



NSF / NCAR Gulfstream V

## INVESTIGATOR'S HANDBOOK



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

## Summary of Revisions

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## Table of Contents

INVESTIGATOR'S HANDBOOK.....	1
Summary of Revisions.....	2
Table of Contents .....	3
List of Figures .....	5
List of Tables .....	7
Introduction.....	8
Key Personnel Contact Information at NCAR/EOL.....	9
List of Acronyms/Definitions .....	10
Chapter 1    Requesting the Aircraft and Instrumentation .....	14
1.1    Aircraft Requests.....	14
1.2    Project Support Services .....	14
Chapter 2    Basic GV Specifications .....	17
2.1    General View.....	17
2.2    Cabin Layout .....	18
2.3    Weight and Balance .....	21
2.4    Cabin Pressurization .....	22
2.5    Aircraft Systems .....	22
Chapter 3    GV Performance and Flight Planning Guidelines .....	28
3.1    Runway Requirements .....	28
3.2    Operational Limits .....	28
3.3    External Configuration Considerations .....	28
Chapter 4    Flight Operations.....	28
4.1    Aircraft Certification Overview .....	28
4.2    Crew Duty Limitations .....	28
4.3    Operating Policies for Flight Planning .....	29
4.4    Flight Personnel Requirements .....	32
4.5    Emergency Procedures.....	33
4.6    Safety Training .....	33
4.7    Security .....	33
Chapter 5    Research Systems Descriptions .....	35

5.1	Structural Modifications .....	35
5.2	Research Power System .....	47
5.3	Data Acquisition System and Display .....	53
5.4	Satellite Data Communication Link.....	57
5.5	Ground Support Computing.....	57
5.6	Data Products.....	58
Chapter 6	Investigator Equipment Packages .....	59
6.1	Structural Considerations .....	59
6.2	Electrical Considerations .....	76
6.3	Air Flow Modeling Data and Availability.....	82
Chapter 7	Feasibility & Instrumentation Integration Procedures .....	84
7.1	Instrument Certification and Approval .....	84
7.2	Project lifecycle reviews and payload certification.....	84
7.3	New Instruments .....	85
7.4	Instruments Previously Flown.....	86
7.5	Feasibility Review of Proposed Campaigns .....	87
7.6	Flight Test Opportunities .....	88
Chapter 8	Insurance – Liability Coverage, Bodily Injury, Property Damage.....	89
Appendix A	.....	90
	Overview .....	90
	Station Locations.....	90
	Normal ICS Operations .....	90
	Other ICS Operations.....	91
Appendix B	.....	92
Appendix C	.....	94

## List of Figures

Figure 2.1: Top, side and front dimensional views of the GV. ....	18
Figure 2.2: GV cabin configuration. Floor stations P9-12 are emergency exits and can only contain seats. Floor stations L1, R1 and L6 can only contain racks. Stations P12 and R6 are permanently assigned to ADS and ADS operator.....	19
Figure 2.3: GV cabin cross section with seats in position (looking aft).....	20
Figure 2.4: GV galley (front view).....	20
Figure 2.5: GV lavatory (plan view) .....	21
Figure 2.6: A representative profile of cabin pressure and ambient pressure during a typical GV flight. PSXC is the ambient atmospheric pressure; PCAB is the GV internal cabin pressure.....	22
Figure 5.1: Drawing of GV inlet aperture pad .....	35
Figure 5.2: View of GV upper fuselage, showing inlet aperture pads (green and red), optical view port (light blue), fuselage mounts (dark blue), and two forward fuselage pads below windscreen (grey circles). Drawing courtesy of Lockheed Martin.....	36
Figure 5.3: View of GV lower fuselage, showing instrument aperture plates (green), optical view ports (light blue), fuselage mounts (dark blue), and four forward fuselage pads (grey circles). Drawing courtesy of Lockheed Martin. ....	37
Figure 5.4: Drawing of GV fuselage mount .....	38
Figure 5.5: Drawing of GV fuselage mount connector plate .....	38
Figure 5.6: Drawing of GV forward fuselage pad .....	40
Figure 5.7: Transmissivity of a single, uncoated Infrasil 302 pane, 10 mm thick. (GV panels are 26.5 mm thick) 2 uncoated windows form one complete viewport.....	41
Figure 5.8: One complete optical port is available with broadband visible anti-reflective coating with also very low reflectivity at 1064 nm. Theoretical curve.....	42
Figure 5.9: Oblong optical aperture, material - SiO <sub>2</sub> or ZnSe. All dimensions in inches. ....	43
Figure 5.10: View of GV from above showing locations of six under-wing hard points with notional wing stores mounted at each hard point.....	44
Figure 5.11: View of the GV tail deck area available for the mounting of scientific equipment .....	46
Figure 5.12: View of the GV MPDB, located on the right side of the forward cabin, opposite the main crew entry door. ....	49
Figure 5.13: 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. ....	51

Figure 5.14: 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. ....	51
Figure 5.15: GV cabin secondary power distribution boxes (SPDBs) .....	52
Figure 5.16: GV cabin secondary power distribution drop boxes (SPDDBs).....	52
Figure 6.1: Standard Equipment Rack .....	69
Figure 6.2: Short (8U) equipment rack drawing. A full size MCE rack is shown in gray scale for comparison. All dimensions in inches. ....	70
Figure 6.3: Allowable equipment weight for mounting to face chart .....	71
Figure 6.4: Allowable face-mounted equipment moment chart .....	72
Figure 6.5: New instrument development flow chart.....	74
Figure 2.1: Typical time line for field project documentation, certification and review processes.....	84

## List of Tables

Table 2.1: GV operational gross weights.....	21
Table 2.2: GV loading information .....	21
Table 4.1: GV crew duty limitations.....	29
Table 5.1: Types of research power available on the NSF/NCAR GV .....	50
Table 6.1: Analytical Factors .....	61
Table 6.2: 14 CFR Part 25, Emergency Landing Load Factors.....	61
Table 6.3: GV Inertia Load Factors .....	62
Table 6.4: GV Design Pressures .....	63
Table 6.5: Flight Conditions for Aerodynamic Loads Analysis.....	64
Table 6.6: Galvanic Corrosion Potential .....	65
Table 6.7: Aircraft-Quality Fasteners.....	67
Table 6.8: External Mounting Provision Capabilities .....	73

## **Introduction**

### **History**

The GV aircraft was made available for research in February, 2005 concluding an extensive two year program of adding research infrastructure modifications to a stock GV. This program was named High altitude Instrumented Airborne Platform for Environmental Research (HIAPER). After completion of this program the aircraft became known as NSF/NCAR GV but sometimes is still referred to as HIAPER in the community.

### **Current status**

The Gulfstream V (GV) aircraft represents a high performance platform that will serve the environmental research needs of the National Science Foundation (NSF) for the next several decades. The capability offered by the GV to carry fairly large, manned payloads to high altitudes and over long distances make it an attractive research vehicle for in-depth studies of the troposphere and lower stratosphere and for remote sensing studies of the Earth's surface or upper atmosphere.

The GV is maintained and operated on behalf of 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 Rocky Mountain Metropolitan Airport (RMMA) in Broomfield, Colorado.

This Investigator's Handbook is intended to serve investigators as a 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 acquisition system and displays; aircraft performance characteristics and considerations; flight operations; integration of investigator equipment packages; EOL standard instrumentation; and aircraft request procedures and project support services.

Investigators who are either considering requesting the use of the GV or who have already been awarded project support with this facility are strongly encouraged to review this handbook and to structure their programs and payloads to the operational guidelines and integration requirements outlined in this document.

While this handbook has been intended to be as comprehensive as possible, it is anticipated 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. The list of key contact personnel given on Page 9 of this document will 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 Facility Manager (303-497-1032).



## Key Personnel Contact Information at NCAR/EOL

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## 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	Computing Data and Software
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
DMT	Droplet Measurement Technologies, Inc.
DOD	Department of Defense
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
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
HIAPER	High altitude Instrumented Airborne Platform for Environmental Research
HSD	High Speed Data
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
LAN	Local Area Network
LAOF	Lower Atmospheric Observing Facilities
LBL	Left Buttline (in inches)
LEO	Low Earth Orbiting
LOC	Localizers
LNAV	Lateral Navigation Localizers
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
NATO	North Atlantic Treaty Organization
NCAR	National Center for Atmospheric Research
NEMA	National Electrical Manufacturers Association
netCDF	Network Compact Data Format
NM	Nautical Mile
NEXRAD	Next Generation Radar
NSF	National Science Foundation
NTP	Network Time Protocol
PCI	Peripheral Component Interconnect
PI	Principal Investigator
PIC	Pilot In Command
PMS	Particle Measuring System
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
SQL	Structured Query Language
SSDB	Secondary Signal Distribution 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
USAF	United States Air Force
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

## Chapter 1 Requesting the Aircraft and Instrumentation

### 1.1 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/deployment/request-info /UserGuide.pdf](http://www.eol.ucar.edu/deployment/request-info/UserGuide.pdf).

### 1.2 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 Computing, Data and Software (CDS) facilities 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.

#### *1.2.1 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 the RAF Standard Instrumentation Manual document. 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.

RAF 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 available from EOL FPS.

### *1.2.2 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, the EOL/DFS Manager, and the RAF Electrical Engineer respectively.

### *1.2.3 Operational and Scientific Support*

A 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.

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, obtain air traffic control 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 after project approval.

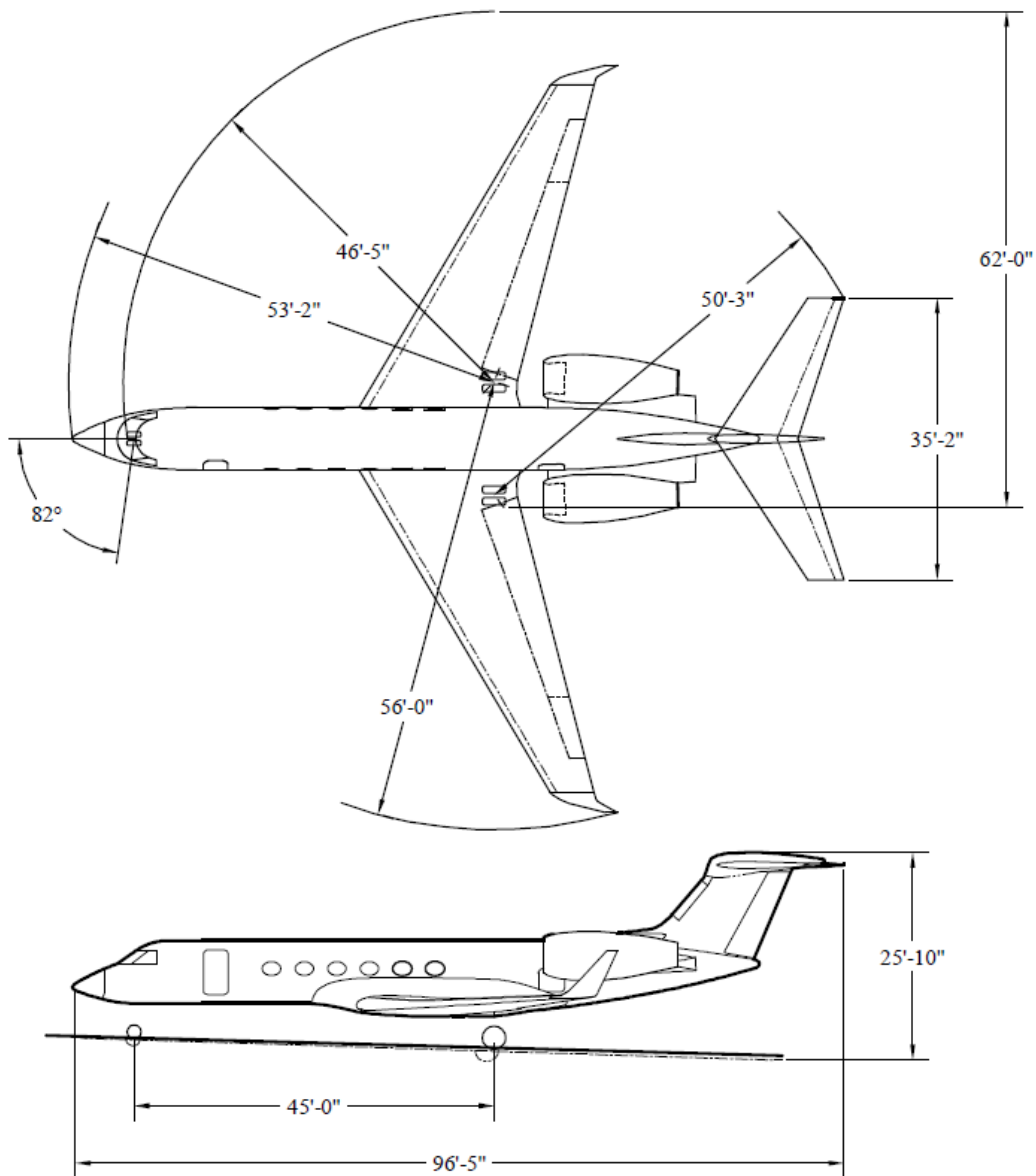


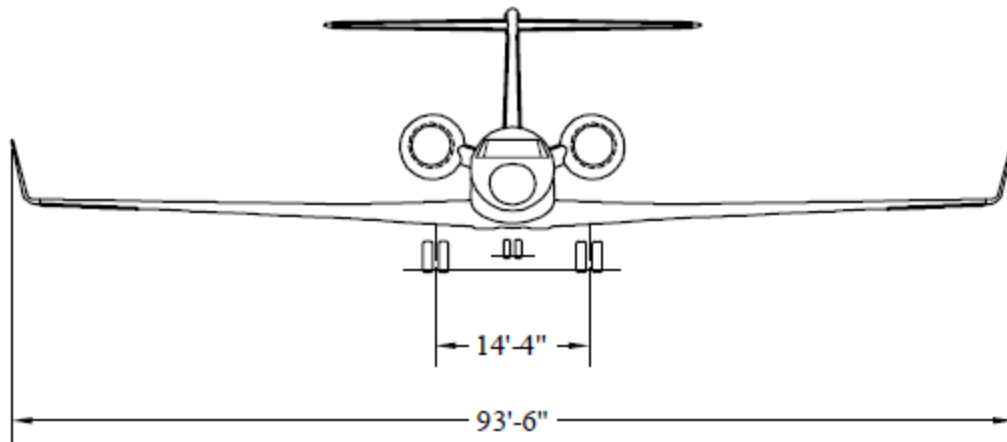
## Chapter 2 Basic GV Specifications

## 2.1 General View

The NSF/NCAR GV aircraft is a Gulfstream Aerospace Corporation (GAC) Gulfstream V 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.

