of this amount. Additionally, a SATCO antenna (12 pounds) installed for real time data transfer and an actinic flux radiometer (6 pounds) are currently installed. Thus the capability to support about 50 pounds of additional User equipment exists.

Conduit is available in the GV tail for running power and signal wires to equipment mounted on the tail deck. Power and signal distribution boxes for the tail deck are located in the aircraft baggage compartment. The tail deck of the GV is not environmentally (i.e., temperature and pressure) controlled. Correspondingly, power and signal wiring that is run to instruments mounted on the tail deck will need to pass through bulkhead connectors in the baggage compartment. Also, investigators wishing to install equipment on the tail deck will need to design instrumentation accordingly to compensate for the exposure of tail deck instrumentation to the ambient environment.

2.1.8 Bulkhead Feed-Through Panels and Installation Conduits

A number of bulkhead feed-through panels and conduit sections are available in the GV to expedite the installation of instrumentation and the routing of power and signal wiring and tubing to and from sensors. Figures 2.9 to 2.11 show drawings and photos of bulkhead feed-through areas in the forward and rear sections of the aircraft that are available for use.

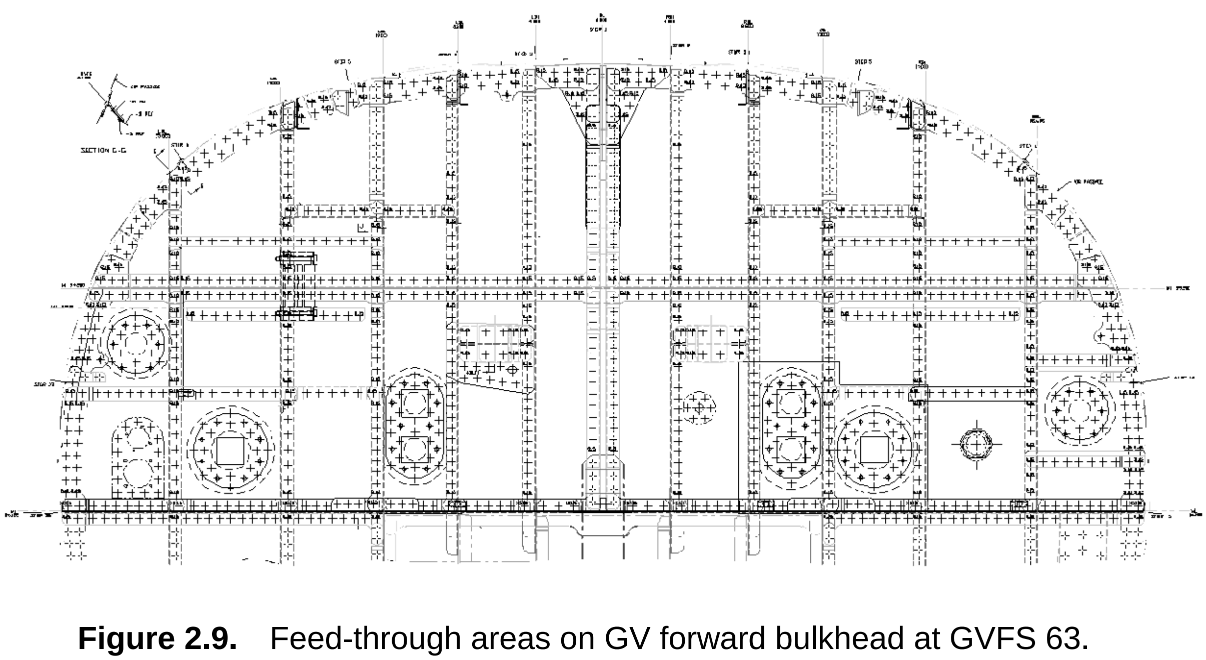

Figure 2.9. Feed-through areas on GV forward bulkhead at GVFS 63. Total feed-through area available for use is 22.09 square inches.

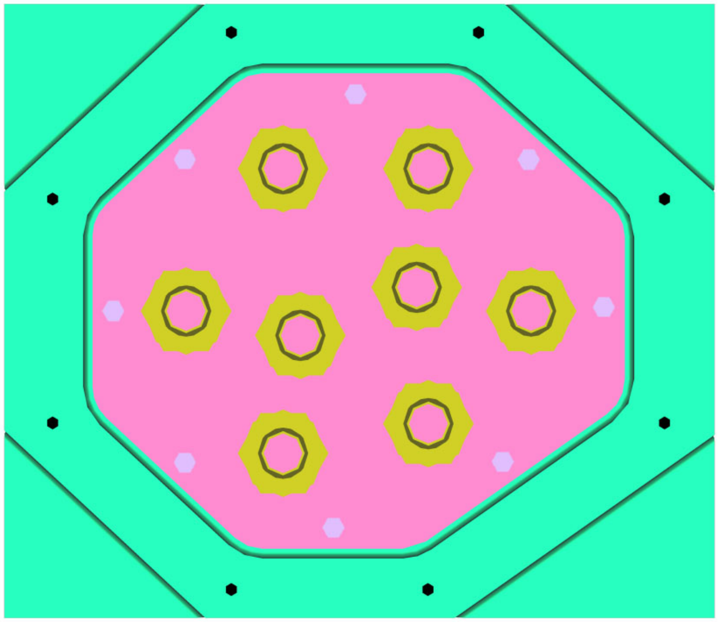

Figure 2.10. Drawing of feed-through section in GV floor underneath gas cylinder storage area aft of galley. Approximate feed-through area is 53 square inches.

LOOKING AFT SECONDARY PRESSURE BULKHEAD (GVFS 684)

Figure 2.11. Photo of feed-though section on right-hand side of secondary pressure bulkhead aft of GV lavatory. Approximate feed-through area is 15 square inches.

The GVFS 63 bulkhead feed-through areas shown in Figure 2.9 are used for running cables and tubing as needed from the nose area of the aircraft into cockpit area. The feed-through areas shown in Figure 2.10 and 2.11 are used for running cables and tubing from the baggage compartment of the GV into the main cabin.

In addition to the bulkhead feed-through areas described above, several conduit sections have been installed in the cabin of the GV to allow for the passage of cables and tubing behind various components of the aircraft and from one side of the aircraft to the other. Conduit sections have been installed behind the galley and the lavatory to allow for the running of cables and tubing from the main cabin to the baggage compartment (and vice versa).

Overhead and under floor conduits have also been installed in the GV to allow for the passage of cables and tubing from one side of the aircraft to another as needed. The two (2) overhead conduits are installed in the aft section of the aircraft, and the two (2) under floor conduits are installed in the forward section of the aircraft, with one (1) forward of and one (1) between the two (2) down-looking optical view ports. See Section 2.3.3 below for more information on these overhead and under floor conduits.

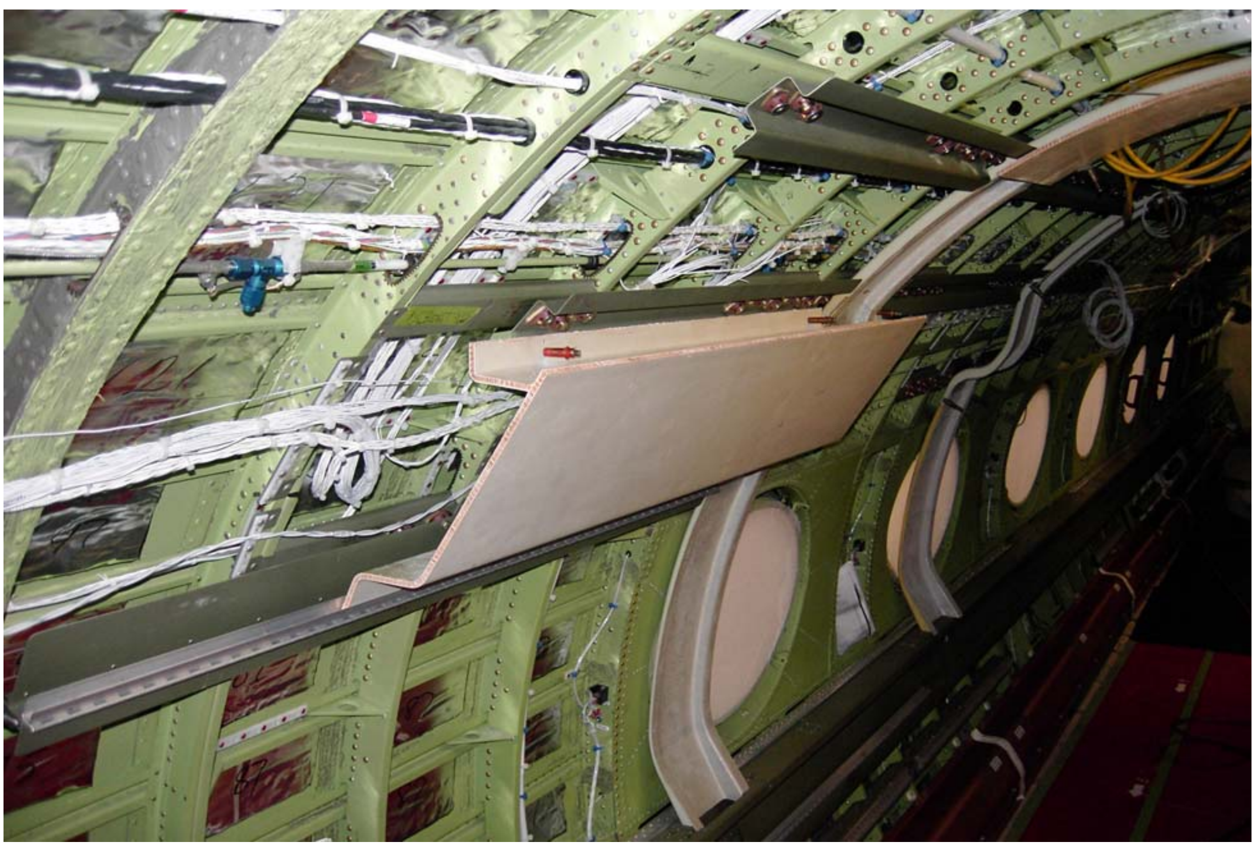

Figure 2.12. **Photo of mock-up of GV overhead conduit design.**

2.2 Standard Instrumentation Racks

NCAR has developed a single-bay, 19-inch, standard instrumentation rack for use on the GV. This rack is shown in Figure 2.12 below. The rack has dimensions of 22.18 inches wide by 26.5 inches deep by 48.62 inches tall. Two (2) pairs of panel mounting rails are attached to the four (4) vertical frame members. The rails conform to ANSI/EIA RS-310-C universal spacing dimensional requirements, providing a 17.75-inch wide by 45.62-inch tall opening (26U). The panel mounting rails enable equipment to be face mounted on the forward or aft rack face, rail, or plate mounted at each vertical frame member. The particular mounting option will be determined by the equipment weight and mass properties. The rack will be attached at the floor seat tracks. The rack is capable of supporting 350 pounds of equipment with a center of gravity 20.0 inches above the floor attachment plane.

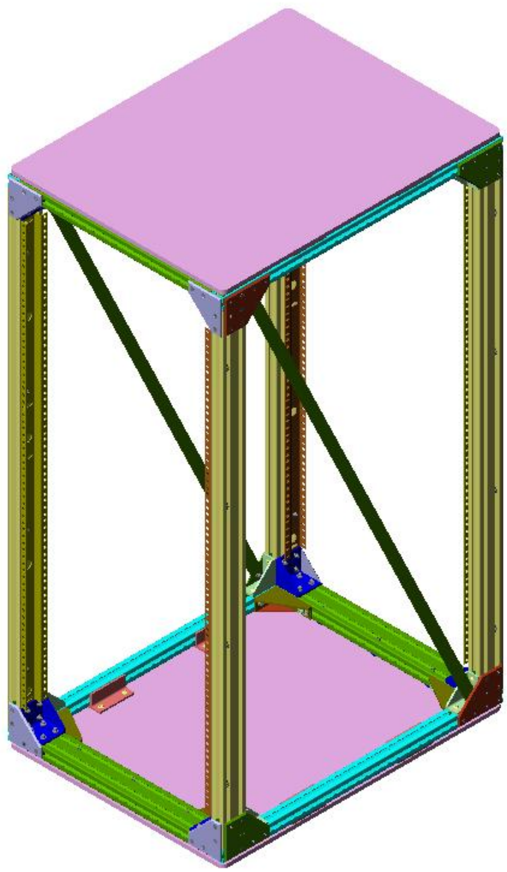

Figure 2.13. Drawing of GV standard instrumentation rack.

Special user equipment racks can be utilized if certain requirements are met. The racks must, at a minimum, satisfy the following: (1) the design requirements of Chapter 5 of this Handbook; and (2) the floor loading capabilities of the GV. Due to the level of effort required to approve special racks, early coordination with RAF Aeronautical Engineering (lord@ucar.edu) is necessary.

To expedite the project upload process, all racks should be flight ready (equipment and instrumentation installed and power/communications ground checked) prior to installation on the aircraft. Failure to do so may lengthen the installation and approval process and could impact the project start date. Racks can be obtained from NCAR in advance for pre-deployment build-up by contacting the appropriate RAF Project Manager. As an alternative, users expecting to fly on the GV frequently may wish to purchase a rack from NCAR or fabricate a standard rack from NCAR provided drawings and specifications. The NCAR/EOL Design and Fabrication Services (DFS) Manager (jfox@ucar.edu) can provide additional information on these latter two options.

2.3 Research Power System

2.3.1 System Description

The primary power source in the GV is the Integrated Drive Generators (IDGs). The power supplied by the IDGs is 115/208 VAC, three-phase, 400 Hz. Power from the two (2) IDGs is normally divided between the two (2) electrical buses, which are designated as the A or B bus (corresponding to the left or right side generators). A third bus (the C bus) can provide additional power (400 Hz, 40 kVA) from the Auxiliary Power Unit (APU) in flight. The APU output degrades at altitudes above approximately 42,000 feet, and GAC recommends not using the APU above this attitude.

The primary research power distribution unit is the Main Power Distribution Box (MPDB), shown below in Figure 2.13. Power return circuitry in the GV is not tied to the aircraft frame but is instead returned to the Main Power Distribution Box (MPDB). The MPDB is referenced to the airframe. Six (6) 3.5 kVA frequency/power converters located in the MPDB provide 115 VAC, 60 Hz power. Three (3) of the converters are powered from the A bus and three (3) from the B bus. This parallel configuration limits the current output to each side of the aircraft to 90 A. The system has excellent voltage regulation and frequency stability. If the input voltage becomes too low (70 to 90 Vrms) or too high (125 to 132 Vrms), the converters shut down to prevent damage to the load.

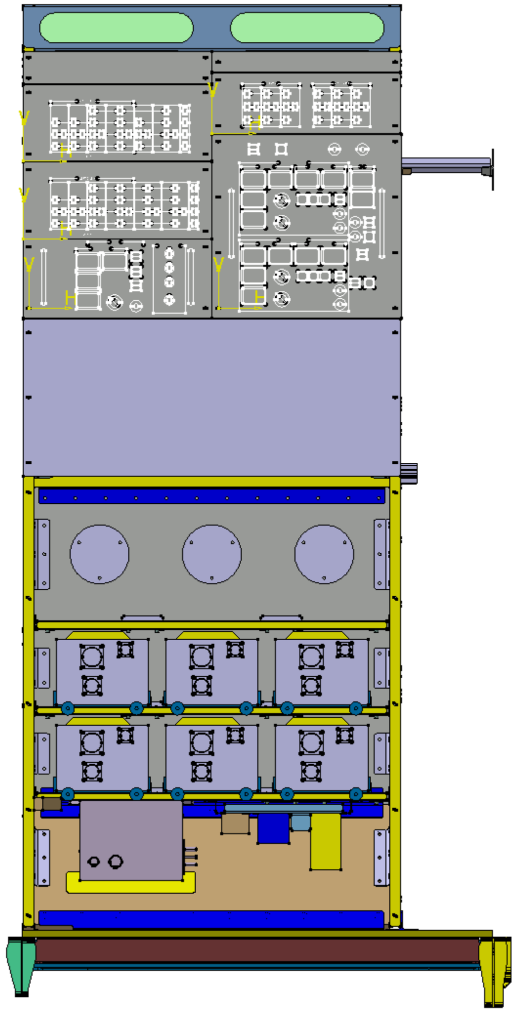

Figure 2.14. View of the GV MPDB, located on the right side of the forward cabin, opposite the main crew entry door.

NCAR flight crew members control the provision of power to investigators on board the GV. A single control switch for the GV research power system is located in the cockpit and is accessible to both the pilot and the co-pilot.

Power from the MPDB is distributed to Secondary Power Distribution Boxes (SPDBs) that are located in the main cabin (eight [8] units), nose (one [1] unit), baggage compartment (one [1] unit), and at each of the six (6) wing hard points. Investigators obtain power for research equipment from the SPDBs. The following table describes the types of research power available.

Type of Power	Location(s)	Total Amount Available
60 Hz, 115 VAC single-phase	All SPDBs	21 kVA (nominally)
400 Hz, 115/208 VAC	Single-phase: All SPDBs Three-phase: Main cabin SPDBs 3 and 4 only and baggage compartment SPDB *Note: Single-phase power available at nose, cabin, and baggage compartment SPDBs is controlled by a weight-on-wheels (WOW) switch and is available only after the GV is airborne*	20 kVA of single-phase power; **or** 20 kVA of three-phase Wye-connection power; **or** combinations of single- and three-phase power totaling no more than 20 kVA
28 VDC	Wing hard point SPDBs only *Note: 28 VDC power at wing SPDBs is controlled by a WOW switch and is available only after the GV is airborne*	5 kW; intended primarily for anti-ice purposes

Table 2.1. Types of research power available on the NSF/NCAR GV.

Investigators should note that 28 VDC power will be provided in the main cabin through the use of rack-mounted converters that operate using 115 VAC, 400 Hz power. Regulation and current capacity will vary according to the type of converter in use.

NCAR recommends that investigators plan on using 400 Hz or 60 Hz power (single-phase) as their primary power source whenever possible. Additionally, it should be noted that 50 Hz power is not available on the aircraft. Investigator using equipment that requires this frequency must provide their own converters.

The 60 Hz converters utilized in the GV research power system have overload capability. However, investigators desiring to operate devices with large in-rush currents (e.g. currents associated with the starting of a single phase motor or a vacuum pump motor) must notify the RAF in advance of these requirements, and such operations must be approved by the RAF.

2.3.2 Power Distribution Boxes and Connectors

As outlined above, SPDBs located along both walls of the main cabin provide power to equipment racks and to investigator equipment. There are four (4) evenly spaced SPDBs on each side of the fuselage. Figures 2.14 and 2.15 show the locations of the

SPDBs in the GV cabin. SPDBs are also provided in the nose, the baggage compartment, and at each of the six (6) wing hard points. Local control for each SPDB is provided by switches/circuit breakers on front panel of the MPDB. Each cabin SPDB has two (2) identical sets of MS3452W connectors. Each set of these connectors are connected to equipment racks by NCAR/RAF-supplied cables. Generally, the RAF provides all cabling from the SPDBs and from the aircraft data acquisition and display system (ADADS) to the mission equipment. Investigators must provide all required mating connectors and are also responsible for providing any cabling required between two or more racks of their own equipment. All wires and cables must comply with the material testing requirements referenced in Section 5.2 of this handbook. Such interconnecting cables may not be routed on the floor in order to maintain free access between racks. Cables that connect racks on opposite sides of the aisle must be routed in one of several cabin pass-throughs (see Section 2.3.3, below).

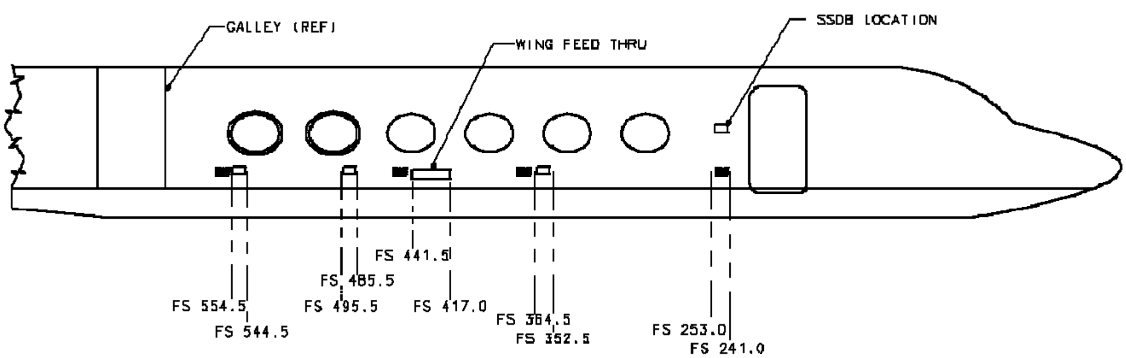

Figure 2.15. Locations of secondary power distribution boxes (SPDBs) and secondary signal distribution boxes (SSDBs) on the left side of the GV cabin. SPDBs are shown in black, SSDBs in white.

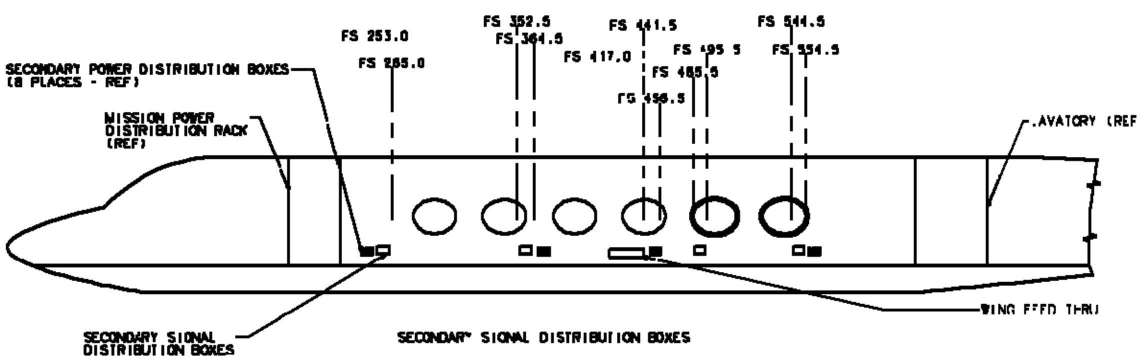

Figure 2.16. Locations of secondary power distribution boxes (SPDBs) and secondary signal distribution boxes (SSDBs) on the right side of the GV cabin. SPDBs are shown in black, SSDBs in white.

Each SPDB in the nose, cabin and baggage compartment provides the following: two (2) circuits with a maximum of 20 amps of 60 Hz power each; one (1) circuit with 20 amps of 400 Hz single-phase; one (1) circuit with 20 amps of 400 Hz three-phase (cabin SPDBs 3 and 4, left and right sides, and baggage compartment SPDB only); and one (1) circuit with 20 amps of 400 Hz single-phase anti-ice power. Figure 2.17 shows the configuration of the GV cabin SPDBs.

The SPDBs will interface to NCAR/RAF-supplied rack mountable secondary power distribution drop boxes (SPDDBs). Figure 2.18 shows the configuration of the GV cabin SPDDBs. These boxes are compatible with: (a) the 400 Hz three-phase provided via NEMA L15-30R, Pass & Seymour S L1530-R, 208/115 3-Phase receptacles; (b) the 60 Hz panel will accept a standard NEMA 5-15P; and (c) the 400 Hz single-phase panel will accept a NEMA 5-20P.

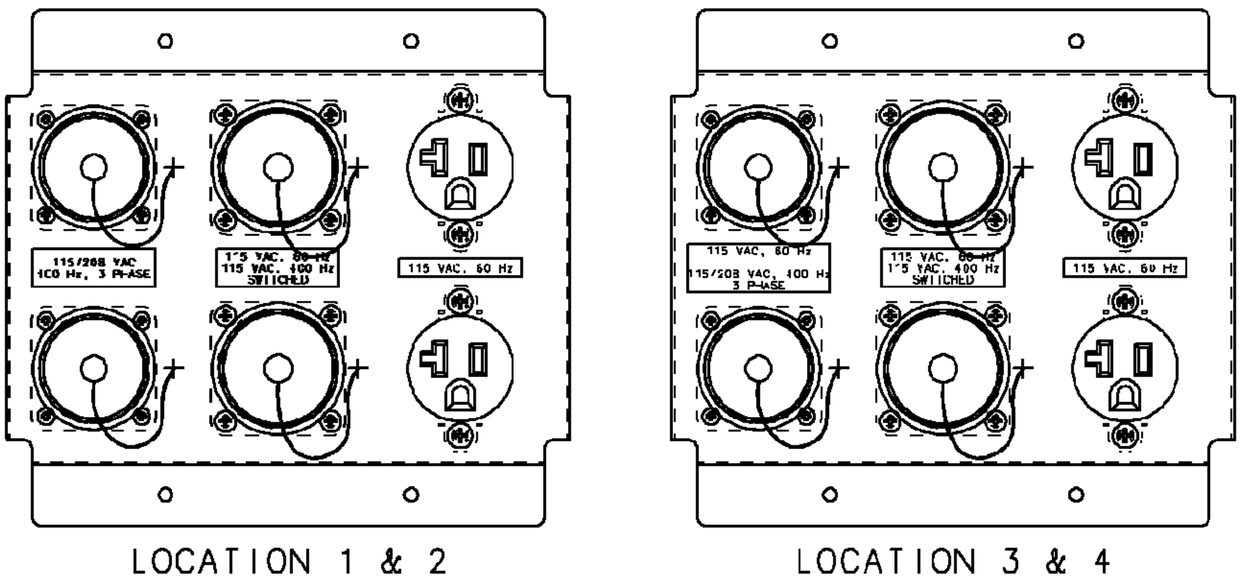

Figure 2.17. GV cabin secondary power distribution boxes (SPDBs).

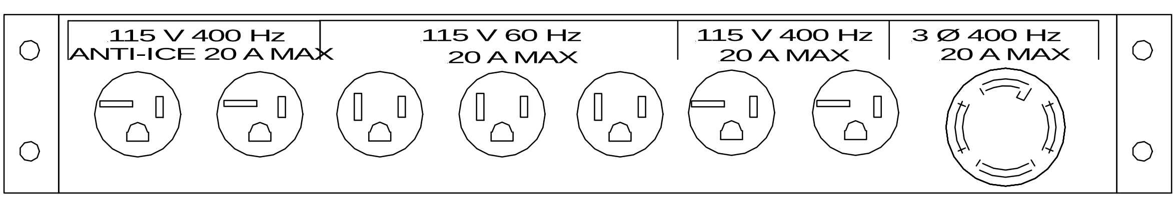

Figure 2.18. GV cabin secondary power distribution drop boxes (SPDDBs).

Power provided to the six (three per side) wing hard points is controlled at the MPDB with switches/circuit breakers. Each wing hard point SPDB provides the following: two (2) 20 amp 115 VAC, 60 Hz circuits; one (1) 20 amp circuit of 400 Hz single-phase; one

(1) 20 amp circuit of 28 VDC anti-ice. The two (2) 20 amp 115 VAC, 60 Hz single-phase circuits and the single 20 amp 115 VAC, 400 Hz, single-phase circuit will accept an MS3456W20-15P"x" connector. The single 20 amp 28VDC anti-ice will accept an MS3456W20-14P"x" connector. The "x" designates the connector insert rotation position from the normal position (see below). The wing SPDBs are designated as OUTBOARD, MID and INBOARD locations. Each of these three locations has a different connector insert rotation. (For example, connections made for the INBOARD location will not mate to the MID location.) The following is a list of connectors by locations that the wing SPBD will accept with the rotations:

OUTBOARD - 400 AND 60 Hz MS3456W20-15PN
OUTBOARD - 28VDC MS3456W20-14PN

MID - 400 AND 60 Hz MS3456W20-15PZ
MID - 28VDC MS3456W20-14PW

INBOARD - 400 AND 60 Hz MS3456W20-15PW
INBOARD - 28VDC MS3456W20-14PX

2.3.3 Crossover Conduits Description

The GV aircraft has four (4) crossover conduits in the main cabin. These conduits provide a means for passing research cabling and tubing from one side of the cabin to the other and for gaining access to nearby instrument aperture plates, pads, and fuselage mounts.

The two lower crossover conduits are located under the floor panels at GVFS 260 RH and LH, and GVFS 320 RH and LH. Each of these conduits has a small gap at the approximate midpoint. This gap allows for the routing of cabling and tubing out of the conduit and to the lower instrument aperture plates and fuselage mounts. The conduit size is approximately 2 inches deep by 4 inches wide, with a 0.25-inch corner radius.

The two upper crossover conduits are located underneath the headliner at GVFS 460 RH and LH, and GVFS 579 RH and LH. Each of these conduits has a small gap at the approximate midpoint and are concealed by a removable cover. The gap allows for the routing of cabling and tubing out of the conduit and to upper inlet aperture pads and fuselage mounts. The conduit size is approximately 1-in. deep by 7-in. wide, with a 0.25-in. corner radius.

2.4 Data Acquisition System and Display

Detailed information on the GV data acquisition and display system can be found in the document *Aircraft Data Acquisition and Display System (ADADS) Reference Manual*, available from the RAF. The following sections are intended to provide users with a general overview of the basic design characteristics and capabilities of the ADADS.

2.4.1 Data Acquisition System Overview

The GV aircraft data system (ADS3) is a modular system that utilizes data sampling modules (DSMs) installed in the cabin, the nose, the baggage compartment, and the wing pods (as needed). This distributed modular concept allows for straightforward expansion and for ease of installation. It also minimizes the amount of wiring required between instrumentation and the DSMs by keeping the DSM as close as possible to the installed sensors. Data from the DSMs are sent to the ADS3 server over the aircraft data acquisition network.

It was a principal design goal of ADS3 that the size of the new DSM be smaller than the older generation 11-slot VME chassis utilized for the NSF/NCAR C-130 DSMs. To achieve this goal, the ADS3 DSM utilizes an industry standard architecture with a large selection of commercially available off-the-shelf (COTS) hardware. This design approach enables the ADS3 to accommodate a wide variety of instrumentation and will also make possible the addition of new instrument interfaces in the future without the need to always develop custom printed circuit boards. The PC-104 architecture was selected for the GV ADS3 due to the advantages of its smaller size and the greater availability of suitable COTS instrument interfaces. The standard PC-104 architecture utilizes the ISA 16-bit data bus, with maximum word transfers typically less than 10 MHz. The PC-104 Plus circuit card contains an additional connector, which is the PCI 32-bit bus capable of 33-66 MHz bus transfer rates. The additional PCI connector on PC-104 Plus boards reduces available space on the circuit card for instrument interface circuitry. The PC-104 (ISA bus) is the ADS3 standard interface. The Plus version will be made available for use in ADS3 if needed.

2.4.2 Data Interfaces

2.4.2.1 Analog inputs

Analog signals are connected to ADADS using twin-ax cables and differential input amplifiers. Analog connectors are referenced to the GV airframe through high-value resistors to prevent ground loops while maintaining reference to the airframe. Each analog channel is calibrated via precision voltage sources as part of standard pre- and post-project calibration procedures.

Per-channel software selectable analog sample rates are 10, 100, 1000, and 10,000 Hz.

ADADS provides analog-to-digital (A/D) conversion with 16 effective bits of resolution at the above-specified sample rates below 10,000 Hz. At 10,000 Hz, the A/D resolution will be reduced to 14 effective bits. All analog channels are sampled simultaneously, with a maximum sampling delay between all channels of 1 millisecond.

2.4.2.2 Digital inputs

Digital data collection includes the acceptance of both serial and parallel data formats. Pulse counting is also available. Data transfer rates are generally determined by the instrument and typically vary from 1 – 50 Hz. ADS3 has the capability to sample and record all rates which are multiples of 1 Hz.

2.4.2.2.1 Serial Data Interfaces

Industry standard asynchronous RS-232 and RS-422 interfaces are provided in ADS3 with rates from 1200 baud to 115 Kbaud.

ARINC-429 transmit and receive channels can be provided at both the standard high and low speeds. A single PC-104 interface card contains at least two (2) receive double-buffered channels. FIFO or dual-port memory will be highly advantageous to alleviate the need for interrupt servicing of every received 24-bit word.

The industry standard HDLC synchronous protocol with clock rates up to 4 MHz and frame buffer sizes up to 4 Kbytes is also provided.

A serial interface based upon programmable logic is available that can be configured to provide custom interfaces such as bi-phase, pulse counting, and APN-232 radar altimeter serial data. In the case of pulse counting, the programmable logic interface is capable of providing at least two (2) 16-bit counters on a single board. All data are double buffered.

Note: *The older-generation PMS 1-D and 2-D serial interfaces are not provided in the GV ADS3.*

2.4.2.2.2 Parallel Data Interfaces

The GV ADS3 provides a parallel digital I/O interface that can be configured for different widths from 1-bit to 32-bits. In addition, there are up to four (4) separate input/output lines that can be used for data strobes and hardware interrupts. These lines are configurable as 1x, 4x, 8x, 16x, and 32 bits.

2.4.3 Network Description

The aircraft is outfitted with multiple networks. The primary data acquisition network interconnects the DSMs and provides gigabit Ethernet over copper twisted pair Category 6 wire. A similar network is provided for data display and user data traffic. (Fiber optic cable is also available and is currently installed in the wings and terminated in the cabin. This is not currently in use.) Network access is available at the eight (8) SSDBs in the main cabin, and at the SSDBs in the baggage compartment and the nose. Figures 2.15 and 2.16 show the locations of the main cabin SSDBs. Network wiring extends to all wing hardpoint locations. A third network links the ADS3 server to the SATCOM link for transmission to the ground.