A dimensional drawing of the GV is shown in Figure 2.1below.





***Figure 2.1: Top, side and front dimensional views of the GV.***

## 2.2 Cabin Layout

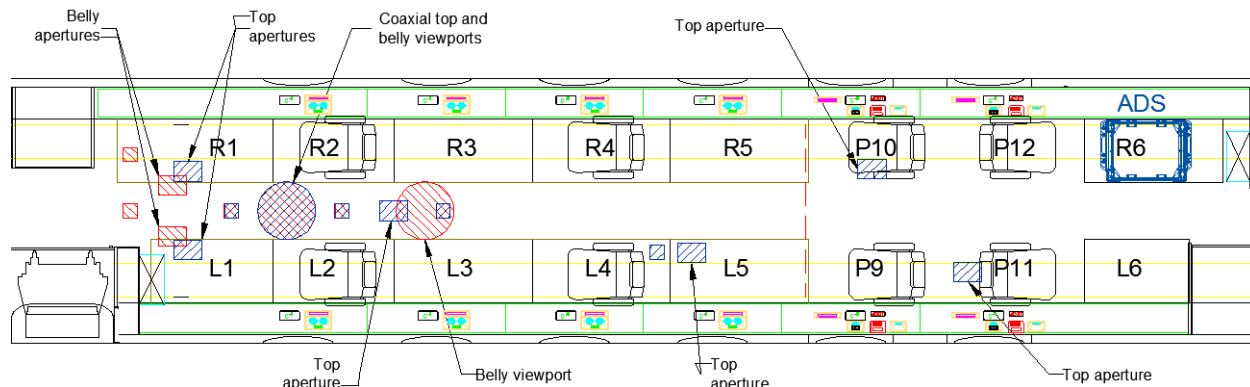
The basic configuration of the GV cabin is as shown in Figure 1.2 below. The aircraft is equipped with a galley and a lavatory in the aft section of the main cabin and with the proper survival and safety equipment, which use will be explained to the investigators in detail in pre-project safety briefings for each approved research project. The research mission power rack is located in the forward section of the cabin immediately across from the main crew entry door. Floor stations L2 - L5 and R2 - R5 (Figure 2.2) can accommodate either an operator seat or an equipment rack. Stations L1, R1 and L6 can only accommodate an instrumentation rack. Note that the rack in position L6 has an operator seat in front of it facing aft, so the rack should be configured to have the controls on the forward facing side and tension straps aligned accordingly. The rack in position R6 is a permanently installed Aircraft Data System (ADS) rack and the seat P12 is permanently assigned to a RAF technician operating the ADS. Note also that not all of the floor stations have equal access to the Inter Communication System (ICS, see also Aircraft operations conducted by UCAR/NCAR personnel are insured – to the extent of the policy coverage – for legal liability arising from third-party claims.

This coverage extends to instrumentation installed on the aircraft as part of NSF-approved flight operations. UCAR also is insured for legal liability involving operation of motor vehicles and general liability hazards.

All UCAR/NCAR staff members are covered by the UCAR Travel Accident Policy as stated in the UCAR Benefits Manual.

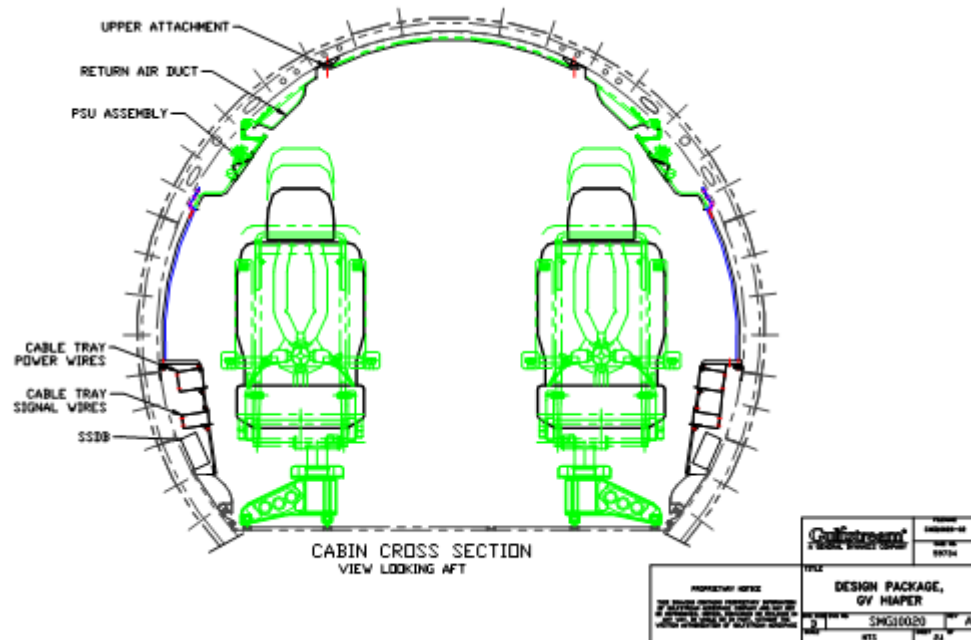
Non-UCAR staff should check with their home institution for workers compensation coverage, medical and life insurance coverage, for possible insurance exceptions related to flying in a public aircraft operation.

Appendix A, Station Locations on page 89) with only floor stations P9, P10, P12 (ADS operator), R4 and R5 being equipped with full cockpit communication capability. The rest of the stations have a listen-only capability with the cockpit and full communication capability to the rest of the cabin.

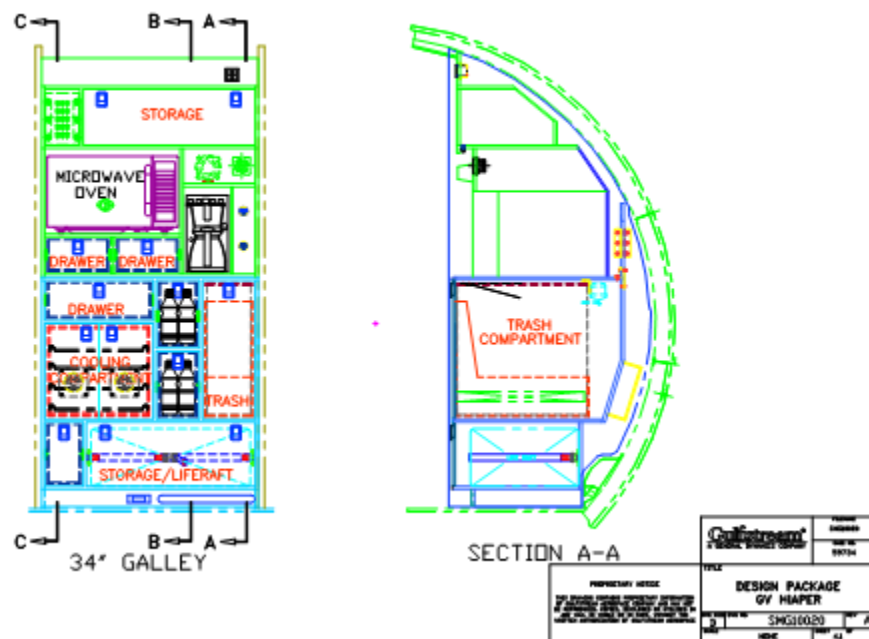


**Figure 2.2: GV cabin configuration. Floor stations P9-12 are emergency exits and can only contain seats. Floor stations L1, R1 and L6 can only contain racks. Stations P12 and R6 are permanently assigned to ADS and ADS operator.**

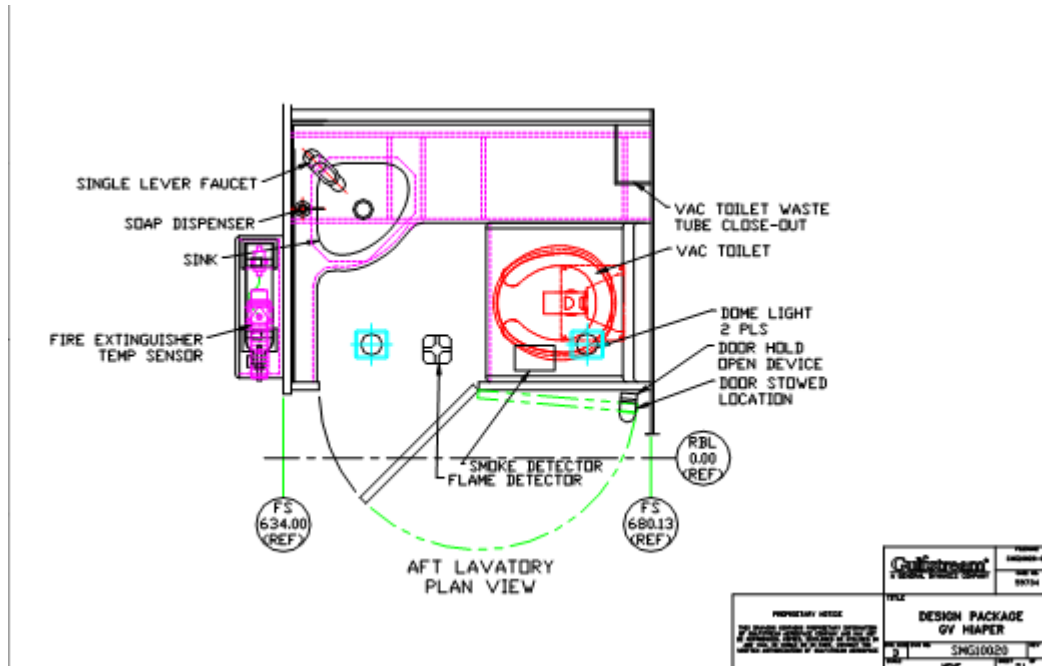
Secondary power distribution boxes (SPDB) and secondary signal distribution boxes (SSDB) are located throughout the aircraft cabin for the provision of power to research equipment (see Section 2.3) and for the transmission of signals to and from instrumentation. Additionally, cabin interior attachment points have been installed on the floor and ceiling of the aircraft for the installation of equipment racks and instrumentation. Utilization of the upper attach rail may allow increased overturning moment for the equipment racks but does not allow increased weight over that specified in Section 2.3. Additionally, upper attach points are not available at all floor stations. 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 2.3 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 2.4 and Figure 2.5 show the GV galley and lavatory, respectively.



**Figure 2.3: GV cabin cross section with seats in position (looking aft).**



**Figure 2.4: GV galley (front view).**



**Figure 2.5: GV lavatory (plan view)**

## 2.3 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 2.1: 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 2.2: GV loading information**

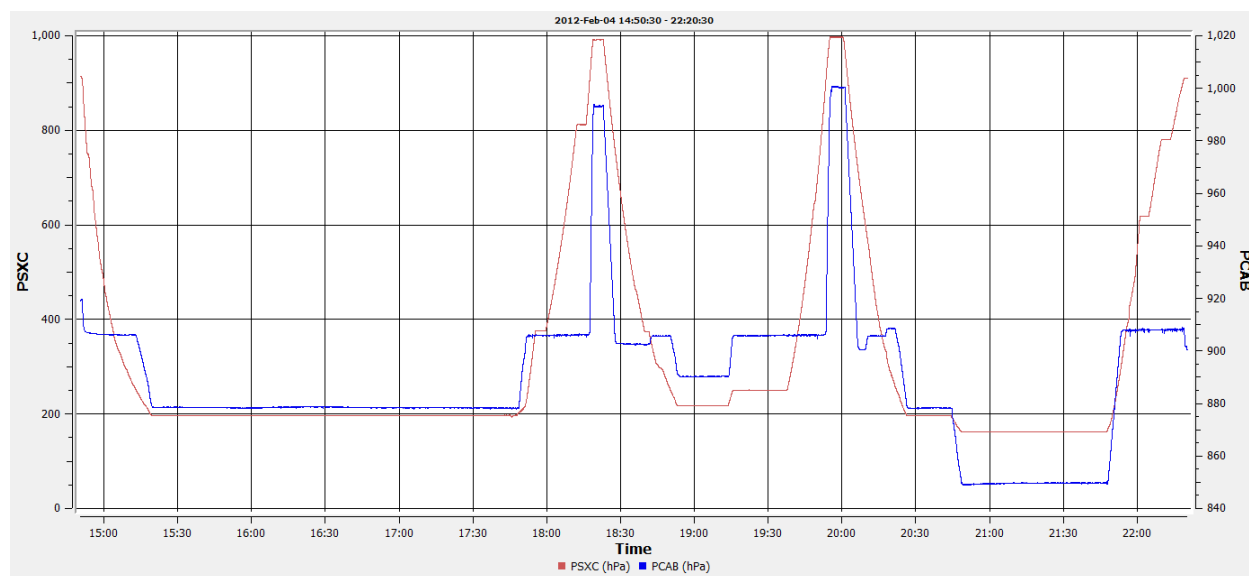
RAF will determine the aircraft zero fuel center of gravity (CG) either by weighing the aircraft or by numerical computation of the configuration prior to each mission to ensure the aircraft center of gravity is within the approved GV envelope.

**Note:** While the GV cabin has space to install up to 10 equipment racks in the forward cabin, installing more than 7 racks in the forward cabin may cause the CG to shift forward of the optimal position and require placement of ballast in the baggage compartment. This in turn impacts the ability to carry luggage or spares, reduces the available fuel load and negatively impacts the aircraft range and practical ceiling. Installation of 7 or more racks at the maximum rack weight may cause the CG to move out of bounds and result in a payload being incompatible with the GV.

## 2.4 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.

Note: some instruments rely upon a stable ambient pressure to maintain operation of internal pressure or flow controllers. Please keep in mind that the GV cabin pressure will change during the flight, approximately tracking the outside ambient pressure but with a lag and minimum pressure platooning at approximately 840 hPa (Figure 2.6).



**Figure 2.6: A representative profile of cabin pressure and ambient pressure during a typical GV flight. PSXC is the ambient atmospheric pressure; PCAB is the GV internal cabin pressure.**

## 2.5 Aircraft Systems

The aircraft is equipped with the following standard 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. For any equipment that will transmit any RF signal the investigators are advised to contact RAF to ensure compatibility with the GV prior to fabrication of such equipment.*

### **2.5.1 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 Micro Air Data Computers (MADC) and three 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

### **2.5.2 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.

### **2.5.3 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 radio frequencies for scientific purposes (i.e., other than routine contact by the air crew with the Federal Aviation Administration Air Traffic Control [FAA ATC]) 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 GV Facility Request Form.*

#### *2.5.4 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.

#### *2.5.5 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.

#### *2.5.6 Global Positioning System (GPS)*

The GPS consists of two 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 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.

#### *2.5.7 Distance Measuring Equipment (DME)*

The DME system consists of two 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 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 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.



### *2.5.8 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.

### *2.5.9 Traffic Collision Avoidance System (TCAS)*

One 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.

### *2.5.10 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 of five video levels (0, 1, 2, 3, and 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).

### *2.5.11 Radio Altimeter (RAD ALT)*

The RAD ALT system consists of two 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.

### *2.5.12 Emergency Locator Transmitter (ELT)*

One 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.

### *2.5.13 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.

### *2.5.14 Intercommunications System (ICS)*

The cockpit ICS delivered with the GV was modified and expanded prior to delivery of the aircraft to 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 Audio Control Panels (ACPs) in the cockpit (for the two pilots and one flight observer) and five ACPs and three Interphone Control Panels (ICPs) in the main cabin (see Aircraft operations conducted by UCAR/NCAR personnel are insured – to the extent of the policy coverage – for legal liability arising from third-party claims.

This coverage extends to instrumentation installed on the aircraft as part of NSF-approved flight operations. UCAR also is insured for legal liability involving operation of motor vehicles and general liability hazards.

All UCAR/NCAR staff members are covered by the UCAR Travel Accident Policy as stated in the UCAR Benefits Manual.

Non-UCAR staff should check with their home institution for workers compensation coverage, medical and life insurance coverage, for possible insurance exceptions related to flying in a public aircraft operation.

Appendix A, Station Locations on page 89). Additionally, one ICP is located in the aircraft baggage compartment. One intercommunications jack is provided in the fuselage nose exterior, and one is also provided in the tail compartment for use by the aircraft mechanics. 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.

### *2.5.15 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 SATCOM system is an Inmarsat Classic and SwiftBroadband (SBB) system. Incorporating the Thrane & Thrane Aviator 700 SATCOM System, utilizing the I-4 Satellite Network. 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.

The AirCell Iridium 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 Aviator 700 SBB Inmarsat system provides global voice and PC modem data capabilities using the Inmarsat SBB service. Data transfers at rates up to 64kbps for circuit switched, ISDN. Up to 128kbps packet switched/streaming (Billed per minute based on the requested amount of bandwidth) and up 432 kbps background Always-on IP data, single shared channel (Billed per megabyte based on the actual amount of data sent and received) are possible using the Inmarsat SBB service.

**Note:** *Due to the high cost of satellite data communications, only EOL computers onboard the GV are allowed internet access. All user systems are only allowed access to the Local Area Network (LAN) onboard the GV. Systems requiring access to the Internet must be identified to the EOL/RAF staff in advance of the project and will be allowed to connect only after a thorough examination by the EOL system administrators.*

The Internet Relay Chat can be made available on all systems including instrument computers. This system does not connect to the Internet directly but goes through the ADS server. Please see Section 5.4 for more details.

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.

### *2.5.16 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.

## **Chapter 3 GV Performance and Flight Planning Guidelines**

### **3.1 Runway Requirements**

7,000 feet of runway is generally required for G-V operations to allow for adequate safety margins in case of emergency aborts and/or landings. However, atmospheric conditions such as rain, ice or hot temperatures may cause an increase in required runway length. RAF Flight Operations may approve shorter runway operations on a case by case basis.

### **3.2 Operational Limits**

Investigators should consult with the RAF project manager for planning research flights. The RAF project manager will work with RAF flight operations group to help analyze the specific conditions required by the research mission. The range and altitude capabilities are significantly affected by payload weights, flight maneuvers required, and departures from standard atmospheric conditions.

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

### **3.3 External Configuration Considerations**

The performance of the aircraft is affected if external devices are installed on the GV (i.e., cooling scoops, wing pods, and inlets). For more information to account for specific external configurations, contact the RAF Project Management, Flight Operations or Aeronautical Engineer.

## **Chapter 4 Flight Operations**

### **4.1 Aircraft Certification Overview**

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 EOL staff (flight crew, maintenance and technician personnel, instrument operators, 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 a single crew are outlined in Table 4.1.

Any 24 hour period	10 flight hours
Any consecutive 7 days	40 flight hours or 60 duty hours
Any 30 day period	120 flight hours
Consecutive working days	6 days
Maximum crew duty period	14 consecutive hours
Maximum consecutive duty days over 10 hours	2 days
Minimum crew rest period	12 consecutive hours
Normal crew duty day	8 hours
Definition of max duty day	10-14 hours
Night Duty	Show time earlier than 5 am LT; landing after midnight
Switching from day to night or night to day flight operations	36 hours notice and no work to all flight crew members

**Table 4.1: GV crew duty limitations**

Investigators are advised that the above limits may be extended for aircraft ferry purposes at the Pilot in command's discretion.

*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

All missions will be flown in accordance with FAA Regulations Subpart B, appropriate Flight Information Planning Publications, ICAO procedures applicable to the host country, and NSF/NCAR directives, and RAF policies and procedures. The RAF project manager can provide further guidance on these policies and procedures.

#### 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.

NSF/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. The GV will not be operated in known or expected hail or graupel formation regions.

NSF/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. Projects planning operations in the proximity of convective systems require the presence of a Mission Coordinator onboard the GV, who is typically an experienced EOL meteorologist. The Mission Coordinator's role is to assess the radar, lightning, satellite and other real time meteorological information and to assist the pilots in selecting safe operation regions and to assist the project scientists in carrying out their research objectives

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

An RAF-approved, radar-trained aircraft meteorologist with access to a real-time radar display may be assigned to monitor and direct the aircraft operations to coordinate with the onboard Mission Coordinator and to assist the investigators on the ground in achieving their research objectives. The aircraft meteorologist 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 Pilot in Command retains overall responsibility for safety of the aircraft and will remain in contact with the Mission Coordinator and the radar scientist for all storm penetrations.

Investigators planning research flights should consult with the RAF project manager and RAF Flight operations to discuss likely limitations on planned research flights.

#### *4.3.2 Altitude Restrictions for NSF/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:

- Anywhere: An altitude allowing, if a power unit fails, an emergency landing without undue hazard to persons or property on the surface.
- 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.
- Over other than congested areas: An altitude of 1,000 feet above the surface, except over open water. In those cases, the aircraft may not be operated closer than 500 feet to any person, vessel, vehicle, or structure.
- Over open water: VFR conditions, a minimum altitude of 100 feet for short durations straight and level; 300 minimum for turns;
- Auto pilot engaged: Minimum altitude of 300 feet above the surface.

Added constraints for hours of darkness or during restrictive visibility:

- 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.

The above minimums have been established with near ideal conditions in mind. The Pilot in command 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.

#### *4.3.3 Use of Oxygen*

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

Unpressurized flights from 18,000 feet to 25,000 feet MSL require pre-flight de-nitrogenation breathing for 10 minutes. All crew members will breathe 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.

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

A supplemental oxygen system is optionally available on the GV that provides an additional oxygen supply to the crew members in the main cabin. This system is intended to provide additional fuel reserve in case of depressurization in a remote location. The supplemental oxygen system can support up to 4 persons in the main cabin, which limits the research crew to three persons. The supplemental oxygen system utilizes the compressed gas rack (see Section 5.1.9) in the aft of the GV cabin, making this rack inaccessible for any other use.

#### *4.3.4 Weather Forecasts*

The Pilot in Command will ensure that the destination and alternate weather forecasts are obtained before reaching Equal Time Point (ETP) on over-water missions. Weather forecasts will provide the Pilot in command with sufficient terminal weather information for diverting or continuing to destination.

#### *4.3.5 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 forming 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 pilot in commands of the aircraft have agreed to do so.

#### 4.4 Flight Personnel Requirements

Under the government regulations for research flights on government-owned aircraft only two types of people may fly on the aircraft: crew members (pilots, copilots, flight engineers, and mechanics) and those that are required to fly for the purpose of the research (referred to as qualified-non crewmembers). Basically this means the flight crew and scientific staff with a specific research task on the flight. Crew manifests require NSF approval prior to the start of any field campaign. This assures that flight personnel are flying for the Government's purpose in conducting research.

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 EOL 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 B of this handbook.

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

##### *4.4.1 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 un-pressurized). The payload certification process is designed to avoid a possibility of cabin de-pressurization. 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. 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.

##### *4.4.2 Operations with unusual windows or inlets.*

The RAF certified 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.



## 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 require flight crew notification as soon as is practical. The Pilot in command 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 Pilot in Command..

## 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 attend an RAF safety briefing before the start of the specific project flight operations. These briefings are normally conducted at the RAF. Arrangements to conduct special briefings in the field can be made with advance request. The briefing takes approximately two hours. 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;
- Briefing and operating procedures on the hazardous materials used in the course of the project;
- Briefing regarding project-specific safety issues;
- Instruction in the operation of aircraft systems (intercommunications system, lighting, seatbelts, emergency exits, etc.);
- Project location specific safety and security concerns, precautions and procedures;
- Additional training for investigators who will also be serving as mission scientists during specific projects will be also provided.

## 4.7 Security

RAF is an ISBAO compliant organization. This means that a certain level of business aviation standards and reporting is maintained, and all users have to comply with the RAF safety and security policies.

Flight operations with the GV are performed from national or foreign airports and all operations are subject to the security measures those airports have in place. In the U.S. this means compliance with the TSA requirements. RAF will arrange for ramp access for the science crew in advance and may request photographs or other personally identifiable information (PII) that is required in order to obtain ramp access clearances

for individuals. RAF does not retain PII after the project and people will be asked for it again as necessary for future projects.

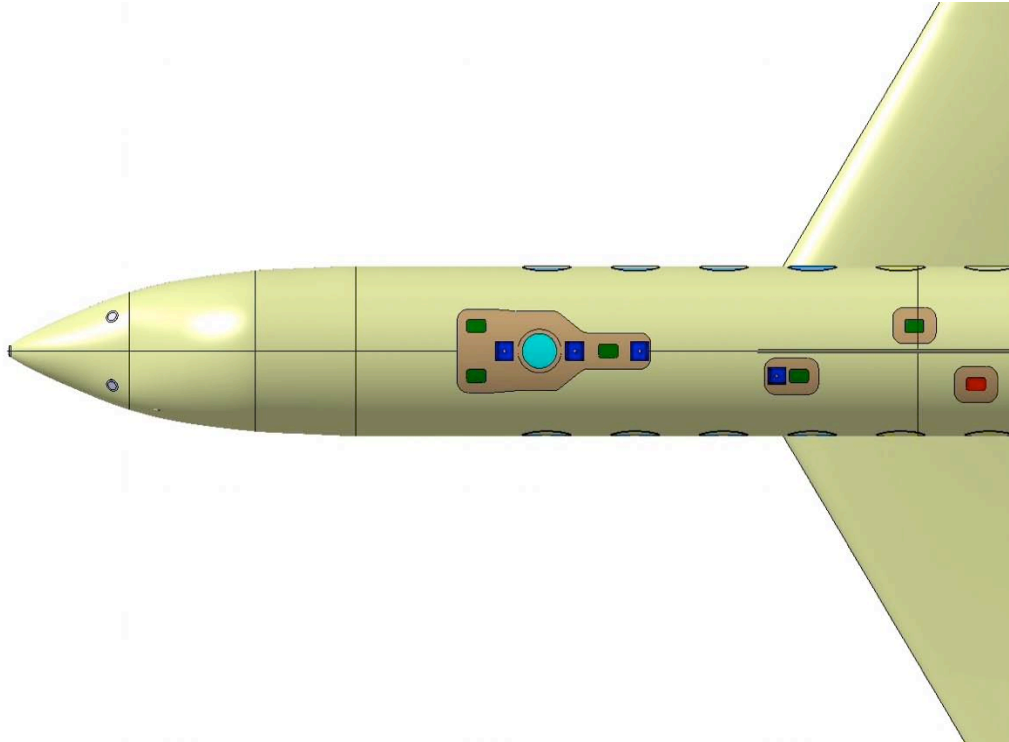
RAF issues bag tags to identify luggage and tool bags that are authorized to fly on the GV. This allows the crew to easily identify bags that should be loaded onto the GV and prevent a possible placement of a suspicious items onboard the aircraft.

Special policies aimed to maintain compliance with the U.S. export regulations also apply and may require limiting access to certain equipment or documentation to foreign nationals.



- 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 5.2 shows the locations on the aircraft of the six inlet aperture pads.

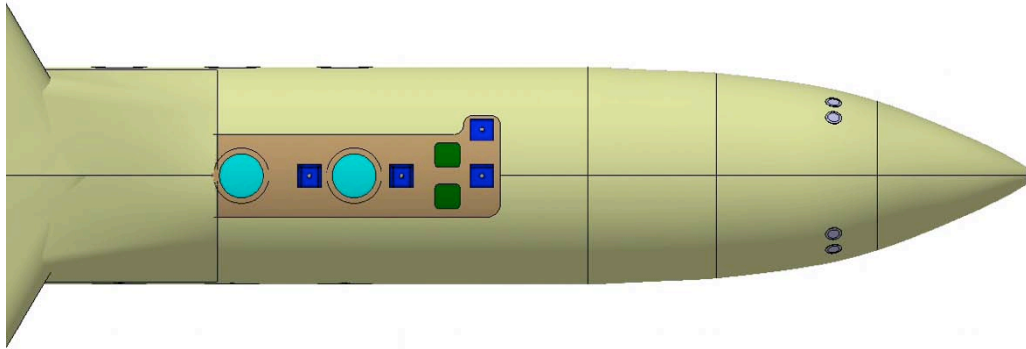


***Figure 5.2: View of GV upper fuselage, showing inlet aperture pads (green and red), optical view port (light blue), fuselage mounts (dark blue), and two forward fuselage pads below windscreen (grey circles). Drawing courtesy of Lockheed Martin.***

In addition to the inlet aperture pads installed on the upper fuselage, two 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 5.1 , above. Figure 5.3 below shows the locations of the two lower fuselage instrument aperture plates.