2.4.4 Data Recording

All data sampled by ADS3 is recorded on redundant systems as "raw" data at sample rate and in the RAF ADS format. Data are stored on removable disk drives and/or other portable storage devices. A structured-query language (SQL) database is available for low-rate data storage/access by investigators who wish to have their data stored in a common database but not sampled through the ADS3. User data not going through a DSM may be sent to the database via the display network.

2.4.5 System Timing and Synchronization

GPS time-of-day is distributed to the DSMs and to the entire aircraft instrumentation suite via Ethernet in both IRIG-B and network time protocol (NTP) formats. A master time server (Datum SyncServer 1000) receives the GPS time-of-day information and provides these formats through an Ethernet connection. Each DSM includes an IRIG-B time distribution PC-104 card. In addition, all DSMs receive the 1 pulse per second (PPS) start-of-second signal from the GPS. The 1 PPS signal may be used to establish the beginning of each one-second interval. The master time server and DSMs establish time-of-day during the boot-up process via the IRIG-B signal and advance time by counting the 1 PPS. While the IRIG-B signal can be used by the GV ADS3 and by users to advance time and to identify the beginning of a one-second period, the 1 PPS time advancement method is considered to be more reliable. Both the 1 PPS and IRIG-B signals are made available to users.

2.4.6 Digital Signal Processing

Information to be provided at a later date.

2.4.7 Data Display Overview

Real-time display of data on board the GV is provided by the NCAR Airborne Environment Research Observing System (AEROS) software package. Complete information about AEROS and instructions for use of the software are available in the *Aircraft Data Acquisition and Display System (ADADS) Reference Manual*. Briefly, the AEROS package operates on both Windows and Linux based computer systems and provides investigators with the capability to generate and view the following types of plots: time series, X versus Y, track, skew T, ASCII list, statistics, and size distribution. Only data streams recorded on the GV ADS3 can be displayed on board using AEROS.

2.4.8 Data Broadcasts

A configurable ASCII serial feed is provided to investigator equipment. The serial port output is typically set to 38,400 baud with N81 for parity data and stop bits once per second. While the configuration of the serial feed changes on a per-project basis, the data stream format always consists of the following parameters in the order given:

date, time, and selected and configured variables. All values included in the serial feed are separated by a space, and the line is terminated by a carriage return/line feed pair. A sample ASCII serial feed stream is given below:

YY/MM/DD HH:MM:SS 1.234956e+00 8.325723e+02 …. \r\n

An Ethernet broadcast of data that is identical in format to the ASCII serial feed is also provided on board the GV. This broadcast consists of a UDP/IP packet sent once per second.

2.5 Satellite Data Communication Link

As outlined in Section 1.5.16 of Chapter 1, both Iridium and Inmarsat SATCOM systems are installed on the GV. Both systems provide voice and fax communications and data transfer capabilities. The near-global coverage and high bandwidth (128 kbps) characteristics of the Inmarsat system also provide the capability for controlling instruments and the GV ADS3 from the ground during flight. Semi-autonomous instruments that are connected to ADS3 can be controlled via the data local area network (LAN) installed in the aircraft. In brief, this involves instrument operators on the ground sending control commands to certain sensors on board the aircraft using the Inmarsat SATCOM system and the data LAN.

The transmission of data products to and from the GV is limited by the available bandwidth of each system (2.4 kbps for the Iridium system and 128 kbps for the Inmarsat system). In the case of the Inmarsat SATCOM system, the available bandwidth must be partitioned between voice communications, instrument control needs, time series and image data transfers, and text messaging in bi-directional mode. An on board computer controlled prioritization algorithm is configured for each GV project to provide control of Inmarsat bandwidth traffic flow and to ensure that critical data and messages are transmitted in a timely fashion.

EOL personnel are currently developing and implementing the software tools that are required for utilization of the GV SATCOM systems for data transfer and instrumentation control. Several tools are already available that will allow real-time web access to either direct field project participants, student groups or even common individuals with a casual interest in aviation research. Direct participants can communicate with onboard observers via text "chat" and the link can be used to transmit radar or satellite images, weather maps or sounding data to help provide in-flight guidance to modify research flight tracks and enable better sampling of targeted phenomena. Data access to in-situ measurements includes up to 20 variables and can include jpeg files taken from digital cameras documenting the flight environment. Outside groups or individuals can access some of this information via the EOL web site (www.eol.ucar.edu) that uses an interface to Google Earth which adds the aircraft track to their global display technology. This web site provides a summary of all ongoing EOL field activities at any time.

2.6 Ground Support Computing

Depending on the region of operations and the location of the operations center, there will typically be a ground based server that will be connected to a LAN where data will be processed post-flight and distributed to users who are connected to the LAN. In real time during a flight the ground server will also be gateway for two-way data communication between the aircraft and the ground. Often connections to a local ISP will be established and data (real time and post flight) can be accessed from remote sites.

2.7 Data Products

Immediately following each GV research flight, EOL personnel use the EOL/RAF Nimbus software package to process the collected data. Nimbus outputs data products in the network Common Data Form (netCDF) format. More information on netCDF is available on-line at http://my.unidata.ucar.edu/content/software/netcdf/index.html. Preliminary data files generated following the completion of research flights are used by RAF personnel to perform initial quality checking of all collected and derived data products. These preliminary files are also made available to investigators for initial review and analysis.

Data from investigator instruments that have been recorded on the GV ADS3 will be processed by Nimbus and released in the primary aircraft netCDF data file. Investigators who elect to record data on stand-alone data systems will be responsible for the processing and release of their own collected data products.

EOL has established a data policy governing the collection and release of data sets collected from all EOL-supported atmospheric observing facilities, including the NSF/NCAR research aircraft. This policy can be viewed on-line at http://www.eol.ucar.edu/dir_off/datapolicy.html. Investigators are strongly encouraged to review and become familiar with this policy in advance of the start of the designated field program.

3. Performance

The basic GV aircraft performance guarantees per the *Gulfstream V Product Specification*, April 2002, Section 2, are as follows:

1. Cruise Speed (TAS; Maximum Cruise Power):

   510 knots +0% -2% (Mach= 0.885) at 60,000 pounds at 35,000 feet

2. Specific Range:

   187 nautical air miles per 1,000 pounds of fuel burned; ±5% at 45,000 feet altitude, 0.80 Mach, and 65,000 pounds

3. FAA Takeoff Distance:

   5,990 feet ±8% at 90,500 pounds, sea level, and International Standard Atmosphere (ISA) conditions

4. FAA Landing Distance:

   2,775 feet ±8% at 75,300 pounds, sea level, and ISA conditions

The data above are based on a typically equipped airplane (49,600 pounds zero fuel weight), including antennae, pitot heads, and anti-collision light installations.

The NSF/NCAR GV will not be typically equipped for research missions. Thus, where applicable, the following sections provide estimated performance information for the NSF/NCAR GV assuming the following conditions:

1. ISA conditions
2. 3,400 pound research payload (49,600 pounds zero fuel weight)
3. 1,600 pound fuel reserve (51,200 pounds landing weight)
4. Take off at maximum gross takeoff weight (90,500 pounds)
5. Max ramp weight of 90,900 pounds (takeoff fuel weight of 400 pounds)
6. Max fuel capacity of 41,300 pounds
7. 15 additional drag counts to account for externally mounted equipment

3.1 Operational Limits

The following operational limits are taken from the *Gulfstream V Airplane Flight Manual*, Rev. 15, November 13, 2000.

The basic aircraft is certified for instrument and night flying, all-weather operation (flight into known icing and turbulence penetration), extended over-water flight, and flight at altitudes up to 51,000 feet.

Flight to the service ceiling for the NSF/NCAR GV will be possible only for low drag configurations (< 15 drag counts) and after the aircraft has reached a light weight condition (approximately 55,000 pounds).

The flight load accelerations for flaps up (0 deg) are +2.5 G and –1.0 G.

3.2 Speed Envelope

The speed envelope for the basic aircraft is taken from the *Gulfstream V Airplane Flight Manual*, Rev. 15, November 13, 2000.

The following table shows the minimum (stall reference speed, Vsr) and the maximum operating speed (Vmo, Mmo – mach number) in knots calibrated for the basic aircraft. Reference stall speeds are based on the maximum takeoff gross weight of 90,500 pounds.

Altitude, feet	Minimum (Vsr), KCAS	Maximum (Vmo), KCAS	Maximum, Mmo
0	143	300	0.454
10,000	154	340	0.612
20,000	172	340	0.733
30,000	186	332	0.867
40,000	189	271	0.885
45,000	NA	240	0.880
50,000	NA	209	0.863

Table 3.1. GV stall reference speed and maximum operating speed information.

For preliminary planning purposes, a research speed for NSF/NCAR GV of 240 KCAS up to 40,000 feet and Mach number 0.77 above 40,000 feet should be considered. The true airspeed (KTAS) and Mach number for these speeds are shown in the table below.

Altitude, feet	KCAS	KTAS	Mach No.
0	240	240	0.36
10,000	240	277	0.43
20,000	240	323	0.52
30,000	240	379	0.63
40,000	232	442	0.77
45,000	206	442	0.77
50,000	184	442	0.77

Table 3.2. GV calibrated airspeed, true airspeed, and mach number versus altitude.

3.3 Takeoff Field Length

The following takeoff data were obtained from the *Gulfstream V Quick Reference Handbook*, Rev. 15, November 13, 2000.

The following table shows the effective runway length required for the basic aircraft at different airport pressure altitudes (APAs) and gross takeoff weights (GTWs). The outside air temperature was assumed to be 15 ^{o}C (standard day at sea level) with a hard surface, level runway, zero wind, and 20 ^{o} flaps.

APA, feet	GTW: 90,500 lb	GTW: 80,000 lb
0	6,110 ft	4,570 ft
4,000	8,290 ft	5,910 ft
6,000	9,800 ft	6,910 ft

Table 3.3. Effective runway length information for GTWs versus APAs.

Since a number of factors influence the required runway length, investigators should contact the RAF Flight Operations Group (boynton@ucar.edu) for specific airport runway length planning information.

3.4 Cruise Altitude

The following cruise altitude information has been estimated from information supplied by Gulfstream Aerospace Corporation.

The initial cruise altitude is dependent on a number of factors including atmospheric conditions, aircraft weight, and aircraft external configuration. Under the previous assumptions, at maximum gross takeoff weight (90,500 pounds), the NSF/NCAR GV can climb directly to 41,000 feet. The following chart shows the aircraft climb performance from sea level.

To, feet	Time, min	Fuel, lb	Distance, nmi
10,000	3	500	15
20,000	7	1,100	35
30,000	14	1,700	75
40,000	24	2,500	145

Table 3.4. GV climb performance from sea level to various altitudes.

Higher initial cruise altitudes (> 41,000 feet) require a lower takeoff weight. If higher altitudes are required during a mission than can be achieved at a given gross takeoff weight, a step climb can be performed after aircraft weight has been reduced by fuel burn off. The following table gives the maximum aircraft weight capable of cruise at a specific altitude for the NSF/NCAR GV. Cruise altitudes are based on a drag increment of 15 counts (.0015), the use of maximum cruise thrust, and a rate of climb of 200 feet per minute (fpm). To date, inlet and instrument protuberances from the fuselage have had a negligible impact on drag count. For planning purposes, a standard fuselage configuration the two pylons and four cans rates a drag count of 6.2. The same fuselage configuration with six pylons rates a drag count of 19.6.

Altitude, feet	Weight at Altitude, lbs	Takeoff Weight, lbs
40,000	88,000	90,500
45,000	71,600	73,800
50,000	54,700	56,200

Table 3.5. Maximum aircraft weight capable of cruise versus altitude.

For comparison, the above data are presented in the following chart with a clean aircraft configuration for comparison:

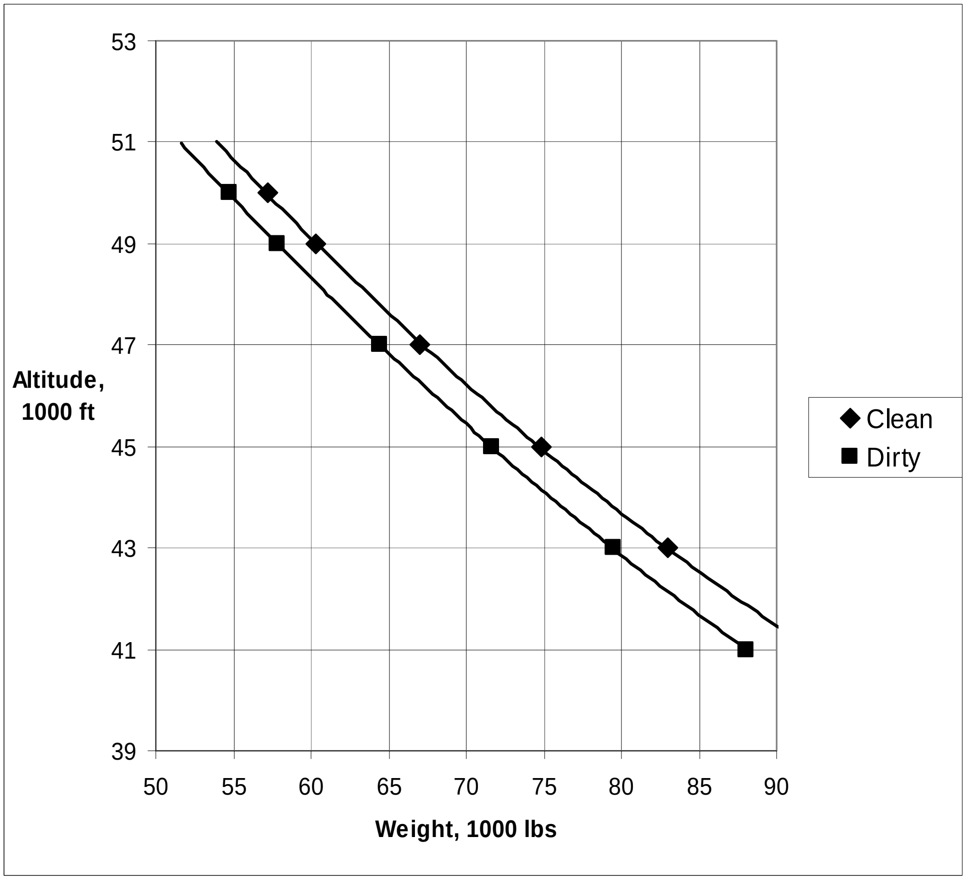

Figure 3.1. Clean versus dirty aircraft configuration chart.

3.5 Range and Endurance

The following range and endurance information has been estimated from Gulfstream Aerospace Corporation supplied information.

The following table shows the range and endurance for the NSF/NCAR GV based on the previous assumptions. The need for additional fuel reserve in remote areas will shorten the distance covered and time at altitude. Fuel loads are subject solely to the Pilot-in-Command's (PIC) discretion and exceptions to the reserve fuel requirement to prolong experiment time will not be made.

Altitude, feet	Takeoff Weight, lbs	Range at Altitude, NM	Endurance at Cruise and at Altitude, hrs	Endurance at Loiter Speed and at Altitude, hrs
0	90,500	2,616	11.0	13.4
10,000	90,500	3,289	11.9	14.6
20,000	90,500	4,051	12.4	15.4
30,000	90,500	4,952	12.8	15.8
40,000	90,500	5,950	13.0	15.4
45,000	73,800	3,959	8.4	9.2
50,000	56,200	897	1.4	1.5

Table 3.6. GV range and endurance information.

As mentioned previously, high altitude operations (> 41,000 feet) at a specific altitude can be achieved only when the aircraft reaches a certain weight. With the aircraft at a lower weight, less fuel is available for the mission. This effectively requires high altitude operations to be conducted close to the landing destination. Additional time at higher altitudes can only be achieved with lower payload weights. Conversely, higher payload weights (less fuel) will reduce the maximum cruise altitude attainable in addition to the maximum range and duration at all altitudes.

Special Note: The ten (10) hour single day crew duty flight hour limit, as defined in Section 4.2, will place de facto caps on the actual single flight endurance and range values list in Table 3.6

The following chart shows the maximum range attainable for different zero fuel weights for a clean aircraft and a data point for a dirty (15 additional drag counts) configuration.

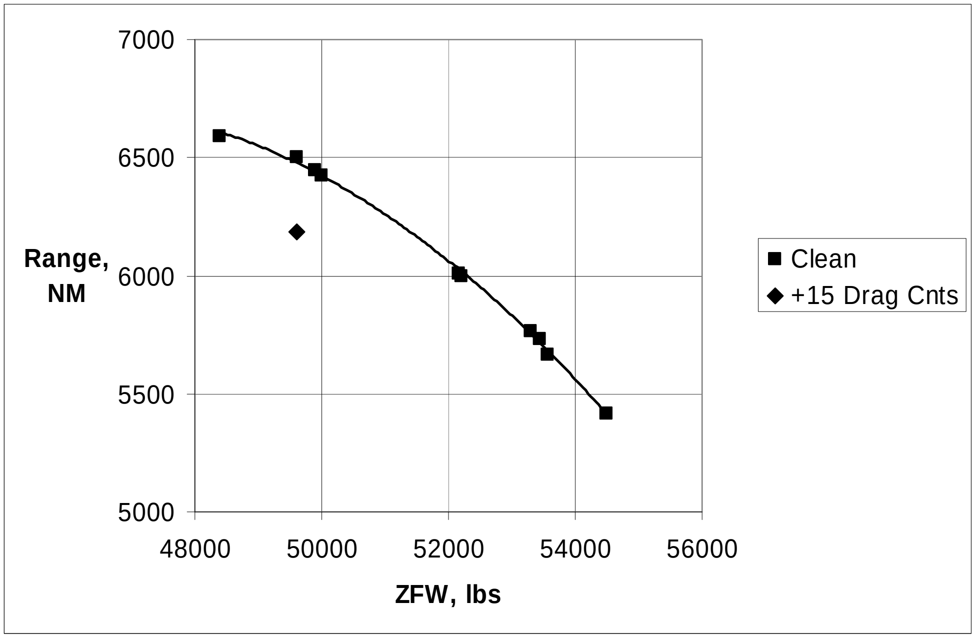

Figure 3.2. Maximum range attainable for different zero fuel rates chart.

3.6 Flight Planning Guidelines

The following flight planning information has been estimated from Gulfstream Aerospace Corporation supplied information.

The following table shows the average specific range and fuel flow for the NSF/NCAR GV aircraft at typical research speeds (240 KCAS below 40,000 feet, Mach 0.77 above 40,000 feet) and average weight at altitude (71,000 pounds up to 40,000 feet, 62,000 pounds at 45,000 feet, and 53,000 pounds at 50,000 feet). For altitudes between 0 and 40,000 feet, max fuel = ((90,500 - 49,600) - climb fuel). For altitudes above 40,000 feet, max fuel = (max wt @ alt – 49,600). Max fuel includes 1,600 pounds reserve fuel.

Altitude, feet	Maximum Fuel, lbs	Specific Range, NM/1000 lbs fuel	Fuel Flow, lbs/hr
0	40,900	66	3,610
10,000	40,400	84	3,310
20,000	39,800	104	3,110
30,000	39,200	128	2,970
40,000	38,400	155	2,850
45,000	22,000	184	2,400
50,000	3,800	215	2,050

Table 3.7. Average specific range and fuel flow for the GV at typical research speeds.

For more detailed flight planning to account for deployment location, local climate, specific payload, specific flight profiles and ATC considerations, contact RAF Flight Operations.

3.7 External Configuration Considerations

The previous range and endurance data consider an additional drag count of 15. This additional drag should approximate typical research configurations (i.e., cooling scoops, several moderately sized wing pods, and several inlets). For more detailed flight planning information to account for specific external configurations, contact the RAF Senior Aeronautical Engineer (lord@ucar.edu).

4. Flight Operations

4.1 Aircraft Certification Overview

As received from GAC, the GV aircraft is certified to the FAA's *Federal Aviation Regulations* (FAR) Parts 25 and 26. The aircraft carries Civil Registration Number N677F and a standard airworthiness certificate (FAA Form 8100-2) in the transport category. RAF operates the aircraft per FAR Part 91.

4.2 Crew Duty Limitations

Crew duty limitations apply not only to RAF staff (flight crew, maintenance and technician personnel, etc.) but also to any other persons flying on board NSF/NCAR aircraft. Research personnel participating on flights should abide by the duty limitations specified. These limitations have been established to prevent crew fatigue from becoming a safety concern during flight operations. Thus, specific project flight schedules may necessitate additional staffing in order to meet the crew duty limitation requirements specified. The crew duty limits for the GV are as follows:

Any 24 hour period	10 flight hours
Any consecutive 7 days	35 flight hours
Any 30 day period	110 flight hours
Consecutive working days	6 days
Crew duty period	14 hours
Minimum crew rest period between consecutive flights	12 hours
Switching from day to night or night to day flight operations	36 hours notice to all flight crew members

Table 4.1. GV crew duty limitations.

Investigators are advised that the above limits may – at the pilot's discretion – be extended for aircraft ferry purposes.

Flight hours are calculated from block to block times, i.e., from the time the aircraft first moves under its own power for the purpose of flight to the moment it comes to a rest at the next point of landing. Crew duty periods start at the briefing time or when the crew is considered on alert and ends when the aircraft is shut down and secured.

4.3 Operating Policies for Flight Planning

NCAR missions will be flown in accordance with FAA Regulations Subpart B, appropriate FLIP publications, ICAO procedures applicable to the host country, and NCAR directives.

4.3.1 *Operations under Adverse Conditions*

Adverse conditions include, but are not limited to, ceiling or visibility at or near minimums, marginal runway conditions, marginal approach aids, aircraft emergencies, severe turbulence, near maximum crosswind, unusual icing, terrain features that present an unusual hazard, and aircraft system malfunctions.

NCAR aircraft will not be operated into known or forecast weather conditions (icing included) that will exceed aircraft limitations. Aircraft limitations will be determined by the applicable flight manual.

NCAR aircraft will not be operated into areas of known or forecast thunderstorms unless radar is installed and operational or the weather forecast indicates that the flight can be conducted through the areas visually.

Final responsibility for the safe conduct of the mission rests with the Aircraft Commander. If in his/her judgment an unsafe condition exists, the mission will be delayed, canceled, or re-routed.

4.3.2 *Maximum Cloud Reflectivity During NCAR Operations*

Radar reflectivities of clouds have traditionally been utilized to establish rainfall rates that in turn are associated with turbulence and possible hail formations. Areas of high reflectivity gradients indicate steep rainfall gradients and are associated with turbulence. In order to maximize safety criteria for NCAR aircraft operations and still accomplish research objectives, maximum cloud reflectivity levels are hereby established. While this will not guarantee that NCAR research aircraft will not sustain damage the risk will be minimized.

<u>Criteria</u> – NCAR aircraft may penetrate, operate under, and operate within two nautical miles of a radar reflectivity echo of up to 40 dbz providing:

a. A properly calibrated ground radar is operated by a skilled technician within the quantitative observing range of the radar.

b. An RAF-approved, radar-trained scientist has access to the real-time display and is assigned to monitor and direct the aircraft operations. The radar scientist will maintain surveillance of the storm radar structure and voice contact with the plane at all times the aircraft is in the near-vicinity of storms, keeping cognizant of growth rates within storms, the fall rates of hail, and the limits of radar scan processes. The Aircraft Commander retains overall responsibility for safety of the aircraft and will remain in contact with radar scientist for all storm penetrations.

c. In the absence of ground radar data, when only airborne radar is utilized, NCAR aircraft will not penetrate, operate under, or operate within three nautical miles of any storm cell having a radar echo that shows contouring reflectivity judged to be 39 dbz or greater.

4.3.3 *Altitude Restrictions for NCAR Aircraft*

Minimum altitudes apply unless a waiver has been obtained.

Except when necessary for takeoff or landing, no person may operate an aircraft below the following altitudes:

a. Anywhere. An altitude allowing, if a power unit fails, an emergency landing without undue hazard to persons or property on the surface.

b. Over congested areas. Over any congested area of a city, town, or settlement, or over any open-air assembly of persons, an altitude of 1,000 feet above the highest obstacle within a horizontal radius of 2,000 feet of the aircraft.

c. Over other than congested areas. An altitude of 1,000 feet above the surface, except over Ocean water. In those cases, the aircraft may not be operated closer than 500 feet to any person, vessel, vehicle, or structure.

d. Over Ocean water - VFR Conditions - An altitude of 100 feet above the surface for straight and level flight, and a minimum altitude of 300 feet for turning maneuvers exceeding bank angle of 5 degrees.

e. Auto pilot engaged – Minimum altitude of 300 feet above the surface.

Added constraints for hours of Darkness or During Restrictive Visibility

f. When operating under these conditions, over a flat surface such as the ocean or polar ice cap, a minimum altitude of 500 feet above the surface will be observed providing the radar altimeter is operational. Flight path excursions of short duration to a radar altitude of 300 feet are permissible.

g. The above minimums have been established with near ideal conditions in mind. The Aircraft Commander must evaluate other factors such as turbulence, surface conditions, fatigue, and duration of flight at low altitudes, etc. It may be necessary to raise these levels to what in his/her judgment, is appropriate for the existing conditions.

Note: These minimums do not apply to coupled approaches.

4.3.4 *Use of Oxygen*

Crewmembers will use oxygen as specified in the appropriate aircraft flight manual, FAR 91.32, or as follows:

a. During daylight when the cabin pressure altitude is above 8,000 feet in excess of four hours, pilots and flight engineers 100% should use oxygen for 10 minutes of the last 45 minutes of the flight.

b. Unpressurized flights from 18,000 feet to 25,000 feet MSL require pre-flight de-nitrogenation breathing for 10 minutes. All crewmembers will breath 100% oxygen from start of pre-breathing until the mission above 18,000 feet MSL has been completed and the aircraft has descended below 18,000 feet.

c. Unpressurized flights above 25,000 feet MSL will not be conducted.

4.3.5 *Cancellation of IFR Flight Plans, Airborne*

a. Flight plans should not be canceled during daylight hours whenever weather in unknown, reported as marginal, or when scud, haze, or other restrictions to visibility are known to exist. In these cases, maximum use of all available navigation facilities should be utilized to effect an instrument approach to the point of intended landing.

b. IFR flight plans should not be canceled during night operations until an instrument approach is initiated and then only if the terminal airfield is in sight and VFR weather conditions are reported and verified by the pilot.

c. The above policy is no way intended to restrict the authority of the Aircraft Commander during inflight emergencies or under any other condition wherein the cancellation of an IFR flight is fully justified.

Note: For safety reasons the aircraft should have flight following until landing.

4.3.6 *Weather Forecasts*

The Aircraft Commander will insure that the destination and alternate weather forecasts are obtained before reaching ETP on over-water missions. Weather forecasts will provide the Aircraft Commander with sufficient terminal weather information for diverting or continuing to destination.

4.3.7 *Normal Procedures for Formation Flight*

Close formation is only to calibrate and datum scientific instruments with other aircraft participating in scientific exercises.

Close formation is defined as when an aircraft is flying in close proximity to another aircraft in such a manner as to require the following aircraft to take all external visual references from the lead aircraft.

Close formation leading is defined as being totally responsible for all aspects of the safety, terrain clearance, positioning and handling for aircraft that are formatting in close proximity to the lead aircraft.

Close formation is only allowed with one other aircraft at any one time - formation lead and the formating aircraft (No.2).

The more restrictive regulations of the aircraft's state of registration, and airspace used, will always apply.

Aircraft shall not fly formation unless the aircraft commanders of the aircraft have agreed to do so.

4.4 Fitness Requirements

The GV aircraft, as delivered, is fully certified in the transport category. Consequently, no special risks to investigators, other than those normally encountered in business air travel, are anticipated. However, certain research situations may require special fitness testing. These include:

- *Operation at reduced cabin pressure.* The GV will not normally be operated at less than normal cabin pressures (e.g., there are no plans to fly the aircraft unpressurized). Any request to operate at reduced cabin pressures must be submitted at the time of the request for usage of the aircraft, and will be considered in the feasibility studies which are submitted to the OFAP. Flights above 14,000 feet internal cabin pressure require physiological training and altitude chamber testing. These training and testing procedures must be arranged well in advance of any flight program where such cabin altitudes will be required. Users considering such requests should discuss their requirements with the RAF prior to submission of the facility request.

- *Operations with unusual windows or inlets.* The RAF plans to certify standard optical windows and inlets to the same standards as the rest of the aircraft. However, if the certifying authorities (i.e., the FAA Designated Engineering Representative [DER], or other FAA representatives) or the RAF determine that there is any increased risk of cabin depressurization due to any specific instrument installation, physiological training and altitude chamber testing may be required.

All persons interested in participating in GV research flights are required to review the document "*Medical Information for Airborne Research*," which has been prepared for the RAF by Dr. Warren Jensen, FAA Senior Medical Examiner and Director of Aeromedical Research of the University of North Dakota. This document is provided in Appendix C of this handbook.

Passengers on the aircraft are strictly limited to designated "crew members" only. Basically this means the flight crew and scientific staff (RAF and Users) with a specific research task on the flight. Crew manifests require NSF approval prior to the start of any field campaign.

4.5 Emergency Procedures

Aircraft emergencies will be handled in accordance with the FAA-approved *Airplane Flight Manual*, Rev. 15, November 13, 2000, and FAA-approved *GV Operating Manual*, Rev. 15, November 13, 2000, when applicable. Emergencies involving onboard research systems emergency or medical emergency situations will be evaluated by the in-flight RAF data system operator and will require flight crew notification as soon as is practical. The Pilot-In-Command (PIC) will be responsible for decisions concerning the flight plan after receiving notification of an emergency. All participants in GV research flights are responsible for promptly reporting any safety concerns (e.g., pressure leaks, smoke in the cabin, etc.) to the PIC.

4.6 Safety Training

RAF personnel have participated in GV all-crew training courses that involve instruction in aircraft ditching safety procedures and cabin evacuation skill training. Some of the safety procedures learned by RAF staff members have been incorporated into the standard RAF GV safety training course for all flight participants.

All individuals who will be participating in GV research flights will be required to successfully complete an RAF safety and operations course before the start of the specific project. These courses are normally conducted at the RAF. Arrangements to conduct special classes in the field can be made with advance request, provided the aircraft is available. The class takes approximately four hours to complete. Topics covered include the following:

- A review of RAF standard operating procedures relevant to flight operations, with an emphasis on ground and airborne safety procedures;
- Training regarding emergency procedures to be followed onboard the aircraft;
- Training on the handling of hazardous materials;
- Briefing regarding project-specific safety issues;
- Instruction in the operation of aircraft systems (intercommunications system [ICS], lighting, seatbelts, emergency exits, etc.)

Additional training for investigators who will also be serving as mission scientists during specific projects is also provided (see Chapter 7, Section 7.2.4 of this handbook).

4.7 Security

At the time of this writing, the FAA and National Security Agency are considering the implementation of several measures that may require passenger screening. This may include a requirement for the performance of background checks. Any measures adopted by the U.S. government which will affect RAF flight operations will be outlined in future releases of this document.

5. Investigator Equipment Packages

This chapter is intended to provide investigators with complete information about structural and electrical guidelines that must be followed as part of the design and construction of research equipment for the GV. While the content of this chapter is intended to be as comprehensive as possible, investigators should also be aware that EOL personnel will assist investigators with meeting all of the requirements set forth herein for the GV. Contact information for appropriate EOL personnel is provided throughout this chapter in order to facilitate communications between users and EOL staff.

5.1 Structural Considerations

This section sets forth the guidelines to be followed for the design, fabrication, and approval of investigator research equipment to be flown onboard the NSF/NCAR GV. The design, modification, and installation of airborne research equipment is one of the more demanding and time consuming aspects of airborne research.

Newly designed, commercially-purchased, and other equipment not designed for aircraft use must be evaluated for structural integrity and, if necessary, be modified or strengthened to comply with the criteria outlined in this section. Also, all equipment designed for aircraft use will be reviewed for conformity to design and installation specifications. In addition to structural considerations, any wiring in user-supplied equipment must adhere to guidelines established and outlined herein.

All equipment must also be designed or modified to attach to the various mounting points and instrument racks on the NSF/NCAR GV. Properly securing all equipment and ensuring that the equipment loads can be reacted to by the aircraft is a mandated requirement to ensure the safety of each crew member and the safe operation of the aircraft. While this requirement is self evident, when combined with the design goal of minimizing weight, it can pose a challenging design problem. A detailed description of the aircraft mounting points and equipment rack capabilities is provided in Chapter 2 of this handbook.

Equipment designs that fail to comply with the guidelines of this handbook or hardware that fails to conform to the design documentation will not be installed on the aircraft until the deficiencies are corrected. In the event that the deficiencies cannot be corrected, the equipment will not be permitted on board the aircraft for flight research. RAF Aeronautical Engineering personnel will assist the user in understanding and complying with the requirements of this section.

5.1.1 Design Criteria

Design criteria refers to the general design philosophy that specifies appropriate margins of safety, special analytical factors of safety, and design loads. All equipment and attachment hardware on the NSF/NCAR GV must be substantiated for structural strength by analysis at a minimum. In general, classic hand-stress analysis techniques and calculations are acceptable. However, for systems possessing a high degree of redundancy (multiple load paths), a finite element analysis may be necessary. In the event a finite element analysis is utilized, the internal loads should be extracted from the finite element analysis and hand techniques used to determine the final margins of safety.