**Figure 5.3: View of GV lower fuselage, showing instrument aperture plates (green), optical view ports (light blue), fuselage mounts (dark blue), and four forward fuselage pads (grey circles). Drawing courtesy of Lockheed Martin.**

### **5.1.2 Fuselage Mounts**

Eight fuselage mounts are installed on the GV fuselage, with four on the upper fuselage and four on the lower. Six of the upper and lower mounts are installed at various locations on the aircraft centerline, and one 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. Figure 5.4 and Figure 5.5 show a fuselage mount and a second (instrument attachment) plate, respectively.



- 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 Figure 5.2 and Figure 5.3, respectively.

### 5.1.3 *Forward Fuselage Pads*

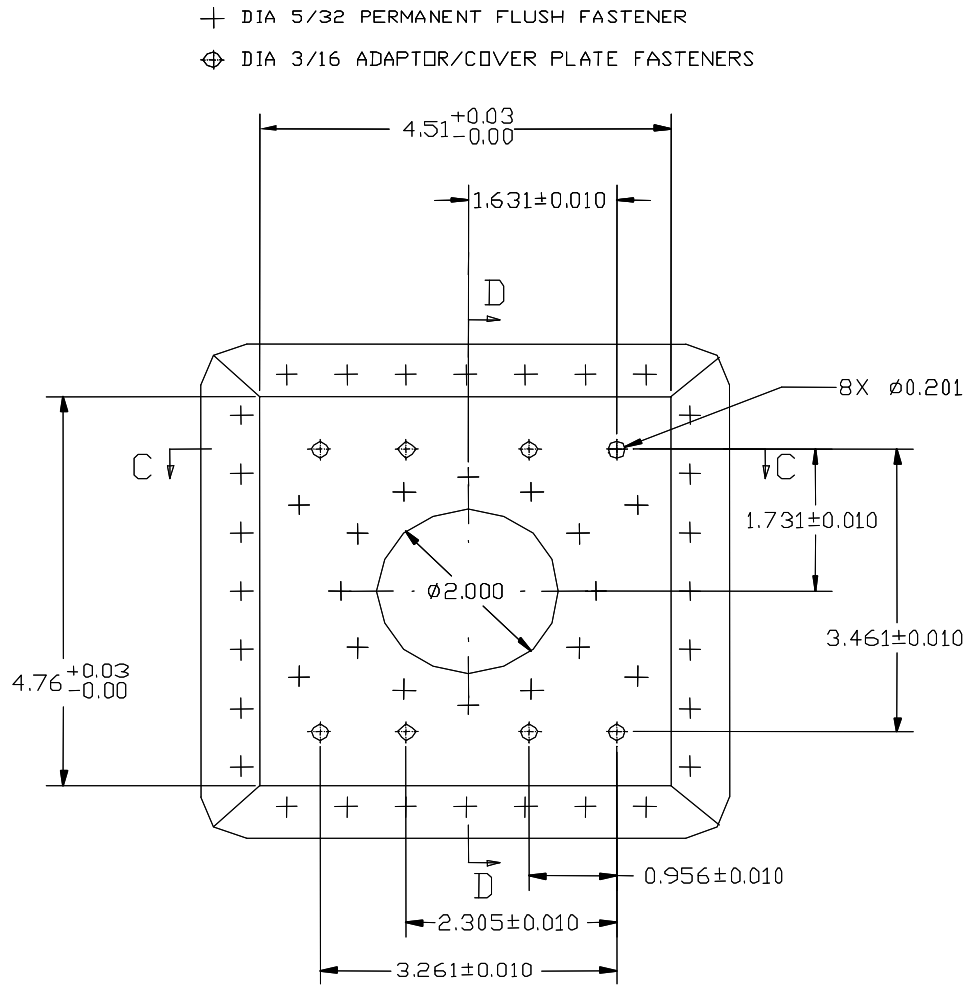
Six forward fuselage (nose) pads have been installed on the NSF/NCAR GV. Four of the pads (two on each side) are located on the sides of the forward fuselage, and the remaining two are located on the upper section of the forward fuselage directly below the aircraft windscreen. Each forward fuselage pad 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 screws. Figure 5.6 shows one of the forward fuselage pads.

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 Figure 5.2 and Figure 5.3, respectively.

Five of the six forward fuselage pads (the four located on the sides of the forward fuselage and the left pad below the windscreen) have been used for the permanent installation of temperature, dew point, and pitot sensors on the aircraft.



**Figure 5.6: Drawing of GV forward fuselage pad**

#### 5.1.4 Optical View Ports

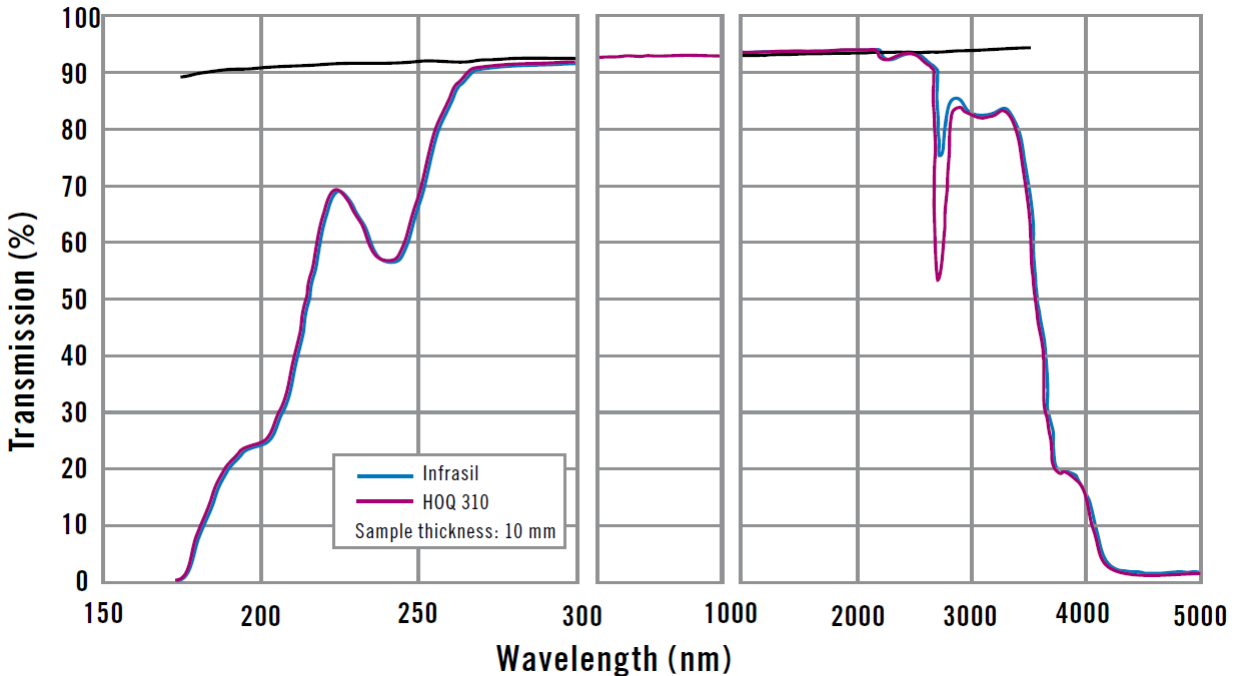
Three 20.5-inch diameter (also known as "large") optical view ports are installed on the aircraft centerline in the forward section of the GV fuselage. Two of the view ports are down-looking and one is up-looking. The forward down-looking and up looking-ports are aligned vertically. Additionally, this 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 optical glass windows. Specific locations for the three 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

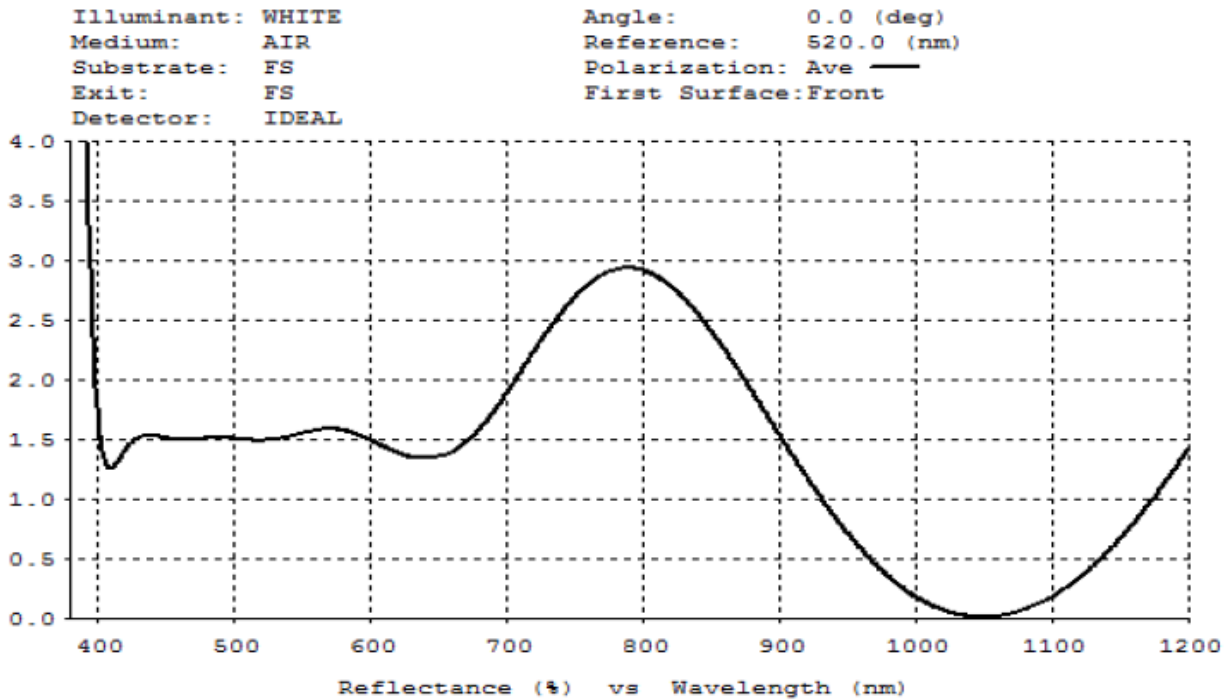


- Aft down-looking view port:GVFS 339.5, BL 0.0, WL 58.25 for internal mounting surface

Currently approved optical windows for the large viewports are double pane, have a 18 inch clear aperture and pane thickness of 26.5 mm. Material is IR-grade fused silica or quartz (Heraeus Infrasil 302 or equivalent, bubble class 0, index homogeneity < 6 ppm. RAF has windows with coatings optimized for 532, 940 and >1,400 nm wavelength and with broadband UV-VIS antireflective coatings (see Figure 5.7 and Figure 5.8 for details).



**Figure 5.7: Transmissivity of a single, uncoated Infrasil 302 pane, 10 mm thick. (GV panels are 26.5 mm thick) 2 uncoated windows form one complete viewport.**



BBAR 520nm plus 1064nm

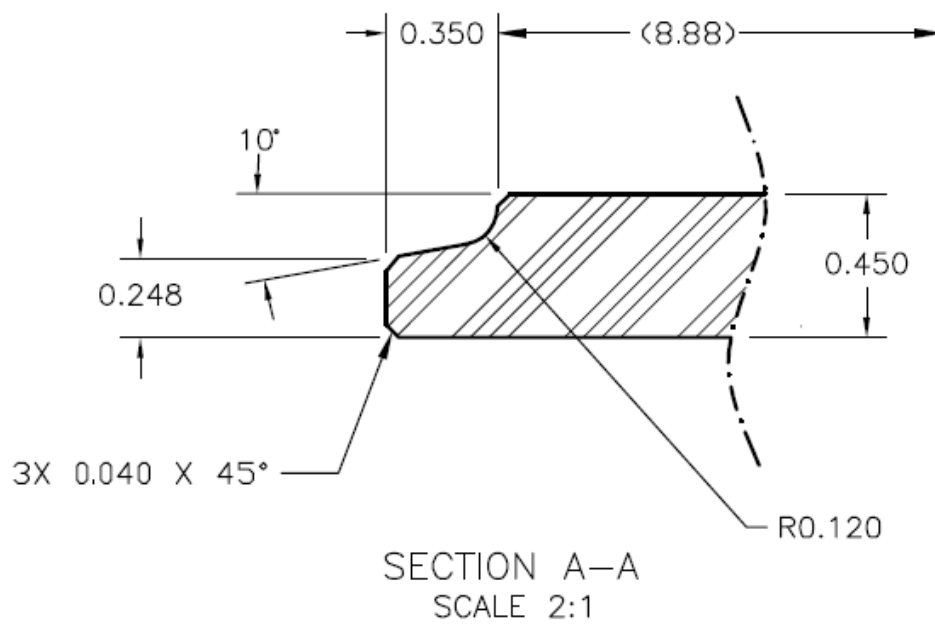
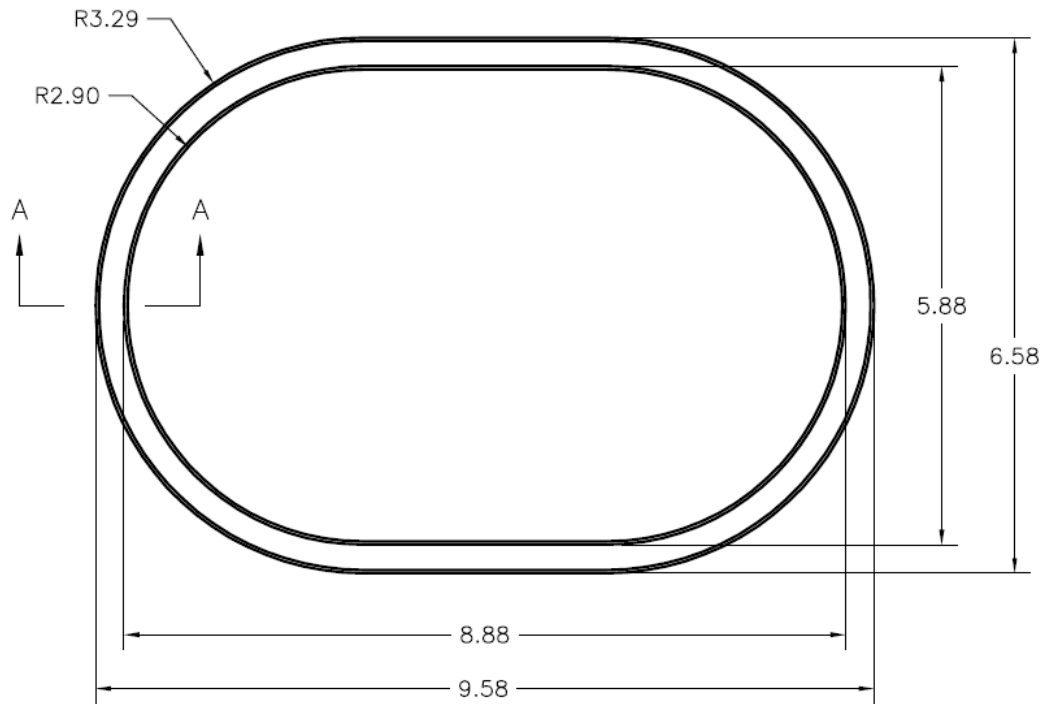
***Figure 5.8: One complete optical port is available with broadband visible anti-reflective coating with also very low reflectivity at 1064 nm. Theoretical curve.***

Investigators requiring a different window material or a coating in a different spectral region should contact RAF for more information.