5.1.1.1 Margins and Factors

In aeronautical design it is customary to compute the margin of safety for particular structural components and attachments. The margin of safety is defined as the ratio of the strength of the member to the applied load multiplied by any factors minus 1, or:

MS = (Allowable/(Actual x Factor1 x Factor2 x ___)) – 1

In lieu of structural tests, a minimum margin of safety of +0.20 in the analysis must be maintained for flight and landing conditions. Emergency landing load conditions are excluded from this "no-test" margin of safety requirement and need show only a positive margin of safety (+0.00). Equipment and attachments substantiated by test also require a minimum analytical margin of safety of +0.00.

In addition to the margin of safety requirement, additional factors are applicable for analysis of research equipment and installations. These additional factors are given in the table below, and it should be noted that multiple factors might apply.

Type	Application	Symbol	Value
Factor of Safety	Applied to limit loads	F.S.	1.50
Aerodynamic Load Factor	Applied to aerodynamic loads not verified by wind tunnel testing when evaluating primary structure.[1]	C_{aero}	1.25
Equipment Mass Factor	Applied to black box mass to account for structural, wire bundle, and any other miscellaneous mass.[2]	C_{mass}	1.25
Fitting Factor, General	Applied to Margin of Safety equation for structural joint evaluations not verified by test and applicable to all conditions.	F.F.	1.15
Fitting Factor, Quick Change Items	Applied to Margin of Safety equation for the attachment of frequently installed/ removed fixed equipment.	F.F.	1.33

Note 1: *The aerodynamic load factor is not used for load conditions where air loads are relieving. When aerodynamic loads are relieving, either ignore the air loads entirely (most conservative) or use a factor of 1.0 if air loads are known to exist for the given flight condition.*

Note 2: *This factor accounts for inaccuracies between the actual and assumed center of gravity location, which is assumed to be at the approximate geometric center of the equipment.*

Table 5.1. Analytical Factors

Additional bearing and/or casting factors may also be applicable depending on the design. Investigators should contact RAF Aeronautical Engineering (lord@ucar.edu) for additional factor values if required.

5.1.1.2 Loads

Equipment installed on aircraft is subject to a variety of loading conditions. These loads can be the result of emergency landing, inertia loading (maneuvering, gust, normal landing), handling loads, pressurization, and aerodynamic lift and drag. All equipment must be analyzed for the required and expected loading conditions and must show a positive margin of safety as described previously.

Emergency landing loads are defined as loading that occurs during other than a normal landing, such as a wheels-up landing or veering off the runway. All equipment (including racks, instruments, pallets, tie-downs, etc.) and supporting structure that attaches to the aircraft in an occupied area (cockpit, cabin) that could cause injury to an occupant if it broke loose must be restrained for the emergency landing conditions listed in the following table:

Direction	Emergency Landing Load Factor (Ultimate)
Up (Normal to Airplane Longitudinal Axis)	3.0g
Forward (Parallel to Airplane Longitudinal Axis)	9.0g
Sideward (Normal to Airplane Symmetry Plane)	±3.0g (Airframe) ±4.0g (Seats & Seat Attachments)
Downward (Normal to Airplane Longitudinal Axis)	6.0g
Rearward (Parallel to Airplane Longitudinal Axis)	1.5g

Table 5.2. 14 CFR Part 25, Emergency Landing Load Factors

The emergency landing condition loads act separately and are ultimate loads. These loads act independent of the flight loads and pressurization loads.

Inertia load factors can result from gust conditions, dynamic maneuvers, and landing conditions. These loads are often more severe than the emergency landing load conditions. All equipment and support structure must be restrained when subjected to flight inertia loads. The following ultimate vertical inertia load factors conservatively apply to the NSF/NCAR GV aircraft at the indicated locations:

Location	Inertia Load Factor (Ultimate, Vertical)
Nose Compartment, Cockpit, Forward and Mid Cabin (GVFS20.25 to GVFS600)	+6.0g, -3.0g
Aft Cabin and Baggage Area (GVFS600 to GVFS758)	+7.0g, -4.0g
Tail Compartment (GVFS758 to GVFS1026), Vertical Tail Deck (WL261), and Wing Store Locations	+9.0g, -6.0g
BL 264 Store Location	+9.75g, -6.75g
BL 123 Store Location	+6.0g, -3.0g
BL 192 Store Location	+6.38g, -3.38g

Table 5.3. GV Inertia Load Factors

Positive g loading will produce a load directed downward, while negative g loading will produce a load directed upward. Additionally, an ultimate lateral inertia load factor of ± 3.0g combined with a 1.5g down load is conservatively applicable to all areas of the aircraft. These load factors may be coupled with pressurization and/or aerodynamic loads depending on the particular installation.

Additional equipment installation criteria apply to lightweight equipment and equipment positioned such that it could intentionally or unintentionally be stepped on or used as a pulling or pushing surface. For lightweight equipment, unless other criteria are more severe, the immediate equipment support structure (bracket, gusset, rail, etc.) should be designed as if a 50 pound ultimate load was acting in any direction at the equipment center of gravity. For equipment that could be stepped on, the installation should be capable of supporting a 375 pound ultimate vertical load. For equipment that could be subjected to pulling or pushing forces, the installation should be capable of supporting a 100 pound ultimate load in any direction.

For certain installations the effects of cabin pressure or equipment pressurization will require investigation. The NSF/NCAR GV aircraft design pressures are:

Design Condition	Pressure, psi
Maximum Relief Valve Pressure, $p_{max\ prv}$	10.48
Ultimate Cabin Pressure, p_{burst}	26.25
Ultimate Cabin + Flight, Internal	15.72
Ultimate Cabin + Flight, External, Conformal (includes Delta Aerodynamic Pressure of 0.5 psi Limit)	16.47

Table 5.4. GV Design Pressures

Additional proof and burst factors for the following systems apply:

- Hydraulic Fluid System

  p_{max} = maximum pump differential pressure plus maximum accumulator pressure

  Pump, Heat exchanger, Accumulator, Tubes, and Fittings:

  $p_{proof} = 1.5 \times p_{max}$ (Limit, Independent of flight loads)

  $p_{burst} = 3.0 \times p_{max}$ (Ultimate, Independent of flight loads)

  Flexible Lines:

  $p_{proof} = 2.0 \times p_{max}$ (Limit, Independent of flight loads)

  $p_{burst} = 4.0 \times p_{max}$ (Ultimate, Independent of flight loads)

- Pressurization System

  p_{max} = maximum pressure differential assuming downstream flow (internal) obstruction, or assuming no downstream resistance to flow

  $p_{proof} = 1.5 \times p_{max}$ (Limit, Independent of flight loads)

  $p_{burst} = 2.0 \times p_{max}$ (Ultimate, Independent of flight loads)

- Pneumatic System

  pmax = maximum pressure differential assuming downstream flow (internal) obstruction, or assuming no downstream resistance to flow

  $p_{proof} = 1.5 \times p_{max}$ (Limit, Independent of flight loads)

  $p_{burst} = 3.0 \times p_{max}$ (Ultimate, Independent of flight loads)

Aerodynamic loads result from lift and drag forces during flight on equipment or components mounted externally on the aircraft. These forces are a function of the aircraft position and speed and of the externally mounted equipment location, shape and size. The following flight conditions should be used for the determination of maximum aerodynamic loading on externally mounted equipment:

Mach	Altitude, k ft	q, psf	Alpha, deg	Beta, deg
.61	0	552	4	0
.61	0	552	2	5
.97	34	344	6	0
.97	34	344	2	5

Table 5.5. Flight Conditions for Aerodynamic Loads Analysis

5.1.2 Construction Guidelines

5.1.2.1 Materials

Aluminum is the preferred material for the fabrication of parts because of its good strength to weight ratio, formability and machinability, availability and cost. Of the numerous alloys available, it is generally best to select 2024, 6061, or 7075 aluminum alloys based upon previous aircraft industry usage and good availability. The following guidelines for aluminum alloy and temper selection should be considered:

- For sheet metal applications (material thickness < 0.125 inches) 2024-T3 clad sheet and 7075-T6 clad sheet are preferred. The advantage of the 2024-T3 clad sheet over the stronger 7075-T6 sheet is that 2024 can be formed in the T3 temper while 7075 material should be formed in the O temper and heat treated after all forming processes.
- For plate material required for machined parts, 2124-T851 or 7075-T7351 should be used for there increased fatigue and fracture properties.
- Extruded material should be 7075-T73 or –T76.
- For lightly loaded structures or if welding is absolutely necessary, 6061 aluminum alloy should be used. Welded materials should be utilized in statically loaded structures only. If loading is repetitive or cyclic, strict quality control during fabrication and the development of on-going inspection requirements (x-ray, dye-penetrant) is necessary to ensure voids, inclusions, and incomplete fusion typical of welded structures to not adversely affect the strength and service life of the component. 6061 must be heat treated after welding in order to develop full strength capability. Material left in the as welded condition will be in the annealed state (O temper) with little strength in the heat-affected zone near the weld.

For machined fittings where aluminum provides insufficient strength or for welded structures, it is preferable to use low alloy steels or corrosion resisting (stainless steel, A286) materials. The 4130, 4140, and 4340 low alloy steels are commonly used and available in a variety of product forms. These steels do require corrosion prevention treatment and thus are not normally used in exterior applications on aircraft. 17-4PH, 15-5PH, and 17-7PH precipitation hardened stainless steels and A286 are commonly used corrosion resistant materials. These materials are strengthened by heat treatment and should not be used in the annealed condition. The 300 series stainless steels are austenitic stainless steels. They can be cold worked to provide additional strength and are readily formed without requiring additional finishing and heat treatment.

All material property data used in strength calculation should be from DOT/FAA/AR-MMPDS-01, Metallic Materials Properties Development and Standardization (formerly Mil-Hdbk-5H), or other acceptable data.

In addition to material selection, material compatibility needs to be reviewed for parts in contact with one another. FAA regulations require the protection of structure from corrosion and other detrimental effects. The following table provides an indication of the galvanic corrosion potential between dissimilar materials.

Potential Tendency for Galvanic Corrosion

The higher the number, the greater the potential. 0-3: Minimal 4-5: Marginal 6-12: High - Avoid if possible, or use sealants and paint barriers to prevent dissimilar material contact.	Mg Alloys	Zn, Galvanized Steel	Pure Al, 5000 & 6000 series Al	Cd, and Cd plating	2000 & 7000 series Al	Low Alloy Steels	Cu, Brass, Bronze	Monel, Ni, Inconel, PH SS	Ti, 300 SS, Graphite
Mg Alloys	0	1	2	4	5	6	10	11	12
Zn, Galvanized Steel		0	1	3	4	5	9	10	11
Pure Al, 5000 & 6000 series Al			0	2	3	4	8	9	10
Cd, and Cd plating				0	1	2	5	6	7
2000 & 7000 series Al					0	1	5	6	7
Low Alloy Steels						0	4	5	6
Cu, Brass, Bronze							0	1	2
Monel, Ni, Inconel, PH SS								0	1
Ti, 300 SS, Graphite									0

Table 5.6. Galvanic Corrosion Potential

5.1.2.2 Fasteners

All fasteners should be aircraft quality hardware (to AN, MS, or NAS standards and specifications). The following list provides information on more commonly used aircraft fasteners:

Designation	Fastener Description
Conventional Rivets	
MS20470AD	Protruding Head Solid Rivet
MS20426AD	Flush, Full Size Head
NAS1097	Flush, Reduced Head
HI-Loks	
HL18	Protruding Shear Head Pin
HL19	Flush Shear Head Pin
HL70	Shear Collar
HL20	Protruding Tension Head Pin
HL21	Flush Tension Head Pin
HL86	Tension Collar
Bolts/Screws	
AN3-AN20	Hex Head Bolt (125 ksi)
NAS6203-NAS6220	Hex Head Bolt (160 ksi)
MS24694	Flush Head, Phillips Drive (125 ksi)
NAS517	Flush Head, Phillips Drive (160 ksi)
AN525	Washer Head, Phillips Drive Screw
MS27039	Pan Head, Phillips Drive (125 ksi)
NAS623	Pan Head, Phillips Drive (160 ksi)
Washers	
NAS1149	Plain Washer
AN970	Large Area Flat Washer
Nuts	
MS21042	Hex Nut, Low Height, Self Lock (160 ksi tension)
MS21044	Hex Head, Full Height, Nylon Lock (125 ksi tension)
NAS1804	12 point, Full height (180 ksi tension)
MS21059	Floating Nutplate, Std Spacing
MS21075	Floating Nutplate, Mini Spacing
MS21061	Floating Nutplate, Std Spacing, One Lug
NAS1473	Self Sealing Nutplate, Std Spacing
NAS1474	Self Sealing Nutplate, Mini Spacing
Inserts	
MS21209	Locking Helical Coil Wire
MS51830	Screw Thread, Key Locked, Regular Duty (Keensert)
MS51831	Screw Thread, Key Locked, Heavy Duty (Keensert)
MS51832	Screw Thread, Key Locked, Extra Heavy Duty (Keensert)
Blind Fasteners	
NAS1669	Hex Head Blind Bolt (Jo-Bolt)
NAS1670	Flush Head Blind Bolt (Jo-Bolt)
M7885/2	Protruding Head Blind Rivet (Cherry-Max CR3213))
M7885/3	Flush Head Blind Rivet (Cherry Max CR3212)
M7885/13	Flush Shear Head Blind Rivet

Table 5.7. Aircraft-Quality Fasteners

5.1.2.3 *Welding*

While bolting and/or riveting are the preferred methods of assembly, welding may be required in some special situations. The following guidelines should be observed for welded structures:

- Materials should be suitable for welding (see material section above);
- Welded structures must be heat treated in order to develop full strength;
- Welding should only be done by currently certified personnel.

5.1.2.4 *Lines and Fittings*

Lines and fittings for hydraulic and pneumatic systems should be aircraft quality and appropriately rated for the expected operating service loads and the required test loads given in Section 5.1.1 (B) above.

5.1.3 Installation

5.1.3.1 *Cabin*

The majority of equipment in the cabin will be mounted in standard racks designed by NCAR that attach to the floor and ceiling tracks in the GV aircraft. The racks are designed to accept standard nineteen inch wide rack mountable equipment. Mounting rails conforming to the universal spacing of EIA Standard RS-310 are provided on each side of the rack both forward and aft facing. The racks are 50 inches high, 21.5 inches wide and 28 inches deep. There are 24U (42 inch) mounting rails on the forward and aft faces for standard 19 inch rack mountable equipment. The mounting rails are symmetrically centered vertically on the rack. The mounting faces of the rails are flush with the forward and aft faces of the rack. A 3/8 inch panel is attached to the top and bottom and can also be used for equipment mounting. These honeycomb panels require inserts to enable equipment mounting. There is 3.6 inches of clearance between the ends of the mounting rails and the inner surfaces of the panels. Figure 5.1 on the following page shows a standard cabin equipment rack.

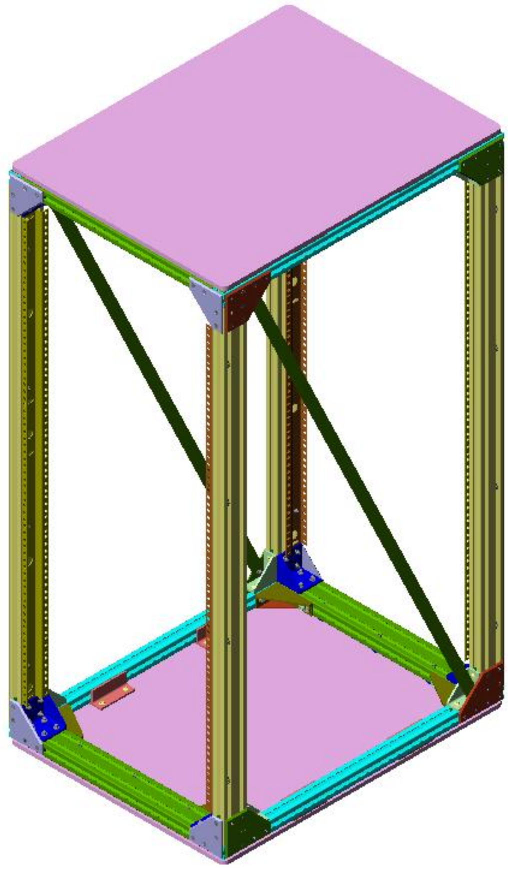

Figure 5.1. Standard Equipment Rack

The maximum allowable equipment weight is 350 pounds. The maximum allowable equipment overturning moment (measured from the bottom of the lower panel, i.e. the base of the rack) is 7,000 inch-pounds. Researchers should prepare a scaled layout of their rack configuration and determine:

- Individual component weight;
- Individual component panel height;
- Individual component center of gravity (cg) distance from panel;
- Total equipment weight (Σ component weights); and
- Total moment (Σ component weight x cg height from base)

Face mounted equipment weight and moment (weight x center of gravity distance from the mounting panel) must fall below the maximum allowable curves given in the following graphs:

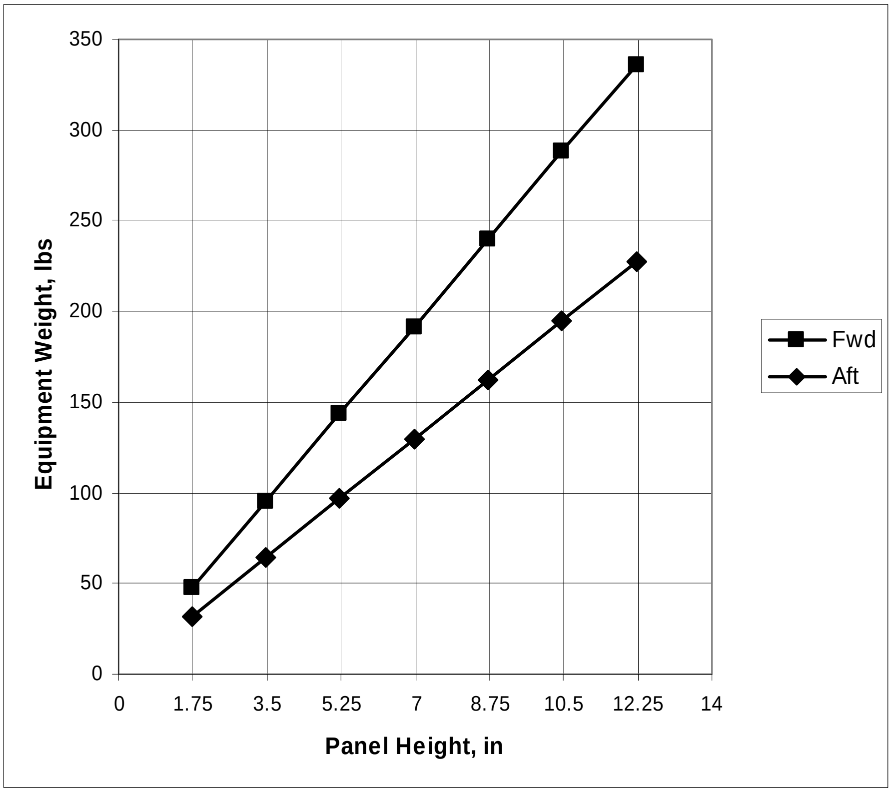

Figure 5.2. Allowable equipment weight for mounting to face chart.

For example, according to Figure 5.2, equipment weighing 75 pounds would require a 2U (3.75 inch) panel for forward face mounting or a 3U (5.25 inch) panel for aft face mounting.

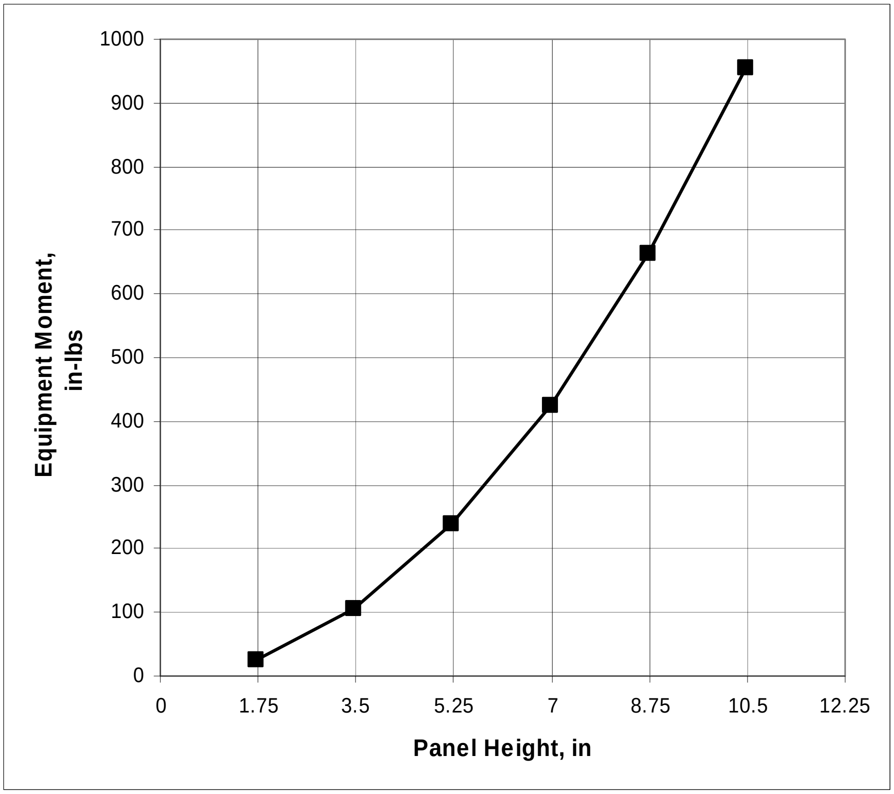

Figure 5.3. Allowable face-mounted equipment moment chart.

Per Figure 5.3, equipment weighing 50 pounds and 8 inches deep (center of gravity = 8 / 2 = 4 inches from the mounting panel) would produce a moment at the face of 200 inch-pounds (Moment = 50 x 4 = 200 inch-pounds) and would require a 3U (5.25 inch) mounting panel height minimum.

For equipment that falls above these allowable curves, additional internal support and bracing (longitudinal mounting rails or trays) will be required. Two types of trays for supporting non-rack mountable and/or heavy equipment are available. Aeronautical Engineering can assist the researcher in determining the proper support requirements.

Modifications to standard equipment racks are not permitted under any circumstances. Stress analysis of the rack structure, track attachments, and floor structure is not required, except for nonstandard installations.

User supplied racks and other nonstandard installations (optical benches, etc.), will require stress analysis of the support structure, equipment attachment locations, and floor/ceiling attachments. Maximum equipment weight for the cabin floor cannot exceed any of the following parameters:

- 49 pounds per square foot uniformly distributed,
- 98 pounds per square foot with a 20 inch central clear aisle, or

- 200 pounds per square foot (187 pounds per square foot on the center aisle) applied to one isolated square foot at least 30 inches from another load.

5.1.4.2. Non-Personnel Occupied Compartments

There is limited room in the nose area, baggage compartment, and tail deck for equipment installations.

Equipment in the nose area and the tail deck will be secured to shelves that are attached to structure in this region. Contact RAF Aeronautical Engineering (lord@ucar.edu) for interface and capability information.

A floor to ceiling open rack standard type per EIA Standard RS-310 will be available. The allowable equipment weight for the rack in the baggage area is 150 pounds with a maximum moment at the floor of 4,200 inch-pounds.

5.1.4.3 Wing Stores

Pod development and certification for flight presents a significant engineering effort. A large instrument pod is currently under development. This pod is currently 20 inches in diameter, 13 feet 4 inches in length with a 48 inch center cylindrical section. The maximum allowable weight for the pod, equipment, pylon and mounting rail is 1500 pounds. The current empty weight estimate for the pod is 200 pounds. Equipment carrying capability should be approximately 1000 pounds. Carriage of this pod will be limited to the center wing hard-point location (BL193).

The design of dual canister stores (support of two PMS style canisters) for each of the wing hard-point locations is also complete. Maximum allowable weight for this configuration is limited to 100 pounds per hard-point. This allows for approximately 25 pounds of equipment per canister.

5.1.4.4 Fuselage Exterior

The numerous fuselage pads, hardpoints, and apertures were described in Chapter 2 of this handbook. The following table presents the structural capabilities for the various locations:

Location	Static Load, pounds	Frontal Area, sq. in., Or Envelope, L in. x W in. x H in.	CG from A/C Skin, inches
Forward Fuselage Pad	2	18	9
Center Fuselage Mounts	25	24	20
Apertures			
External Equipment	50	54	12
Internal Eqt, Upper	25	16 x 16 x 8	8
Internal Eqt, Lower	25	13.5 x 10.5 x 9.5 inbd, 7.5 outbd	16
GVFS290.5 Optical Ports	90	NA	
GVFS339.5 Optical Port			
Optical Insert	90	NA	
External Equipment	36	65	10

Table 5.8 External Mounting Provision Capabilities

5.1.4 Certification

The research scientist is responsible for ensuring that their equipment package meets the design criteria of this handbook. Failure to follow these guidelines may require rework of research equipment packages that may affect project cost and schedule. Equipment that cannot be approved for flight research will not be permitted onboard the aircraft.

The RAF will be responsible for the final approval and/or certification of all aircraft modifications and equipment installations. It is expected that the majority of research equipment will be considered miscellaneous, non-required electrical equipment per FAA Advisory Circular AC25-10. This finding will simplify the approval process for installations while maintaining an appropriate level of safety.

In order to accomplish the approval/certification process, the RAF will require the following data package from the research scientist for each equipment installation:

- Descriptive Data: Component, assembly, and installation drawings are preferred. However, with cost and schedule constraints, marked up photographs, sketches, written descriptions, marked-up excerpts from manufacturers' parts catalogs, or similar document excerpts are acceptable. The data must be sufficient to completely describe the individual equipment components and complete assembly/installation. The data will generally include dimensional geometry, weight and balance information, materials, fasteners used and attachment location, vendor data for off the shelf items, ratings and power requirements, etc. Scaled and dimensioned layouts of equipment mounted in standard racks, with weight and moment information will be required. Any special processes or specifications used in the fabrication of the research equipment package should also be described;

- Substantiating Data: The substantiating data package will be comprised of analyses and test plans and reports if necessary. The basic load conditions for the GV and allowable material strength data have been previously discussed in this handbook. Thus, a structural analysis and electrical loads analysis is generally all that is required. The researcher should ensure that the analytical methods and assumptions are appropriate, that all applicable loading conditions are checked, and that sufficient margins of safety exist for all structural elements and electrical components. RAF Aeronautical Engineering can usually assist the researcher with the structural analysis report depending on workload. RAF Electrical and Instrumentation Group can assist with the electrical loads analysis, again depending on workload. Early coordination and planning will be required in order to determine the appropriate level of effort for both the research and the RAF staff so project schedules are not adversely affected.

For typical equipment packages, all data should be submitted to the RAF prior to the start of fabrication in order to reduce the risk of rework being required. Additionally, all required data must be provided to the RAF at least eight (8) weeks prior to the start of equipment installation on the aircraft. A longer lead time may be required for complex or unusual installations.

Additional review will be required for the following hazardous equipment/materials:

- Lasers
- RF Emitters
- Cryogens (oxygen, hydrogen, methane, ethane, and ethylene prohibited)
- Compressed Gases
- Toxic Gases (may require containment)
- Batteries
- Pressure Vessels/Systems
- Motors/Pumps (except for small fan units in commercial electronic equipment – 400 Hz motors rated explosion proof or totally enclosed non-ventilated are preferred; DC brush-type motors are generally not acceptable)
- Heaters (surfaces >130^{o}F require shielding and labeling)
- Power Distribution Equipment
- Radioactive Materials

- Flammable/Noxious Materials (PVC jacketed wire [except in commercial units] and cable or plumbing is not acceptable - Teflon based materials should be used; consult RAF Safety Committee concerning material acceptability)

Researchers should prepare and submit safety documentation to the RAF Safety Committee and coordinate with RAF Project Management to ensure that appropriate approvals are obtained prior to the start of operations.

5.2 Electrical Considerations

The following sections provide guidance to investigators for the electrical design of equipment intended for flight on board the NSF/NCAR GV. Electrical components within a research system can be the source of potentially hazardous situations in flight, the latter of which can include interference with basic aircraft systems, fire, shock, etc. Correspondingly, care must be taken during the equipment selection and wiring processes in order to minimize these risks.

5.2.1 Wiring Practices

5.2.1.1 Materials Selection and Testing

Because the GV will be maintained and operated as a certified civil aircraft, all wiring insulation used in investigator equipment packages must comply with Federal Aviation Regulations (FAR) Part 25.869(a) (4), Fire Protection: Systems. This regulation requires insulation on electrical wire and electrical cable to be self-extinguishing when tested in accordance with Part I of Appendix F of FAR Part 25. Investigators can view the FARs (which are contained in Title 14 – Aeronautics and Space – of the Code of Federal Regulations [CFR]) on-line at http://ecfr.gpoaccess.gov. RAF personnel will assist investigators in complying with regulatory requirements. However, it should be noted that the investigator is ultimately responsible for providing the proper documentation as to the type of wire that has been used in the equipment package and verification that the wire meets the requirements outlined above.

The RAF will stock some wire and cable in-house that has passed the requisite flammability testing. Small quantities of approved wiring from RAF stock can be provided to investigators under special circumstances. However, investigators should not assume that the RAF will provide the wiring needed for all user equipment needs. Below, guidelines for compliance with applicable FAA requirements are given, and it is the responsibility of investigators and instrument builders to follow these guidelines in order to ensure that approved wiring is used in equipment to be deployed on the GV. Investigators are also strongly encouraged to contact Kurt Zrubek (kurt@ucar.edu) of the RAF Engineering and Instrumentation group early in the instrumentation design/project payload configuration process for assistance in interpreting and complying with these requirements.

The following wire types meet FAA requirements and can be used on the GV:

- Wiring specifically listed in FAA Advisory Circular 43.13-1B, Table 11-11 (Open Wiring) and Table 11-12 (Protected Wiring). A copy of FAA Advisory Circular 43.13-1B can be downloaded at http://www.faa.gov/certification/aircraft/av-info/dst/43-13/default.htm.
- Wiring for which an existing FAA Form 8110-3 can be supplied. This form – when signed by a qualified person (i.e., a FAA Designated Engineering Representative, or DER) – is used to document that the wire/cabling in question meets the requirements of FAR Part 25.869(a) (4).

The following wire types are exempt from the testing requirements outlined above and can be used on the GV:

- Wiring installed within commercial off the shelf (COTS) equipment chassis, computers, monitors, etc. Commercial power strips are the exception and are not acceptable, unless they have been modified to incorporate an aircraft approved circuit breaker and aircraft approved wire.
- Wiring provided by a manufacturer to interconnect two or more COTS units (i.e. keyboard and mouse wires, monitor cables, etc.).

Instrument builders must demonstrate that all user-fabricated interconnecting wire (e.g., from component to component, component to aircraft interface, etc.) complies with the requisite FAA requirements. Wire and cable types referred to here include any special types of wire, such as high-speed data wire, fiber optic cable, coax cable, etc. NCAR recommends that Teflon jacketed wire be used by investigators to construct special purpose wire and cable as such wire is known to meet flammability testing requirements. Polyvinyl chloride (PVC) wiring is not permitted for these applications without specific approval due to hazards associated with smoke and noxious fumes generated when such wiring burns.

In the case of existing research equipment (defined here as equipment that has been flown on a research aircraft prior to January 1, 2005), the FAA Denver Aircraft Certification Office (ACO) has agreed that demonstration of compliance with electrical wire insulation flammability requirements (via burn testing and/or the submission of Forms 8110-3) will not be required provided that the following conditions are met:

- Wiring and associated electrical components are enclosed in a metal box suitable for containing a fire;
- The box is positioned such that it is clearly visible in the aircraft cabin; and
- Power to the box can be easily disconnected via a main power switch or an aircraft grade circuit breaker.

Investigators should note, however, that FAA compliance will be required for any modifications made to pre-existing (previously flown) research equipment. Additionally, it must be emphasized that compliance will continue to be required for all user-fabricated interconnecting wiring (including the wire, tubing, chafe protection materials, etc.) that is external to a metal enclosure and that is located inside the GV cabin.

Wire compliance must be demonstrated by the provision of data that clearly defines the wire by manufacturer and part number. Additionally, a Form 8110-3 from a FAA authorized burn test facility must also be provided for the wire or cable. It should be noted that manufacturer data sheets stating that the wire is in compliance with FAA flammability requirements are not sufficient and will not be accepted by NCAR and the FAA.

In selecting wire to use in the development of equipment for the GV, investigators should note that some wire manufacturers burn test their wire and can provide the necessary Form 8110-3. PIC Wire & Cable (www.picwire.com) and Electronic Cable Specialists (www.ecsdirect.com) are two companies that perform such testing and can provide the requisite forms. PIC Wire & Cable uses a company called Skandia, Inc. (815-393-4600) to perform their wire flammability testing, and Skandia will supply the Form 8110-3 for PIC wire they have previously tested for a small fee.

In the case where investigators elect to use wire that has not received prior FAA approval, a sample of the wire will need to submitted for flammability testing. This process involves a sample (approximately 10 feet in length) of the wire and identifying documentation from the manufacturer being submitted to a designated burn test facility. A packing list for the wire that includes information regarding the type of wire purchased, the manufacturer, and the manufacturer's part number will suffice for identifying documentation. When submitting the wire and identifying documentation, the following information must also be provided with the request for testing:

- Make of the aircraft: Gulfstream
- Model: GV
- Serial Number: 677
- Aircraft Registration Number: N677F

NCAR has used a company, Flame Out (402-795-2122), to perform wire testing and to generate the required Form 8110-3 for wire and cable used in NCAR installations on the GV. Skandia, Inc. (815-393-4600) is another recommended facility. When selecting a burn test facility, investigators must make sure that the facility in question has an in-house flammability DER to witness the testing and to provide the FAA Form 8110-3. Once burn testing has been completed – and if the wire passes – the test facility will issue the Form 8110-3. This 8110-3 will reference the tested wire by manufacturer and part number and will also reference the GV by make, model, and serial number.