Figure 5.2 and Figure 5.3 above show the positions of the three view ports.

The aft lower viewport plate can support an external instrument/inlet weighing 36 pounds maximum with a center of mass located 10 inches from the aircraft skin. Limit drag and aerodynamic side forces are 60 pounds and 290 pounds respectively. A safety factor of 2 should be applied to aerodynamic limit loads for ultimate. Contact RAF Aeronautical Engineering for additional guidance.

In addition to the large viewports all of the aircraft inlet apertures (see Section 5.1.1) and window blanks (see Section 5.1.6) are capable of carrying a 9-inch oval glass pane (see Figure 5.9).



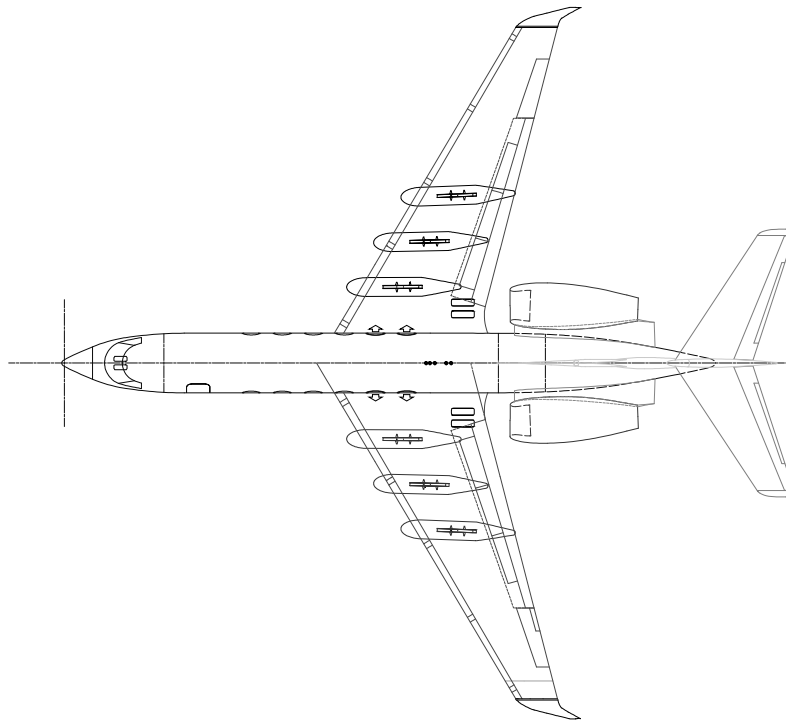
**Figure 5.9: Oblong optical aperture, material - SiO<sub>2</sub> or ZnSe. All dimensions in inches.**

### 5.1.5 Wing Hard Points, Pylons, and Pods

Six under wing hard points (three 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 5.10, below, shows these hard point locations with notional wing stores depicted at each hard point.



**Figure 5.10: View of GV from above showing locations of six 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 lbs. 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 5.2.2 of this chapter for wing power and signal wiring information). All wing stations of the aircraft can be equipped with pylons capable of mounting two standard PMS/DMT style instrumentation cans per pylon. There are two certified GV wing stores configurations: 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.

20" diameter wing pods with a 1,000 lbs weight capability can be installed in the middle wing stations. These pods are only certified to be flown in the full wing store configuration with inboard and outboard stores configured with pylons carrying dual PMS canisters.

See Sections 6.1 and 6.3 of this document for information regarding the airflow and aerodynamics data available from RAF for the various wing pod designs.

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 6.1 and 6.3 of this document for additional information regarding the types of airflow and aerodynamics data available from RAF.

#### *5.1.6 Window Blanks*

The window frames of the aircraft can each support a modest equipment load (approximately 900 inch-lbs). All 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.

RAF currently has window blanks and designs for installation of optical apertures and small GPS antennas into the window blanks. Details of the window-mounted optical aperture are shown on Figure 5.9.

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.

#### *5.1.7 Tail Deck*

The tail deck of the GV (located at the top of the T-tail of the aircraft underneath an aerodynamic cowl, see Figure 5.10 for a picture of this area) is available for the installation of scientific equipment.



**Figure 5.11: 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. This area normally houses a SATCOM antenna and an upward looking radiometer optical receiver. Up to an additional 50 lbs of equipment can be installed in this area. Users intending to utilize the tail deck should contact RAF in advance because tail fairing modifications would likely be required and extended scheduling of such modifications is necessary.

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 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.

### **5.1.8 Tubing and cable routing pathways**

The GV contains infrastructure for connecting scientific equipment components located in the different parts of the aircraft. Several pressure bulkhead feed-throughs exist in the forward cabin, the aft cabin and in the wing root areas on the sides of the cabin at the floor level. All of these pass-throughs require potting of the passing wire, optical fiber or tubing to prevent cabin de-pressurization in flight.

Inlet tubing can be routed along the walls of the cabin utilizing cable troughs (shown in cross section on Figure 2.3) and along the ceiling rail.

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 overhead conduits are installed in the aft section of the aircraft near the floor stations 5 and 6 (Figure 2.2), and the two under floor conduits are installed in the forward section of the aircraft, with one forward of and one between the two down-looking optical view ports, near floor stations 1 and 2. These conduits are the only means of bringing wiring or tubing across the cabin. See Section 5.2.3 below for more information on these overhead and under floor conduits.

#### *5.1.9 Compressed gas cylinder rack*

A permanent rack for securing gas cylinders in flight is permanently installed in the aft cabin of the GV behind the galley. The rack can hold up to three size AL or 100A (48 inches tall and 7.25 inch diameter) aluminum cylinders with regulators. Steel cylinders are not supported.

#### *5.1.10 Baggage compartment rack*

A specialized rack installed in the GV baggage compartment can be utilized to install pump or other similar equipment. Connectivity to this equipment involves passing plumbing lines through the secondary pressure bulkhead and may involve substantial effort. Investigators wanting to install pumps in the aft rack should contact RAF in advance to explore this possibility.

#### *5.1.11 Main Cabin Equipment Racks*

Main Cabin Instrumentation racks are discussed in detail in Section 6.1.3.1 below.

### **5.2 Research Power System**

#### *5.2.1 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 IDGs is divided between the two 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 in Figure 5.12. Power return circuitry in the GV is not tied to the aircraft frame but is instead returned to the Main Power Distribution Box. The MPDB is referenced to the airframe. Six 3.5 kVA frequency/power converters located in the MPDB provide 115 VAC, 60 Hz power. Three of the converters are powered from the A bus and three 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.

RAF 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 delivery to the main cabin equipment and wing instruments is further controlled by the MPDB, which is monitored by the ADS operator.

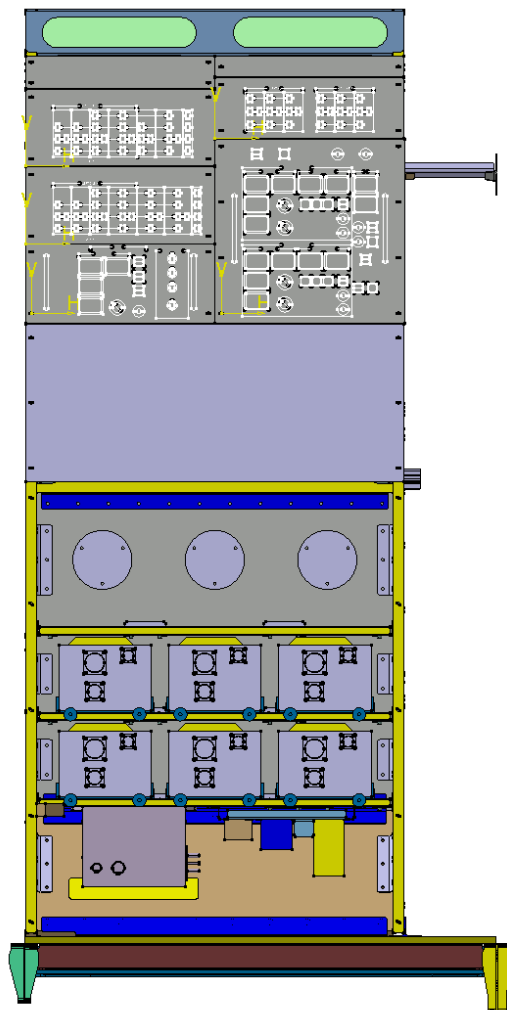
Power from the MPDB is distributed to Secondary Power Distribution Boxes (SPDBs) that are located in the main cabin (eight units), nose (one unit), baggage compartment (one unit), and at each of the six wing hard points. Investigators obtain power for research equipment from the SPDBs. Table 5.1 describes the types of research power available.

Investigators should note that 28 VDC power can only 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.





**Figure 5.12: View of the GV MPDB, located on the right side of the forward cabin, opposite the main crew entry door.**

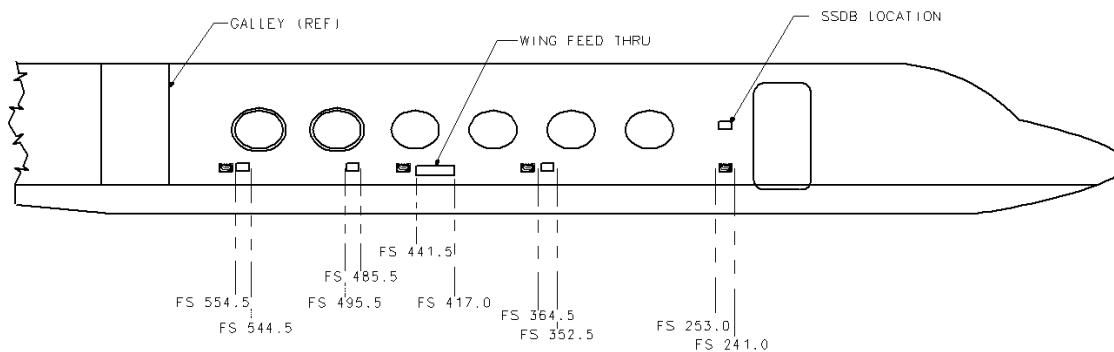
Type of Power	Location(s)	Total Amount Available
60 Hz, 115 VAC single phase	All SPDBs	21 kVA (nominally)
400 Hz, 115/208 VAC	<p>Single-phase: All SPDBs</p> <p>Three-phase: Main cabin SPDBs 3 and 4 only and baggage compartment SPDB</p> <p><b>Note:</b> Single-phase power available at nose, cabin, and baggage compartment</p>	<p>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</p>

	<i>SPDBs is controlled by a weight-on-wheels (WOW) switch and is available only after the GV is airborne</i>	
28 VDC	Wing hard point SPDBs only  <b>Note:</b> 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

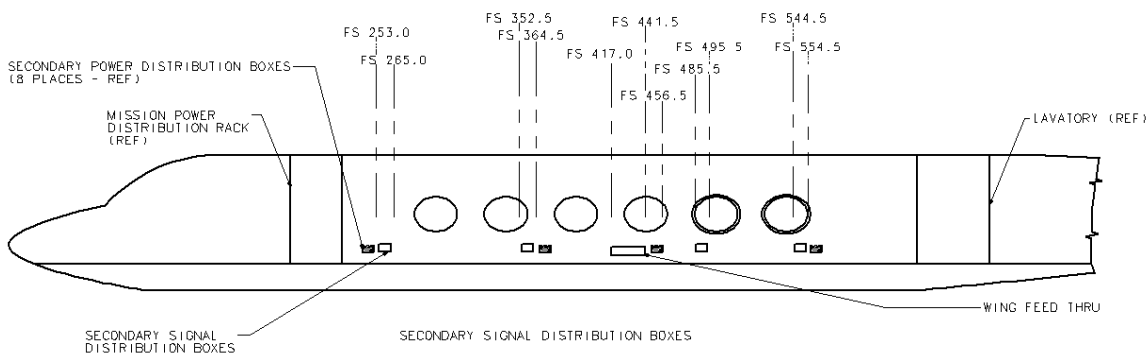
**Table 5.1: Types of research power available on the NSF/NCAR GV**

### 5.2.2 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 evenly spaced SPDBs on each side of the fuselage. Figure 5.13 and Figure 5.14 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 wing hard points. The control for each SPDB is provided by switches / circuit breakers on the front panel of the MPDB. Each cabin SPDB has two identical sets of MS3452W connectors. Each set of these connectors are connected to equipment racks by RAF-supplied cables. Generally, the RAF provides all power cabling from the SPDBs and from the Aircraft Data System (ADS) 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 6.2 of this handbook. Such interconnecting cables may not be routed on the floor or suspended across spaces between racks in order to maintain free access between racks and prevent potential grabbing by hand. Cables that connect racks on opposite sides of the aisle must be routed in one of several cabin pass-throughs (see Section 5.2.3).



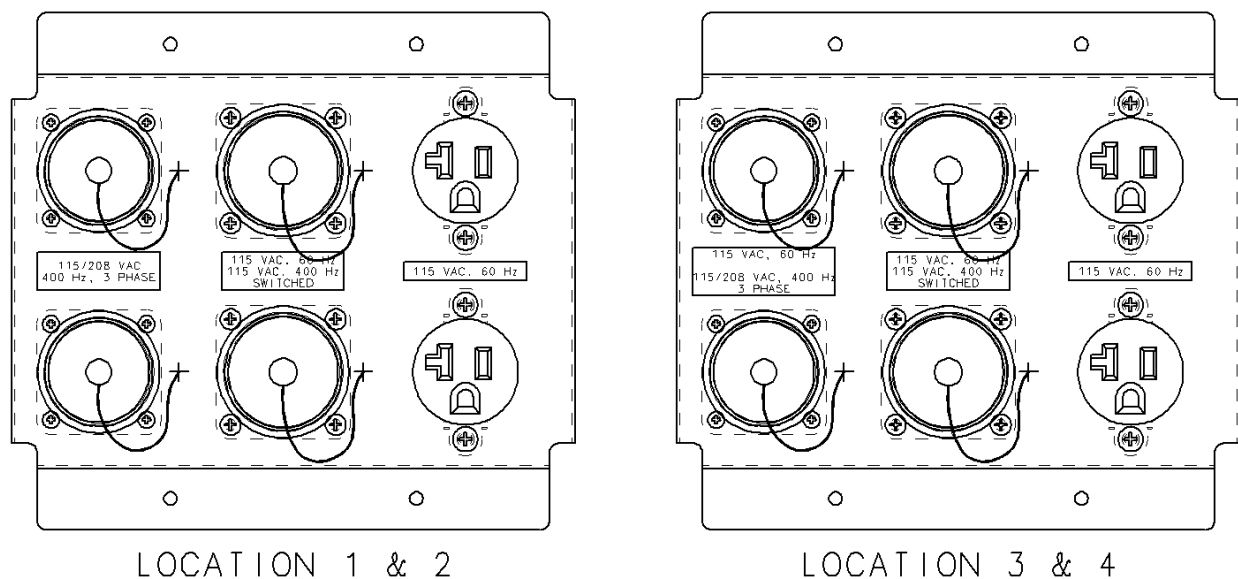
**Figure 5.13: Locations of secondary power distribution boxes (SPDBs) and secondary signal distribution boxes (SSDBs) on the left side of the GV cabin. SPDBs are shown in black, SSDBs in white.**



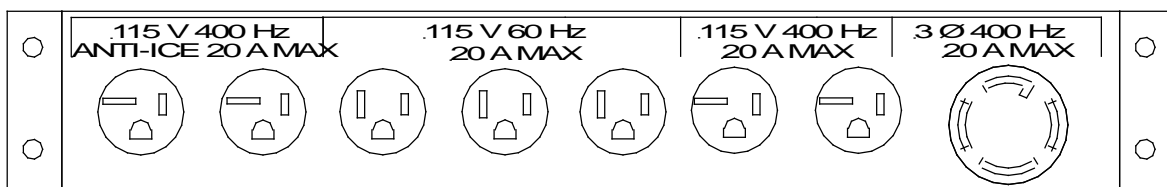
**Figure 5.14: Locations of secondary power distribution boxes (SPDBs) and secondary signal distribution boxes (SSDBs) on the right side of the GV cabin. SPDBs are shown in black, SSDBs in white.**

Each SPDB in the nose, cabin and baggage compartment provides the following: two circuits with a maximum of 20 amps of 60 Hz power each; one circuit with 20 amps of 400 Hz single-phase; one 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 circuit with 20 amps of 400 Hz single-phase anti-ice power. Figure 5.15 shows the configuration of the GV cabin SPDBs.

The SPDBs will interface to RAF-supplied rack mountable secondary power distribution drop boxes (SPDDBs). Figure 5.16 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 5.15: GV cabin secondary power distribution boxes (SPDBs)**



**Figure 5.16: 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 20 amp 115 VAC, 60 Hz circuits; one 20 amp circuit of 400 Hz single-phase; one 20 amp circuit of 28 VDC anti-ice. The two 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

### *5.2.3 Crossover Conduits Description*

The GV aircraft has four 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.

## **5.3 Data Acquisition System and Display**

The GV Aircraft Data System consists of the aircraft data system server (ADS) and data acquisition system, Distributed System Modules (DSM), Data Displays (typically RAF laptops or instrument computers configured for data display) and associated signal wiring and network infrastructure. The following sections are intended to provide users with a general overview of the basic design characteristics and capabilities of the ADS system.

The ADS is an evolving system. It is linked with the Mission Coordinator Display tools, which were first deployed on a large scale in 2011, and with the EOL Field Catalog system. In combination these tools can be utilized for mission guidance, remote instrument control from the ground and real time research data delivery and distribution.

### *5.3.1 Data Acquisition System Overview*

The GV Aircraft Data System (ADS) is a modular system that utilizes data sampling (a.k.a distributed system) 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 ADS server over the aircraft data acquisition gigabit network.

The ADS DSM utilizes an industry standard architecture with a large selection of commercially available off-the-shelf (COTS) hardware. This design approach enables the DSM to accommodate a wide variety of inputs from onboard 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 data collected by DSMs are immediately transmitted to the ADS server (see Section 5.3.4 for additional details). The server runs a data acquisition software that time stamps and logs all received data and also runs a secondary process that re-samples the acquired data to 1 s intervals and prepares them for real time display. All signals recorded through the DSMs by the ADS server are available for display onboard the GV in real time. A configurable subset of these data is transmitted to the EOL ground servers in flight for real time display on the ground. This subset is project specific and can be configured between flights, but not during a flight.

The PC-104 architecture was selected for the GV DSM 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 DSM standard interface. The Plus version will be made available for use in DSM if needed.

The ADS system can be configured to accept calibration parameters in order to present calibrated data on real time displays. Please note that field level data from investigator instruments are not distributed as part of the EOL data delivery and will not be available as part of EOL data files after the end of the field phase of a project.

## 5.3.2 *Data Interfaces*

### 5.3.2.1 *Analog inputs*

Analog signals are connected to DSMs using twin-ax cables connected to internal 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.

A DSM 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.

### 5.3.2.2 *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. ADS has the capability to sample and record all rates which are multiples of 1 Hz.

### 5.3.2.3 Serial Data Interfaces

Industry standard asynchronous RS-232 and RS-422 interfaces are provided in ADS 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 receive double-buffered channels. First In – First Out (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 high level data link control (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 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.*

### 5.3.2.4 Parallel Data Interfaces

The GV ADS 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 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.

### 5.3.2.5 UDP interface

5.3.2.6 *The DSMs are capable of receiving the UDP stream from instruments, and due to the simplicity of the connection this is the preferred way of data acquisition that is utilized more and more on the GV. The interface is configured during the preflight installation of instruments when the RAF software engineers work with the instrument investigators to assign the IP addresses for UDP broadcasts and to configure the data packets for signal interpretation. Specialized interfaces*

Optical, USB and firewire interfaces are also available for data acquisition. These are specialized and require additional advanced consultation with the RAF technical and software groups.

## 5.3.3 Network Description

The aircraft is outfitted with two Ethernet 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 for high bandwidth data transmission is also available, is currently installed in the wings and terminated in the cabin. ) Network access is available at the eight SSDBs in the main cabin, and at the SSDBs in the baggage compartment and the nose. Figure 5.13 and Figure 5.14 show the locations of the main cabin SSDBs.

Network wiring extends to all wing hardpoint locations. A separate network links the ADS server to the SATCOM link for transmission to the ground.

#### *5.3.4 Data Recording*

All data sampled by ADS 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.

#### *5.3.5 System Timing and Synchronization*

A GPS time-of-day signal 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 (EndRun Technologies Tempus LX) receives the GPS time-of-day information and provides these formats through an Ethernet and IRIG-B coaxial connections. 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 ADS 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.

#### *5.3.6 Data Display Overview*

Real-time display of data on board the GV and on the ground is provided by the NCAR Airborne Environment Research Observing System (AEROS) software package. AEROS can be downloaded from <http://www.eol.ucar.edu/raf/Software>. The AEROS package operates on Windows, Mac and Linux based computers and provides investigators with the capability to generate and view the following types of plots: time series, X versus Y, track, skew T, one-line and streaming ASCII lists, statistics, and size distribution. Only data streams recorded on the GV ADS can be displayed on board using AEROS and only the data sent to the ground via SATCOM can be viewed on the ground using AEROS.

#### *5.3.7 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.

## 5.4 Satellite Data Communication Link

As outlined in Section 2.5.15, 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 ADS from the ground during flight. Semi-autonomous instruments that are connected to ADS 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 ([http://www.eol.ucar.edu/flight\\_data](http://www.eol.ucar.edu/flight_data))

## 5.5 Ground Support Computing

### 5.5.1 *Flight support system*

The AEROS data display onboard the GV and on the ground can be optionally augmented to several levels by the inclusion of auxiliary data displays called summarily the Mission Coordinator Display (MCD) tools. The MCD provides updating map overlays of data such as satellite imagery, real time flight track display of the GV and, optionally, collaborating research aircraft; lightning strike data; dropsonde data; NEXRAD or onboard weather radar data; vertical temperature data; lidar data etc. These supporting products are not made available to all projects by default but are provided on a request basis at the level necessary for the particular project. They can be used for real-time

flight change requesting, weather targeting or avoidance and fine tuning the flight patterns.

### *5.5.2 Field catalog system*

EOL field catalog is another level of mission support software that is designed to ingest, store, distribute and archive a large variety of configurable data products. The catalog typically includes satellite imagery and time loops; model generated products; instrument status reports; flight reports and scientific briefs; picture archives; preliminary datasets from the aircraft instruments and any other data necessary for the project.

### *5.5.3 Ground data QC and distribution system*

Depending on the region of operations and the location of the project 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.

## **5.6 Data Products**

Immediately following each GV research flight, EOL personnel will process the collected data and output the results in the network Common Data Form (netCDF) format. More information on netCDF is available on-line at <http://www.unidata.ucar.edu/software/netcdf>. 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 ADS will be processed by Nimbus and can be released in the preliminary aircraft netCDF data files or removed from them if requested by the instrument investigator. All investigators who record data on stand-alone data systems are responsible for the processing and release of their own collected data products according to the timelines established by the project.

EOL has established a NSF-approved 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/data/data-policy>. Investigators are strongly encouraged to review and become familiar with this policy in advance of the start of the designated field program.

## Chapter 6 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 to enable developers to construct fully compliant equipment, investigators should also be aware that EOL personnel can 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.

Research equipment design should follow the guidance in FAA Advisory Circular 20-168 and RTCA DO-313. These documents standardize and streamline the process for demonstrating compliance with airworthiness requirements for non-Essential, non-required aircraft cabin systems and equipment. Normal operation of the equipment, or failure of it to perform its intended function, cannot adversely affect the safety of the aircraft or its occupants, or the proper functioning of required equipment and systems.

### 6.1 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 users in understanding and complying with the requirements of this section.

### 6.1.1 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.

#### 6.1.1.1 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:

$$MS = (\text{Allowable}/(\text{Actual} \times \text{Factor1} \times \text{Factor2} \times \dots)) - 1$$

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 Table 6.1 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)	Caero	1.25
Equipment Mass Factor	Applied to black box mass to account for structural, wire bundle, and any other miscellaneous mass.(2)	Cmass	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

**Table 6.1: Analytical Factors**

**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.

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

#### 6.1.1.2 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 Table 6.2. The emergency landing condition loads act separately and are ultimate loads. These loads act independent of the flight loads and pressurization loads.

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 6.2: 14 CFR Part 25, Emergency Landing Load Factors**

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 ultimate vertical inertia load factors outlined in Table 6.3 conservatively apply to the NSF/NCAR GV aircraft at the indicated locations.

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  $\pm 3.0g$  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

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 6.3: GV Inertia Load Factors**

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 lbs 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 lbs ultimate vertical load. For equipment that could be subjected to pulling or pushing forces, the installation should be capable of supporting a 100 lbs 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 given in Table 6.4.

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 6.4: 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

- $p_{max}$  = 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)
- $p_{burst} = 3.0 \times p_{max}$  (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 flight conditions shown in Table 6.5 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 6.5: Flight Conditions for Aerodynamic Loads Analysis**

## 6.1.2 Construction Guidelines

### 6.1.2.1 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 their 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 do 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. Table 6.6 provides an indication of the galvanic corrosion potential between dissimilar materials.

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

**Table 6.6: Galvanic Corrosion Potential**

### 6.1.2.2

### Fasteners

All fasteners should be aircraft quality hardware (to AN, MS, or NAS standards and specifications). Table 6.7 provides information on more commonly used aircraft fasteners.

Designation	Fastener Description
Conventional Rivets MS20470AD MS20426AD NAS1097	Protruding Head Solid Rivet Flush, Full Size Head Flush, Reduced Head
HI-Loks HL18 HL19 HL70 HL20 HL21 HL86	Protruding Shear Head Pin Flush Shear Head Pin Shear Collar Protruding Tension Head Pin Flush Tension Head Pin Tension Collar
Bolts/Screws AN3-AN20 NAS6203-NAS6220 MS24694 NAS517 AN525 MS27039 NAS623	Hex Head Bolt (125 ksi) Hex Head Bolt (160 ksi) Flush Head, Phillips Drive (125 ksi) Flush Head, Phillips Drive (160 ksi) Washer Head, Phillips Drive Screw Pan Head, Phillips Drive (125 ksi) Pan Head, Phillips Drive (160 ksi)
Washers NAS1149 AN970	Plain Washer Large Area Flat Washer
Nuts MS21042 MS21044 NAS1804	Hex Nut, Low Height, Self Lock (160 ksi tension) Hex Head, Full Height, Nylon Lock (125 ksi tension) 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 6.7: Aircraft-Quality Fasteners**

#### 6.1.2.3 *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.

#### 6.1.2.4 *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 6.1.1.2 above.

### 6.1.3 *Installation*

#### 6.1.3.1 *Main Cabin Equipment Racks and other cabin installations*

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 19 inch racks

are designed to the EIA-310 standard (19" mounting rail dimension; 17.72" clear opening; 18.312" mounting hole spacing; refer to the EIA-310-D standard for full details when designing rack mounted 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 (please ensure that custom-built enclosures conform to the EIA-310 dimension requirements). 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. 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. A 3/8 inch panel is attached to the top and bottom and can also be used for equipment mounting. These aluminum 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.