Copies of all requisite 8110-3 forms for wire used in research equipment must be provided to the RAF by investigators.

5.2.1.2 Arc Protection

Reduced atmospheric pressure increases the possibility that arcing may occur between high voltage components and ground. (In fact, arcing is four times more likely to occur at 40,000 ft. than at sea level.) Consequently, investigators are required to take the following specific steps to prevent such arcing:

- High voltage leads must be sufficiently insulated;
- In the case of equipment mounted in unpressurized canisters open to the outside atmosphere, appropriate electrical system design procedures (including sufficient lead separation, the insulation of high voltage components, and the avoidance of sharp bends and solder "peaks") must be employed; and
- All contacts on terminals carrying voltage must have guards to prevent accidental human contact.

5.2.1.3 Grounding

All primary power ground connections in research equipment must be made to the third wire of a 115 VAC volt plug or to the fifth wire of a 400 Hz three-phase plug. The low or return conductors then return to the GV MPDB. All power-neutral leads must be returned to the power system. Such leads cannot be tied to the airframe.

5.2.1.4 Clamping

All cabling inside equipment racks must be clamped to inhibit movement. Existing holes and/or openings on racks can be used for such clamping.

5.2.2 Electrical Equipment Guidelines

5.2.2.1 Batteries

It is permissible for research equipment to make use of small numbers of AA, AAA or D-type alkaline or nickel-cadmium (Ni-Cd) batteries without special approval from the RAF. All other usage of batteries on the aircraft requires advance approval by RAF flight safety personnel. The RAF strongly recommends that investigators select batteries with benign chemistries that are hermetically sealed. The following battery types are recommended:

- Alkaline
- Silver-zinc (Ag-Zn)
- Nickel-cadmium (Ni-Cd)
- Sealed lead acid

When designing equipment that requires batteries, investigators should take into account the following considerations when making a battery selection:

- Battery assembly (see discussion above);
- Battery shipment into the field, including packaging requirements, safety issues, applicable shipping restrictions, battery shelf life limitations, and final disposal (hazardous material) requirements.

Specific RAF approval of battery use is required for batteries that make use of hazardous materials and/or in cases where the number of batteries to be used exceeds six (6). Additionally, investigators should be aware that approval of battery usage is dependent upon the total aircraft configuration and the assessed risk for all potential hazardous items on board the GV. Approval will be given for a specific GV project configuration or flight. Investigators are required to submit complete vendor specifications data sheets to the RAF Safety Committee for review prior to installation of the batteries and associated instrumentation on the aircraft.

5.2.2.2 Uninterruptible Power Supplies (UPS)

Please note that UPS's are currently not acceptable for use on the GV.

5.2.2.3 Electric Motors

Early consultation with RAF personnel during the electric motor selection process is essential and will help to avoid problems at the time of equipment installation. Each electric motor to be used on board the GV must be reviewed and approved by the RAF Safety Committee (genzling@ucar.edu). For all equipment that utilize high energy rotor devices (i.e., pumps), investigators will need to provide confirmation to the RAF that failure of the rotor(s) at high operating speeds will not adversely affect aircraft systems, structures, or occupants. Advisory Circular 25-22, Section 25.1461, *Equipment Containing High Energy Rotors*, details the procedures and requirements that must be met to ensure satisfactory operation of high energy rotor devices. Investigators can view and download this Advisory Circular online at http://www.gofir.com/fars/advisory_circulars/frame2.htm. Confirmation provided to the RAF can be in the form of a written manufacturer's statement, results of rotor device testing at an outside test facility, or results generated from investigator-conducted device testing witnessed by an NCAR engineer.

The usage of 400 Hz motors is preferred, as such motors do not introduce starting transient loads on the 60 Hz power converters employed on the aircraft. Larger motors (e.g. those used in vacuum pumps) must be protected by a thermal overload device. Additionally, single-phase motors must be equipped with solid state switches to inhibit arcing at the contacts during start up. In the absence of arc suppressors, motors must be shown to be spark free during operation.

Motors that are rated as explosion-proof or totally enclosed and non-ventilated are recommended for use on the GV. However, many fractional horsepower, AC permanent split-capacitor motors are acceptable for use on the aircraft depending on their application and location and if they are proven to be safe in the event of motor failure. Large DC brush-type motors are generally not acceptable due to electrical arcing that occurs at the brushes.

5.2.2.4 Heaters

All heaters to be used on the GV must be reviewed by the RAF to ensure that electrical safety requirements are met, that proper circuit protection devices are used, and that any high temperature, exposed surfaces that might serve as ignition points for flammable gases or that may cause injury to flight personnel are identified. Exposed surfaces with temperatures above 54º C (130° F) are generally considered safety hazards and must be surrounded by adequate shielding and be labeled with caution signs.

5.2.3 High Voltage Components

Following guidance of Advisory Circular AC 25-10 (i) Guidance for installation of Miscellaneous, Non-required Electrical Instrumentation, "Because of the possibility of airplane decompression, a means must be provided for either automatic removal of power from all components containing CRT's or the installation of a barometric switch for each component using a CRT, unless the high voltage circuits and components have been shown to be free of arcing under appropriate environmental tests specified in RTCA DO-160B dated July 1984, or equivalent tests receiving prior approval by the FAA."

High Voltage is considered to be any piece of equipment using high voltage, 1000 volts or higher and with a current draw of more than 1.0 amp, used inside and/or outside the cabin.

With the advent of flat panel technology, display CRT's have become obsolete, other instruments may use some form of a CRT and they would need to comply. Consequently any instrument using high voltage, a Lidar may be an example, will be required to automatically remove power from the high voltage source if decompression is a possibility. Other acceptable means are to prove that there is no arcing potential or enclose the high voltage section, wiring and associated electrical components in a metal box suitable for containing a fire. Some forms of potting/conformal coating may be acceptable if the materials are proven to pass the 25.853(a). Investigators can choose to remove the power from only the high voltage section of the instrument or the whole instrument. Typically, the barometric switch is used to control a relay to remove power. They are relatively small and fairly economical, more so that enclosing in a certified metal box. http://umainstruments.com/ (Flight Instruments, Pressure Warning Switches) this would be up to the instrument builder to determine which way to go.

5.3 Data Recording and Interface Capabilities

Information on the GV data acquisition and display system, available data interfaces and on board networks, and data and time broadcasts is provided in Chapter 2 of this handbook. Users are also referred to the *Aircraft Data Acquisition and Display System (ADADS) Reference Manual* for complete information on the aircraft's data recording and display capabilities.

5.4 Air Flow Modeling Data and Availability

As part of the effort to identify suitable locations for the various GV fuselage modifications and for the wing hard points, NCAR personnel worked with the GAC Aero/Icing Group to generate air flow and particle trajectory data for the aircraft fuselage and wings. Because these data are considered proprietary by GAC, they cannot be published in this handbook or distributed to investigators. However, GAC has agreed that NCAR can discuss the results with members of the scientific community and can answer specific questions that investigators may have regarding air flow characteristics and particle trajectories at selected locations, air speeds, and flight altitudes. Questions about available air flow and particle trajectory data products should be directed to Dave Rogers, RAF Scientist (dcrogers@ucar.edu), and Mark Lord, RAF Aeronautical Engineering (lord@ucar.edu).

Below is a summary of the air flow and particle trajectory data products that EOL has in its possession:

- Streamlines generated from the aircraft environmental outflow valve located on the forward right side of the aircraft;
- Particle concentration factors, concentration ratios, and accelerations on a vertical plane at the wing hard points for particle sizes of 20, 100, and 1000 microns;
- Particle concentration factors, concentration ratios, and accelerations on vertical (BL 3) and horizontal (WL 100, 145) planes through the fuselage for particle sizes of 20, 100 and 1000 microns;
- Boundary layer thickness along streamlines generated over the fuselage from the tip of the GV nose to the empennage. Except for deviations around protrusions (e.g., the wing-to-body fairing), the boundary layer thickness follows the basic rule of thumb of one inch of depth increase per each 100 inches of fuselage length (with fuselage length measured from the tip of the GV radome);
- Velocity magnitude contour plots, streamline plots, and velocity vector plots with the locations the same as those detailed in bullets 2 and 3, above; and
- Locations of supersonic regions at mach 0.77 and an aircraft angle of attack (AOA) of 2^{o}.

6. NCAR/EOL Standard Instrumentation Overview

The NSF/NCAR GV aircraft comes equipped with a package of standard instrumentation that flies on all HIAPER research missions. The measurements made by these sensors form the core of any research program and provide the information necessary to place the aircraft in space and time while characterizing the basic "state" of the local environment. Data from all of these systems are recorded on the HIAPER airborne data system (ADS) and can be displayed onboard, in real time, via the network of display stations.

6.1 State Parameter Sensors

The following table lists types and descriptions of instruments and standard measurements taken onboard the NSF/NCAR GV during flight.

State Parameters Sensors

Measurement		Instrument	Range	Resolution	Accuracy	Response Time
Position	Internal - Latitude and Longitude	Honeywell LASEREF III/IV Inertial Reference Unit (2 units)	global	0.00017 deg	0.164 deg (6 hrs)	0.1 s
	Operational Characteristics: There are several types of errors generally associated with Inertial Reference Unit (IRU) systems which affect the data after a successful alignment. The first one to consider, because it affects every flight, is the navigational position drift. Errors in both positions (LAT,LON) vary in an oscillatory fashion in flight. These oscillations will vary in magnitude from flight to flight, will typically be out of phase, and maintain a period of roughly 84 minutes. This phenomenon is known as the Schuller oscillation and is caused by the fact that the earth is not a true inertial system. Overall performance is judged through final position errors noted upon the completion of each flight. Position errors of less than 1.0 nmi/hr are within normal operating specifications. The Global Positioning System (GPS) is considered to be the most accurate position reference system and is used to correct the inertial reference system (IRS) data for use in the WIND calculations.					
	External – Latitude and Longitude	Garmin Model OEM WASS GPS-16	global	±0.1 m	15 m	1 s
	Operational Characteristics: These units are simple receivers that triangulate position (GLAT, GLON) based on signals from multiple satellites maintained by the United States Government. A minimum of three (3) satellites are needed to determine aircraft position. The number of satellites currently being monitored by the system is recorded in the GMODE variable. Satellite coverage continues to improve over time as the number of satellites in orbit increases and a loss of signal is extremely rare. If the combination of individual satellite signals being received varies due to long range transits or sharp aircraft attitude changes, discontinuities in the system's position track can occur. The unit's status function (GSTAT) will provide a diagnostic value that monitors all other problem sources (battery, etc).					
Ground Speed	Vector	Honeywell LASEREF III/IV Inertial Reference Unit (2 units)	0-400 m/s	0.002 m/s	4.115 m/s (6 hrs)	0.1 s
	Operational Characteristics: There are several types of errors generally associated with IRU systems which affect the data after a successful alignment. The first one to consider, because it affects every flight, is the navigational position drift. Errors in the ground speed components (VEW, VNS) vary in an oscillatory fashion in flight. These oscillations will vary in magnitude from flight to flight, will typically be out of phase, and maintain a period of roughly 84 minutes. This phenomenon is known as the Schuller oscillation and is caused by the fact that the earth is not a true inertial system. The Global Positioning System (GPS) is considered to be the most accurate ground speed reference and is used to correct the IRS data for use in the WIND calculations.					
	Vector	Garmin Model OEM WASS GPS-16	0-500 m/s	0.05 m/s	±0.1 m/s	1 s

Measurement		Instrument	Range	Resolution	Accuracy	Response Time
Attitude	Pitch	Honeywell LASEREF III/IV Inertial Reference Unit (2 units)	±45 deg	0.00017 deg	±0.05 deg (6 hrs)	0.02 s
	Roll		+90 deg	0.00017 deg	±0.05 deg (6 hrs)	0.02 s
	True Heading		360 deg	0.00017 deg	±0.2 deg (6 hrs)	0.04 s
	Vertical Velocity		±200 m/s	0.0095 m/s	±0.15 m/s (6 hrs)	0.02 s
	Operational Characteristics: The data defining the basic attitude of the aircraft is obtained directly from the IRU via an ARINC 429 interface. Values of pitch angle, roll angle, true heading and vertical velocity (PITCH, ROLL, THDG, VSPD) are required as inputs to the 3-D wind calculations. Small, systematic errors in some of these parameters can result from the physical positioning of the IRU within the air frame. The alignments of the IRUs are rechecked any time one of the units is removed from the aircraft. Any remaining errors can be identified through the results of the calibration maneuvers used to assess the overall accuracy of the wind measurement system.					
Altitude	Standard Atmosphere Pressure (MSL)		0-16,000 m	2 m	±200 m	0.05 s
	Operational Characteristics: This derived parameter represents an aircraft altitude above sea level based on the National Advisory Committee on Aeronautics (NACA) Standard Atmosphere. Typically a surface pressure of 1013 mb is used to define the sea level reference point. Normal fluctuations in surface pressure can therefore result in errors of +-200 m. Under certain high pressure conditions near sea level, PALT values can even be negative. In exotic tropical or arctic locations the local lapse can introduce significant errors as well.					
	Pressure Damped Inertial (MSL)	Honeywell LASEREF III/IV Inertial Reference Unit (2 units)	0-16,000	2 m	±150 m	0.2 s
	Operational Characteristics: This value is output directly from the IRU and is derived from a combination of the vertical acceleration of the aircraft and the static pressure. The same basic limitations apply to this measurement (ALT) as apply to PALT, above.					
	Global Satellite (MSL)	Garmin Model OEM WASS GPS-16	0-16,000 m	0.1 m	±10 m	1 s
	Operational Characteristics: This measurement is a direct output of the GPS position system. It takes a minimum of four (4) satellites to provide the data needed to resolve the GPS altitude (GALT). In the event that four satellites are not in range, or if the compliment of satellites being received changes for any reason, discontinuities in the value of GALT will result.					
Static Pressure	Ambient Pressure	Paroscientific Model 1000 Digiquartz Transducer	50-1,085 mb	0.00001 mb	±0.1 mb	0.02 s
	Operational Characteristics: Instrument is generally not susceptible to outside interference or thermal drift. The corrected value (PSXC) is a derived variable, however, and can be influenced by errors in dynamic pressure (QCX). Calibration: Units are calibrated PRE/POST project using an in house transfer standard.					

<table>
<tr><th colspan="2">Measurement</th><th>Instrument</th><th>Range</th><th>Resolution</th><th>Accuracy</th><th>Response Time</th></tr>
<tr><td rowspan="2"></td><td>Cabin Pressure</td><td>Rosemount Model 1201F Transducer*</td><td>250-1,035 mb</td><td>0.07 mb</td><td>±1.0 mb</td><td>0.05 s</td></tr>
<tr><td colspan="6">Operational Characteristics: Instrument is susceptible to some thermal drift. This should not be a factor in such a controlled environment. Since there are no aerodynamic effects on this measurement, the raw source output is the final value.
Calibration: Units are calibrated PRE/POST project using an in house transfer standard.</td></tr>
<tr><td rowspan="3">Air Speed</td><td>Radome Dynamic Pressure</td><td rowspan="2">Mensor Model 6100 Digital Pressure Transducer</td><td>0-200 mb (0-250 m/s)</td><td>0.00001 mb (0.01 m/s)</td><td>±0.02 mb (±0.5 m/s)</td><td>0.05 s</td></tr>
<tr><td>Heated Pitot Dynamic Pressure</td><td>0-200 mb (0-250 m/s)</td><td>0.00001 mb (0.01 m/s)</td><td>±0.02 mb (±0.5 m/s)</td><td>0.05 s</td></tr>
<tr><td colspan="6">Operational Characteristics: Most common problem is icing (radome). An unheated radome is also susceptible to blockage by ice particles from passage through fairly dense, cold clouds. Such blockages can generally not be cleared until the aircraft descends to an altitude where the ambient temperature is above freezing. Since this is a primary sensor for a number of derived variables, such occurrences could impact those calculations as well. Due to its importance as a reference parameter, redundant sensors are normally flown on each aircraft. The fuselage Pitot installation has good anti-ice capabilities but the radome unit will provide the most accurate values for the WIND calculations. Comparisons should be made with corrected values (QCRC, QCFC) only and differences should remain less than
+- 0.5 mb.
Calibration: Units are calibrated PRE/POST project using an in house transfer standard.</td></tr>
<tr><td rowspan="4">Ambient Air Temperature</td><td>Fast Response System</td><td>Rosemount Model 102AL TAT Sensor (2 units)*</td><td>-80 to +40 C</td><td>0.006 C</td><td>±0.5C</td><td>0.02 s</td></tr>
<tr><td colspan="6">Operational Characteristics: All ambient temperatures are derived parameters which are dependent upon the total temperature measured by the sensor and the reference dynamic pressure (QCX). This parameter must also be examined when troubleshooting atypical behavior. The most common problems are loss of flow due to icing of the sensor housing or evaporative cooling of the sensing element resulting from cloud/precipitation penetrations. These errors in in-cloud temperatures can be as large as 0.5 to 1.0oC and will always appear as negative biases.
Calibration: Units are calibrated PRE/POST project using an in-house variable resistance decade box in place of the sensing element. The platinum wire sensing elements are certified annually using an in-house transfer standard and temperature bath.</td></tr>
<tr><td>All Weather System</td><td>HARCO Model 100990-1 De-iced TAT Sensor (2 outputs)</td><td>-80 to ±40 C</td><td>0.006 C</td><td>±1.0 C</td><td>0.2 s</td></tr>
<tr><td colspan="6">Operational Characteristics: Basically the same instrument as "A" except for the addition of deicing heaters to the sensor housing. Instrument response is slightly slower than the unheated version.
Calibration: Units are calibrated PRE/POST project using an in-house variable resistance decade box in place of the sensing element. The platinum wire sensing elements are certified annually using an in-house transfer standard and temperature</td></tr>
</table>

Measurement		Instrument	Range	Resolution	Accuracy	Response Time
	bath.					
Humidity	Tropospheric Reference	Buck Research Model 1011C Hygrometer (2 units – direct & dew point)	-75 to ±50C	0.006 C	±0.5 C (td>0); ±1.0 C (Td<0)	0.2 s-10 s
	Operational Characteristics: This system provides a direct measurement of the ambient dew point temperature (DPLC, DPRC). Chilled mirror dew point sensors are relatively slow and primarily limited by their cooling and optical trigger components. Random drift or rapid oscillations in the signal can be indicators of a balance problem. The inlet housing is unheated and susceptible to flow restrictions caused by icing conditions. Large dew point depressions (ATX - DPRC) >20 cause extreme forcing of the Peltier cooling system in this unit and can result in instrument lag times as great as 30 seconds. This can be very important during rapid soundings or when flying in very dry air near the top of the troposphere. Data collected during cloud penetrations should result in dew point depressions on the order of 0 < (ATX - DPRC) < 1^{o}C. Negative in cloud depressions indicate either poor calibration or possible element wetting of the reference temperature sensor. When the sensor output falls below 0^{o}C, the system (DPL, DPR) is really producing a frost point temperature. The corrected data have been converted into an equivalent dew point temperature. Calibration: Units are calibrated PRE/POST project using an in-house variable resistance decade box in place of the sensing head. The optical sensing head is certified annually by the manufacturer.					
	Stratospheric Reference (Direct-Absolute Humidity)*	May-Corp Open Path TDL Absorption Hygrometer	0.001-10 g/m3	0.0002 g/m3	5 to 10%	1 s
	Operational Characteristics: Absolute humidity is measured by the method of optical absorption of 1.368 um emitted from a diode laser source. A multi-pass Herriott cell pattern is employed to provide a 4 m optical path length. The enhancement in sensitivity enables a 1 ppmv detection limit (.0002 g/m3 at 200 mb and 193K). The high spectral selectivity of the diode allows an extremely selective measurement, including discrimination against liquid water interference. In certain mechanical environments, correlated optical noise can be observed in the signal. Collection of each scan over the entire absorption peak minimizes the resultant degradation in instrument performance. Calibration: The instrument is calibrated before and after each project, with occasional in-field calibrations, as necessary. The output from a pressure-controlled LI-COR dew point generator is provided as input to a pressure-controlled dynamic dilution system. This flow system will supply a known water vapor stream to the instrument. The calibration gas is introduced into the inlet of a leak-tight flow cell, which is sealed between the surfaces of the optical housings. The instrument response is measured at several pressure, temperature and humidity combinations.					

Table 6.1. State Parameters Sensors

6.2 Three-Dimensional Winds System

The three-dimensional winds system consists of five (5) static ports on the aircraft radome. One is located at the radome stagnation point. The other four (4) ports are equally spaced around a circumferential section of the radome with two (2) aligned vertically and the other two (2) aligned horizontally. Measurements derived from these ports are described below:

Three-Dimensional Winds System

Measurement		Instrument	Range	Resolution	Accuracy	Response Time
Attack Angle	Radome Differential Pressure	Mensor Model 6100 Digital Pressure Transducer	0-150 mb	0.00001 mb	±0.015 mb	0.05 s
	Operational Characteristics: Most common problem is icing (radome). An unheated radome is also susceptible to blockage by ice particles from passage through fairly dense, cold clouds. Such blockages can generally not be cleared until the aircraft descends to an altitude where the ambient temperature is above freezing. The raw inputs for these measurements are ADIFR and BDIFR for attack and sideslip, respectively. There are no redundant sensors for either system. Calibration: Units are calibrated PRE/POST project using an in house transfer standard.					
Sideslip Angle	Radome Differential Pressure	Mensor Model 6100 Digital Pressure Transducer	0-150 mb	0.00001 mb	±0.015 mb	0.05 s
	Operational Characteristics: Most common problem is icing (radome). An unheated radome is also susceptible to blockage by ice particles from passage through fairly dense, cold clouds. Such blockages can generally not be cleared until the aircraft descends to an altitude where the ambient temperature is above freezing. The raw inputs for these measurements are ADIFR and BDIFR for attack and sideslip, respectively. There are no redundant sensors for either system. Calibration: Units are calibrated PRE/POST project using an in house transfer standard.					
Winds	Horizontal Components		0-100 m/s	0.012 m/s	±0.5 m/s	0.05 s
	Vertical Components		-20 to +20 m/s	0.012 m/s	±0.1 m/s	0.05 s
	Operational Characteristics: Ambient wind data from HIAPER are derived from measurements taken with the radome wind gust package. Direct measurements of attack, sideslip and true airspeed are combined with the aircraft attitude and ground speed data to derive the three-dimensional wind field along the aircraft's path. As is normally the case with all airborne wind gust systems, the ambient wind calculations can be adversely affected by either sharp changes in the aircraft's flight attitude or excessive drift in the onboard IRS. Turns, or more importantly, climbing turns are particularly disruptive to this type of measurement technique. Wind data reported for these conditions should be used with caution. Special sets of in-flight calibration maneuvers are conducted periodically during a field deployment to aid in the performance analysis of the wind gust measurements. The calibration data can identify any systematic biases in the pitch, sideslip, true heading, and true airspeed parameters. These offsets can then be removed from the final data set. Drift in the IRS accelerometers are removed using an algorithm that employs a complementary high-pass/low-pass filter that removes the long term drift by correcting the aircraft ground speed components with the accurate GPS reference data, while preserving the shorter term fluctuations measured by the IRS.					

Table 6.1. Three-Dimensional Winds System

7. General Information

7.1 Aircraft Requests

EOL manages and operates the majority of NSF's Lower Atmospheric Observing Facilities (LAOF) and makes them available on a competitive basis to qualified researchers from universities, NCAR, and other government agencies. Deployment decisions for each facility are driven by the scientific merit of the proposed use, the capabilities of a specific facility to carry out the proposed observations, and availability of the facility for the requested time period. The NSF/NCAR GV is part of the LAOF group. Correspondingly, proposed usages of the aircraft for research are eligible for NSF deployment pool funding support.

Procedures for requesting use of the GV and other NSF-supported facilities are outlined in the *NSF Lower Atmospheric Observing Facilities User Guide*. This document may be directly retrieved on-line at www.eol.ucar.edu/dir_off/OFAP/info/UserGuide.pdf, or from the EOL Field Project Services website at www.atd.ucar.edu/requests.html.

7.2 Project Support Services

Investigators interested in requesting usage of the NSF/NCAR GV for support of their research program can expect comprehensive, end-to-end field project support from EOL. Personnel within the Field Project Services (FPS) and Computer and Data Services (CDS) groups and the RAF are available to provide assistance at all stages of a project's lifecycle, from the early planning phase, through the deployment period, and extending out beyond the final data processing and distribution phase.

The sections below provide more detailed information about the specific types of programmatic support provided by EOL staff members.

7.2.1 Basic and Specialized Research Instrumentation

Several basic and specialized instrument packages can be made available to GV users upon request. Standard instruments available on the aircraft are described in Chapter 6 of this handbook. EOL personnel assume responsibility for installing and maintaining these instruments. In addition, EOL staff members will help investigators with the installation of user-supplied instrumentation on the GV. All user-furnished equipment will need to comply with specified EOL design and interface requirements. Requirements for the integration of investigator equipment packages are detailed in Chapter 5 of this handbook.

EOL personnel supervise the installation of user-supplied equipment on the GV in order to ensure compatibility with existing aircraft operations and instrumentation systems and to ensure that all safety of flight and engineering requirements are met.

EOL/RAF staff members provide in-flight oversight of equipment operation. However, this does not normally include the operation of user-supplied instrumentation. If investigators will require EOL personnel to provide in-flight sensor operation assistance, this requirement must be identified on the aircraft request form.

7.2.2 Data Recording and Processing

As discussed in Chapter 2 of this handbook, the GV is equipped with a data acquisition and display system for the recording of data products and the provision of graphical and tabular data outputs during research flights. While in the field, EOL personnel perform post-flight data processing and quality analysis using on-site computer equipment and data processing and display software packages. The processing of data in the field is not intended for the provision of final data sets but is, instead, intended to provide investigators with the chance to perform preliminary, "quick look" analyses of collected GV data.

Prior to the field deployment phase of a project, arrangements can be made for the transfer of "quick look" data products from the field to NCAR and/or investigator home institutions via the Ethernet or other technologies. Investigators wishing to have such data transfer capabilities in the field must indicate this on their submitted aircraft request document.

Requests for the support of specialized NCAR computing resources must also be detailed in the submitted aircraft request form.

7.2.3 Engineering Support

EOL can provide aeronautical, mechanical, and electrical engineering support services to investigators in order to ensure that user-supplied equipment meets all design and fabrication requirements set forth for the GV (see Chapter 5 of this handbook). Requests for such assistance must be clearly identified on the aircraft request form and should also be discussed with EOL personnel during the pre-project planning phase.

Specific questions about aeronautical, mechanical, and electrical engineering support services available within EOL should be addressed to RAF Aeronautical Engineering (lord@ucar.edu), the EOL/DFS Manager (jfox@ucar.edu), and the RAF Electrical Engineer (spowart@ucar.edu), respectively.

7.2.4 Operational and Scientific Support

An EOL/RAF Project Manager is assigned to each GV program to serve as a point of contact for platform investigators and to work with them to plan the most effective scientific experiment possible. Based on his/her knowledge of the program's scientific requirements, the Project Manager may assist in defining particular sensors for the instrumentation package, the design of flight profiles, or the most applicable data processing techniques. At a minimum, EOL staff members are normally responsible for project planning (in close cooperation with project investigators), conduct of project operations, quality control oversight for EOL-supported sensors, oversight of data system performance, EOL data processing, and final EOL data delivery to the user. Delivery of user (non-EOL) data is normally not a responsibility of EOL personnel. More in-depth scientific participation is dependent on the specific needs and wishes of the requesting scientists and should be discussed with EOL scientists at the time the aircraft request form is submitted. For general information about RAF project management services, investigators should contact the leader of the RAF Scientific Project Management Group, Jorgen Jensen, (jbj@ucar.edu)

Project principal investigators are required to guide and participate in the in-flight conduct of research. This may be done through delegation to another qualified member of the investigator's group or through delegation to a qualified member of the RAF support team. In all such cases, it is necessary for the principal investigator and the investigator's group to visit the RAF prior to the start of the field program to receive orientation and training in the safe operations of instrumentation and any associated data recording equipment. Project investigators normally participate in the instrumentation flight tests, which are conducted prior to the scientific field phase of the program.

A mission scientist is normally required on the GV to perform in-flight mission coordination and to handle communications with pilots, scientific crew members, and ground support personnel. Because the mission scientist communicates directly with the pilots during flight operations, specialized training in cockpit and flight procedures/protocol is required. The RAF pilots will provide this training to project investigators who wish to serve as mission scientists, provided there are no impediments (e.g., language barriers) to the investigator being able to communicate effectively. Alternatively, EOL can supply a trained mission scientist. It should be noted that mission scientists are normally not in a position to operate cabin instrumentation during flight.

The RAF pilots work with investigators and with the assigned RAF GV Project Manager to plan missions, obtaining FAA flight clearances, and to address special requests pertaining to flight operations. Requests for diplomatic clearances – which are required when operating in most foreign countries – are initiated by EOL personnel.

7.2.5 Insurance – Liability Coverage, Bodily Injury/Property Damage

Aircraft operations conducted by UCAR/NCAR personnel, its officers, trustees and member institutions, the Government of the United States, and user organizations are insured – to the extent of the policy coverage – for legal liability arising from third-party claims.

This coverage does not extend to any cloud or atmospheric seeding operations. If such operations are desired, UCAR/NCAR will not participate until or unless adequate cloud seeding insurance is arranged and paid for by the investigator. Such insurance will require review and approval by UCAR and must name both UCAR and the U.S. Government as additional parties to be insured. In addition, if special dropsonde or radar chaff-seeding insurance is needed, such insurance must be arranged and the cost will be charged to the user organization.

UCAR also is insured for legal liability involving operation of motor vehicles and general liability hazards.

All UCAR/NCAR staff members and other authorized persons flying aboard NCAR-operated aircraft are covered by the UCAR Travel Accident Policy as stated in the *UCAR Benefits Manual*.

Appendix A

NSF/NCAR GV Intercommunications System (ICS) Operating Instructions

Overview

The Intercommunications System (ICS) installed on N677F consists of eight (8) Audio Control Panels (ACP) and four (4) Interphone Control Panels (ICP). The ACP units are used to select desired audio sources to be coupled to either the headphones or speaker (cockpit only), and adjust incoming audio signal and outgoing audio side tone levels. The ICP units are provided as intercom/call station to station only via headset/boom mike inputs.

The ICS COM system has three nets: (1) Cabin Common, (2) Cockpit Local, and (3) Cabin Local.

Station Locations

ACP 1 / ICP 1 – Pilot LH 301
ACP 2 / ICP 2 – Copilot LH 388
ACP 3 / ICP 3 – Observer LH 546
ACP 4 / ICP 4 – Cabin Station LH 497 and LH 738 (Baggage Compartment)
ACP 5 – Cabin Station RH 301
ACP 6 – Cabin Station RH 399
ACP 7 – Cabin Station RH 497
ACP 8 – Cabin Station RH 546 (ADS)

Normal ICS Operations

In order to communicate in the main cabin with the ACP and ICP units, use the Cabin Common Net. The following buttons should be illuminated:

1) HOT MIC
2) ICS Common

ICS Local provides two nets, one for the cockpit only and one for the cabin. This provides a second net for the cabin for ACP communication only. The ICP units cannot listen or talk on the Local Net. To use the Local Net, the following buttons should be illuminated:

1) HOT MIC
2) ICS LOCAL

The ICP unit can only transmit on the ICS Common Net.

In order to communicate with the cockpit, use the ICS Common Net. To call the cockpit, push and release the CALL button (an audio signal will be sent to the cockpit ICS Local Net). The cockpit will them switch over to the ICS Common Net for the communication. The Cabin ACP unit cannot monitor the cockpit communications over the cockpit ICS Local Net.

Other ICS Operations

Communication over the VHF radio is available through the ACP units only. In order to communicate outside the aircraft on the VHF radio, the cockpit must first select the desired frequency. Select both VHF2 Audio and VHF2 Microphone. To use the VHF radio, the following buttons should be illuminated:

1) VHF2 Audio
2) VHF2 Microphone

To listen to VHF communication, select only the VHF2 Audio button. (**WARNING:** If both VHF2 Audio and Microphone are selected, the operator will be able to transmit outside the aircraft and any other station that has the VHF2 selected will be able to transmit as well, creating the ability to cause walkover communications.)

Communication over the SATCOM is available through the ACP units only. INMARSAT (SAT 1) or IRIDIUM (SAT 2) phone calls via the cockpit are available to all the ACP locations. Dialing is only available in the cockpit. To use the INMARSAT, the cockpit must dial the desired number and the following buttons should be illuminated:

1) SATCOM Audio
2) SATCOM Microphone

A quick push of the SATCOM Microphone button selects SAT 1 or the INMARSAT for communication. To speak, press the PTT switch on the fuselage ICS headset hanger to the down position.

To use the IRIDIUM, the cockpit must dial the desired number and the following buttons should be illuminated:

1) SATCOM Audio
2) SATCOM Microphone

An extended push (of approximately 4 seconds) of the SATCOM Microphone button selects SAT 2 or the IRIDIUM for communication. To speak, press the PTT switch on the fuselage ICS headset hanger to the down position.

Appendix B

NSF/NCAR GV Satellite Communications (SATCOM) Systems Operating Instructions

(See attached file: ***UCAR SATCOM Training***)