The bottom plate of the MCE rack can be bear equipment by modifying it to install potted threaded inserts. This type of installation is highly recommended for heavy components such as pumps. Equipment attached to the bottom plate has a zero inch CG height in the rack and does not contribute to the overturning moment (although it does contribute to the total weight, which is limited by the maximum GV floor loading).

The upper MCE rack plate can be removed to allow limited protrusion of components from the rack internal space. Upper plates should be installed on all racks that do not have such protruding parts, for equipment protection.

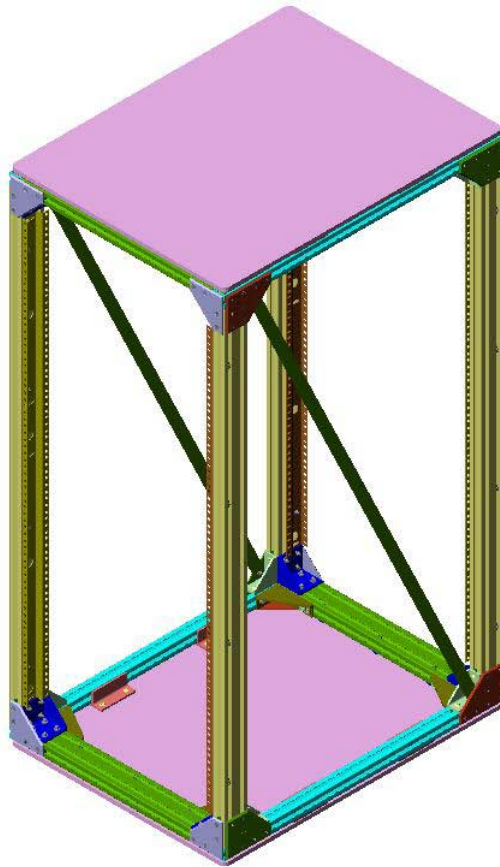
Figure 6.1 shows a standard cabin equipment rack.

The maximum allowable equipment weight is 350 lbs. 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-lbs. 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 (S component weights); and
- Total moment (S component weight x cg height from base).

A rack attached to the floor seat track and ceiling rail (not available at all floor stations, contact RAF for more information) can support 340 lbs of equipment with the CG located at 25 inches above floor level (8,400 in-lbs overturning moment).

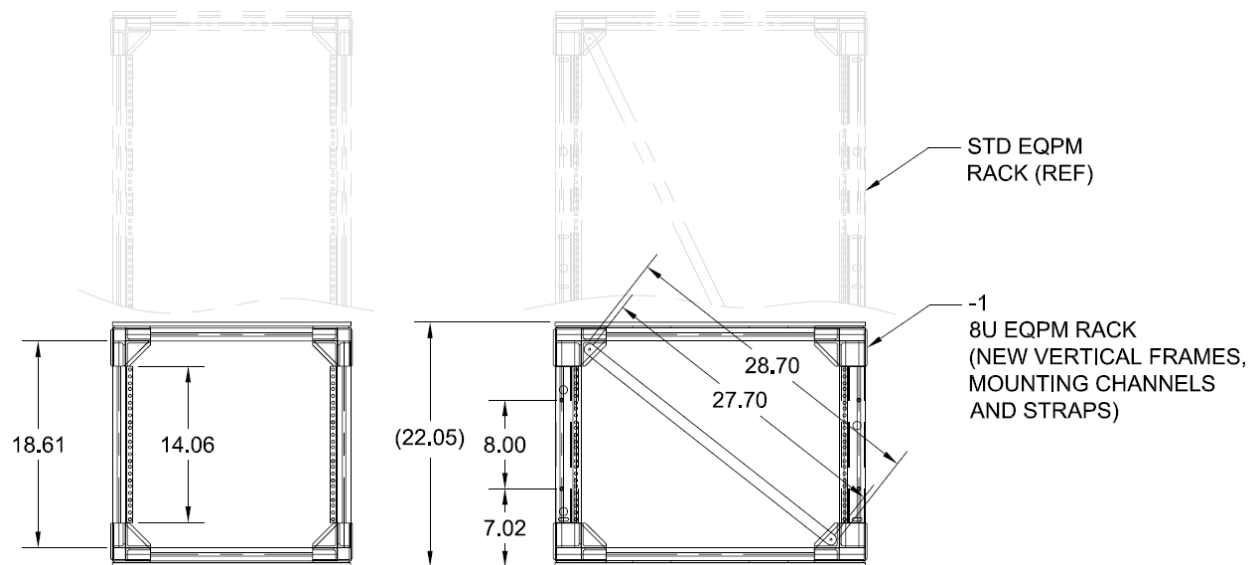
RAF has designs and actual parts for additional hardware for rackmount installations. Full length and half length aluminum shelves are available with a 70 lbs and 20 lbs load capacity, respectively. Laptop mounting trays and storage drawers are also available.



**Figure 6.1: Standard Equipment Rack**

Short, 8U equipment racks are also available (Figure 6.2). These racks allow installation of equipment into the internal 8U of space and can support equipment on the top mounting surface that does not fit within the constraint of a standard 19 inch rack mount form factor.

**Note:** keep in mind that oversize instruments can only be accommodated on the GV as long as proper egress clearances are maintained in the cabin. Contact RAF in advance to ensure instrument compatibility with the GV cabin if you think a short rack can be utilized.



**Figure 6.2: Short (8U) equipment rack drawing. A full size MCE rack is shown in gray scale for comparison. All dimensions in inches.**

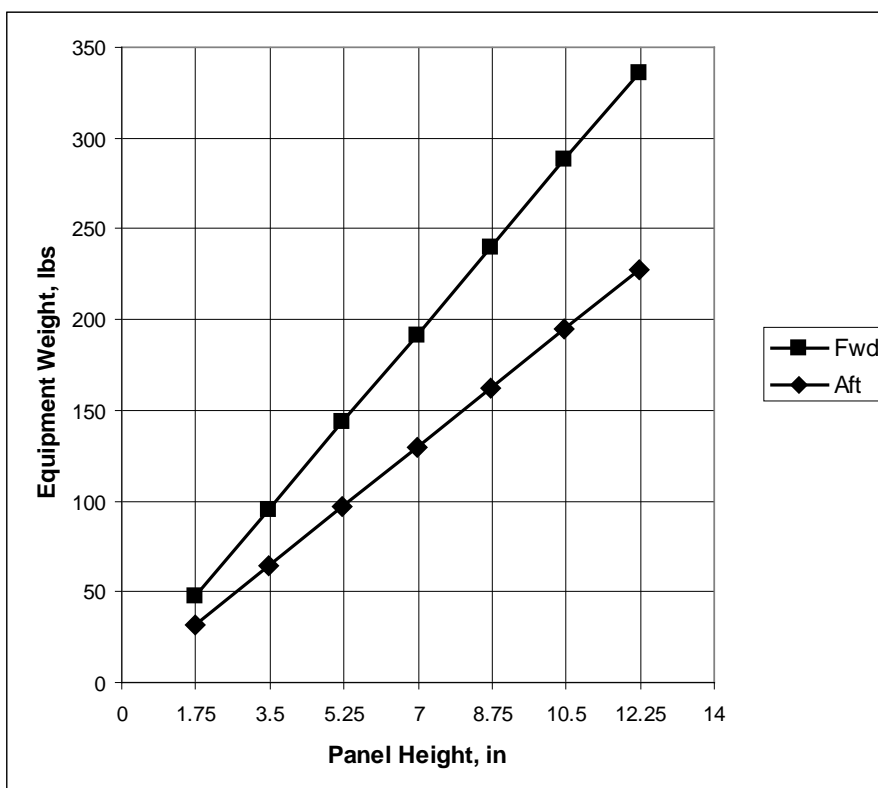
For installation of large optical instruments in the proximity of the optical viewports in the forward cabin there exists a design for a longer, half height rack that can accommodate a large instrument on the top, more equipment in the rack and spans two floor stations L1 and L2. The existing rack is instrument specific and cannot be used for other installations, however the design is approved and certified can be replicated if necessary. This design also includes a cantilever mounting for a telescope aligned with the forward coaxial viewports.

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 EOL 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 can provide additional information on these latter two options.

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 Figure 6.3. For example, equipment weighing 75 lbs would require a 2U (3.75 inch) panel for forward face mounting or a 3U (5.25 inch) panel for aft face mounting.

Per Figure 6.3, equipment weighing 50 lbs 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-lbs (Moment =  $50 \times 4 = 200$  inch-lbs) 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.



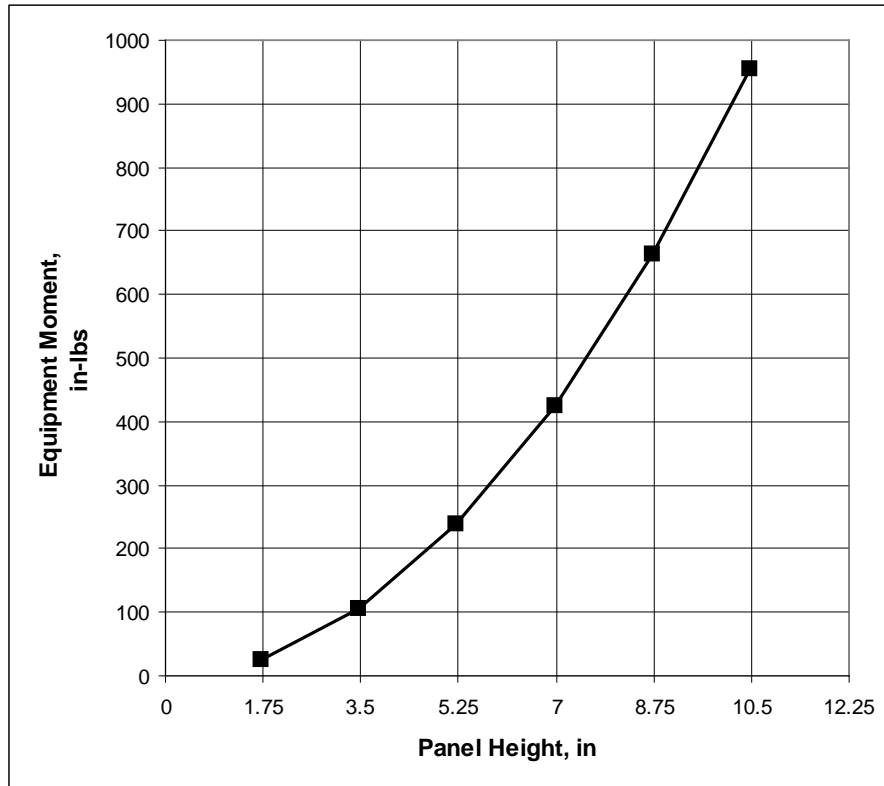
**Figure 6.3: Allowable equipment weight for mounting to face chart**

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. Due to the level of effort required to approve special racks, early coordination with RAF Aeronautical Engineering is necessary.

Maximum equipment weight for the cabin floor cannot exceed any of the following parameters:

- 49 lbs per square foot uniformly distributed,
- 98 lbs per square foot with a 20 inch central clear aisle, or
- 200 lbs per square foot (187 lbs per square foot on the center aisle) applied to one isolated square foot at least 30 inches from another load.



**Figure 6.4: Allowable face-mounted equipment moment chart**

#### 6.1.3.2 *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 the RAF Aeronautical Engineering group 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 lbs with a maximum moment at the floor of 4,200 inch-lbs.

#### 6.1.3.3 *Wing Stores*

Refer to Section 5.1.5 above for the overview of available wing store configurations.

#### 6.1.3.4 *Fuselage Exterior*

The numerous fuselage pads, hardpoints, and apertures were described in Chapter 2 of this handbook. Table 6.8 presents the structural capabilities for the various locations.



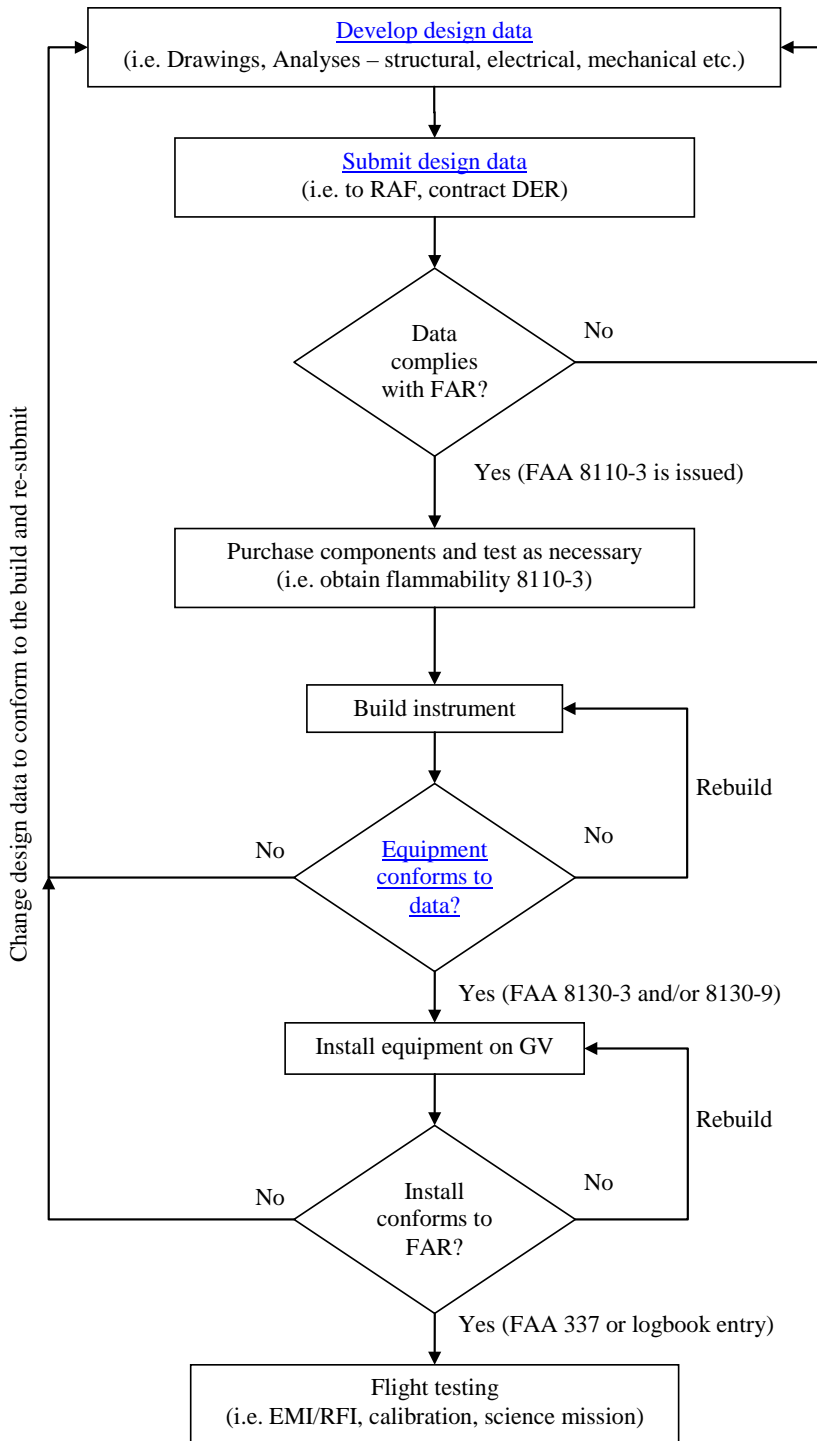
Location	Static Load, lbs	Frontal Area, sq. in., Or Envelope, L in. x W in. x H in.	CG from A/C Skin, inches
Forward Fuselage Pad	2	18	9
Center Fuselage Mounts	25	24	20
Apertures			
External Equipment	50	54	12
Internal Eqt, Upper	25	16 x 16 x 8	8
Internal Eqt, Lower	25	13.5 x 10.5 x 9.5 inbd, 7.5 outbd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

**Table 6.8: External Mounting Provision Capabilities**

#### 6.1.4 Certification

The instrument provider 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. Following the new instrument development flowchart shown on Figure 6.5 will help ensure that the design process is tied with the necessary certification steps and minimize the wasted effort.

## Certification process for NCAR aircraft instrumentation



### Glossary of abbreviations

RAF: NCAR Research Aviation Facility

DER: Designated Engineering Representative

**Figure 6.5: New instrument development flow chart**

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:

#### *6.1.4.1 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.

#### *6.1.4.2 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 margin of safety exists for all structural elements and electrical components. RAF Aeronautical Engineering can usually assist the researcher with the structural analysis report depending on workload. RAF's 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 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
- Cryogenics (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 >130oF 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 and coordinate with the RAF Project Management to ensure that appropriate approvals are obtained prior to the start of operations.

## 6.2 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.

### 6.2.1 *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 the Certification Engineer 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).
- Wiring from the approved wire list provided in Appendix C or from the updated List of Approved Wire and Materials on the RAF web site: <http://www.eol.ucar.edu/instrumentation/aircraft/G-V/documentation/approved-wire>.

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.

### **6.2.2 Flammability**

Non-Essential, Non-required Equipment must meet flammability requirements. Enclosure in a six sided metal case or containment device or burn testing from an FAA-accepted testing lab.

Non-metallic and/or vented cases and/or exposed panels (> 36 square inches) and significant internal components such as circuit boards (> 36 square inches) must be flammability tested. Small parts (knobs, handles, rollers, fasteners, clips, grommets, rub strips, pulleys, and small electrical parts) and components with a UL label and a volume < 50 cubic inches are exempt.

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](http://www.picwire.com)) and Electronic Cable Specialists ([www.ecsdirect.com](http://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 be 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***

Companies such as Flame Out (402-795-2122), Skandia, Inc. (815-393-4600) or any other certified to conduct FAA approved flammability testing can be contacted to perform wire testing and to generate the required Form 8110-3 for wire and cable used in NCAR installations on the GV. 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.

### ***6.2.3 Electrical Requirements, System Wiring, Marking & Placards***

Circuit Protection – Wiring must be protected by an appropriately rated Circuit Breaker

Wire Selection and Identification – Wire must be properly sized, designed for airborne use and properly identified.

Marking & Placards – Circuit breakers or switches shall be clearly marked or placarded

Flammability – Must meet applicable flammability requirements

### ***6.2.4 Electromagnetic Compatibility (EMC/EMI)***

Non-Essential, Non-required Equipment should be tested to ensure it does not interfere with aircraft systems.

### ***6.2.5 Stress Certification, Crashworthiness and Structural Integrity***

Installation must be structurally secured and validated by design data, analysis and/or test of the unit enclosure.

Glass - components must be tempered or contained; sizes above 15 inches diagonal must pass a static abuse load and dynamic ball test or be suitably protected with a shield. This also applies to all LCD computer monitors and laptop screens.

### ***6.2.6 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.

### ***6.2.7 Equipment Bonding and Grounding***

Proper bonding – provide a low-impedance path to the aircraft basic structure.

Electrical - Output neutrals of the powers supply should not be tied to the input neutral, the input and output neutral should not be tied to the airframe. The ground of the three

wire power can be tied to chassis, rack airframe. Signal shields should not be tied to output neutral.

### *6.2.8 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. Channel inserts for rack frames and clamps are available at RAF to assist with this task.

### *6.2.9 Electrical Equipment Guidelines*

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.

Large batteries are not acceptable for flight installations unless they carry a Technical Standard Order (TSO)-C173 certification. Further FAA certification and approval may be required; users should contact RAF in advance if their equipment relies upon the use of such batteries.

#### *6.2.9.1 Uninterruptible Power Supplies (UPS)*

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



#### 6.2.9.2 *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. 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](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.

#### 6.2.9.3 *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 54° C (130° F) are generally considered safety hazards and must be surrounded by adequate shielding and be labeled with caution signs.

#### 6.2.10 *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 as most 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 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 and are available from various suppliers such as <http://umainstruments.com/> (under Flight Instruments, Pressure Warning Switches).

### 6.3 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 RAF Aeronautical Engineering.

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

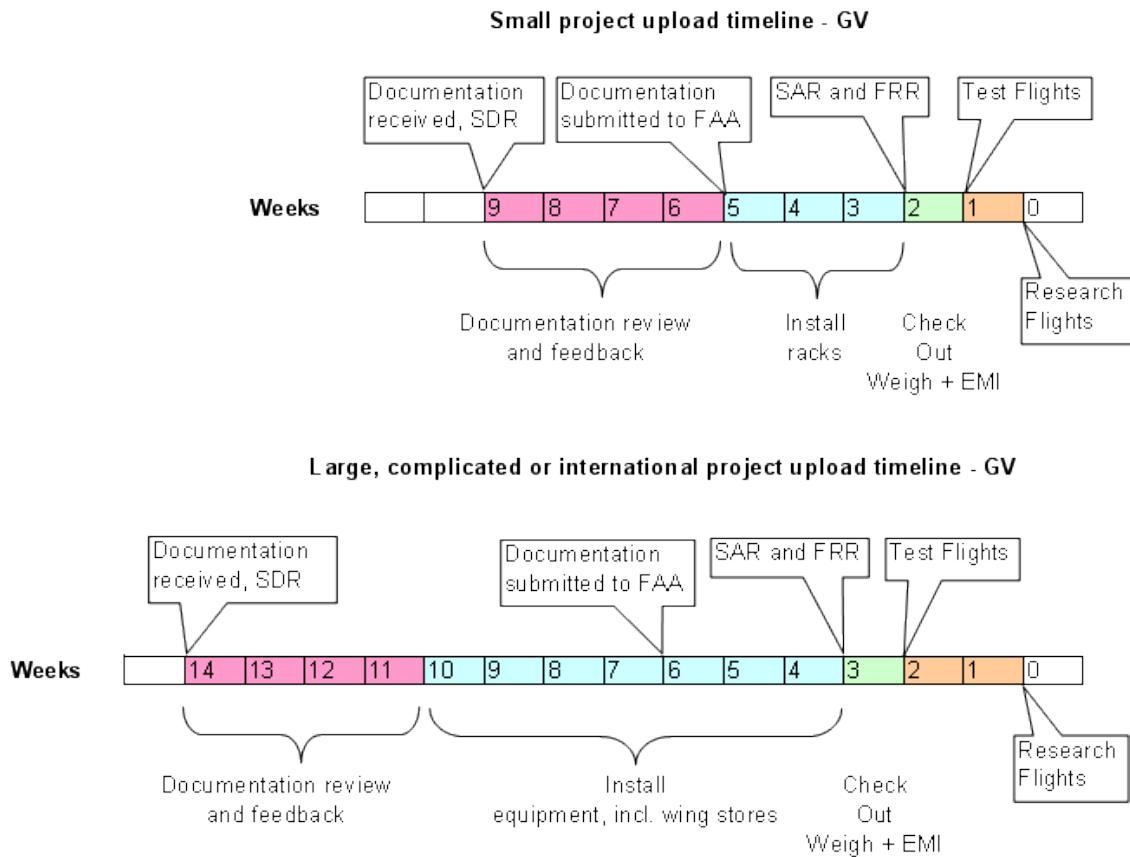
rule of thumb of one inch of depth increase per each 100 inches of fuselage length (with fuselage length measured from the tip of the GV radome);

- 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  $2^\circ$ .

## Chapter 7 Feasibility & Instrumentation Integration Procedures

### 7.1 Instrument Certification and Approval

New instruments still under development are often included in requested research payloads. Field deployments have very specific deadlines and it is difficult to fully assess the airworthiness, functionality, and availability of these systems on such a time line (see Figure 2.1 for the typical time line of field project certification, upload, test flight and deployment).



**Figure 2.1: Typical time line for field project documentation, certification and review processes.**

As discussed in Section 2.3, special arrangements need to be made to certify and “pre”-test these instruments prior to their inclusion in an approved research payload.

### 7.2 Project lifecycle reviews and payload certification

In preparation for project upload, several reviews will take place. They are: System Definition Review (SDR), System Acceptance Review (SAR) and Flight Readiness Review (FRR).

### 7.2.1 SDR

The SDR is to be held about a month prior to the beginning of project upload. The purpose of the SDR is to assess the status of documentation and instrument readiness for project installation with sufficient time to correct omissions and mistakes in documentations. (For equipment flown previously on the GV the documentation is needed only if the equipment has since changed). Participants in the SDR are RAF staff in consultation with the lead instrument and project PIs.

The next two milestones will take place one week before the first planned test flight. At this point the installations of equipment into the aircraft should be completed.

### 7.2.2 SAR

The purpose of the SAR is to assess the state of measurements from each instrument as installed on the aircraft. Instrument PIs will be asked to comment on measurements, data logging, communication with other systems, etc. and essentially provide an overview of the measurement quality at the time of the SAR. Participants in the SAR include RAF staff, instrument PIs, and the lead experiment PI.

### 7.2.3 FRR

The FRR will determine the airworthiness of the payload and will also be held one week prior to the first flight. The lead RAF aeronautical engineer (Mark Lord) will go through instrument installation one-by-one, and ask the RAF group heads (maintenance, technicians and pilots) if all required information (structural, materials, electrical, etc.) have been provided by the instrument PI. Instrument PIs do not participate in the FRR.

These reviews are not "pass-fail" exams but rather they are a formalized way of assessing the project preparedness status at several critical stages in the lead up to the project launch. We stress that the installations should essentially be done prior to the SAR and the FRR, and that the week between these reviews and the first test flight should only be used for minor instrument tune-ups, calibrations, etc.

Results of all reviews will be summarized and distributed to the project participants via E-mail.

### 7.2.4 EMI Test and safety briefing

In addition, three activities need to take place before the first test flight: the airplane must be weighed; electromagnetic interference (EMI) test conducted and all persons flying on the aircraft must attend a safety briefing. Attending an RAF safety briefing for an earlier project does not count: safety briefings are mandatory before each project.

## 7.3 New Instruments

New instruments that have never flown on any aircraft before must successfully complete a flight test sequence prior to approval for use on a field deployment. Such testing must be done to insure both the airworthiness and functionality of the instrument. PI's will be asked to denote which instruments are "required" to meet their scientific goals. "Required" sensors must complete this process at least three months prior the scheduled start of the payload integration. "Clones" of previously flown instruments will

be exempted from this requirement on a case-by-case basis depending on a review of any documented differences between the two systems. Sensors considered to be “optional” to the scientific goals of the experiment may delay testing until the project specific, pre-deployment flight tests with the clear understanding that a failure to perform satisfactorily will result in their removal from the payload prior to the field deployment.

Instruments that have not flown before and need to participate in a flight test sequence can satisfy that requirement by requesting a test flight sequence either as a part of the request process for a field deployment, or as a separate request for instrument flight testing (see Section 7.6, below). We recommend that proposers discuss instrument testing needs with RAF management and engineering and their NSF project officer when planning future field programs with new instrumentation.

For the purpose of approval for flight some particularly important factors are: non-metallic materials; power consumption; and wiring.

### **7.3.1 G-V**

Participation on any flight test program on this platform requires that the instrument pass through the FAA certification process. Details on this process, including material, power and wiring constraints, as well as design and fabrication documentation requirements can be found in Chapter 6.

### **7.3.2 C-130**

For this category only, the basic requirements on materials and power/wiring constraints are the same as the G-V. No formal FAA certification is required, but documentation on key system components must still be submitted to the RAF on the certification schedule outlined in the certification material above. However, it is highly recommended that newly designed instruments to be flown on the C-130 comply with the full set of requirements for the GV. This will ensure their future compatibility with the GV.

## **7.4 Instruments Previously Flown**

Instruments that have successfully been flown on one of the NCAR aircraft, or any other manned research aircraft in the international fleet, will typically be exempt from the pre-upload functionality flight testing requirement. However, systems that have undergone modification since their last deployment must be re-evaluated to establish the extent of the changes. If the modifications are deemed to be significant (i.e. replacement of a primary component with new technology), some form of additional flight testing may be required. Key factors that will be evaluated are: non-metallic materials; power consumption; and wiring.

### **7.4.1 G-V**

Participation on any field program on this platform requires that the instrument pass through the FAA certification process. Details on this process, including material, power and wiring constraints, as well as design and fabrication documentation requirements can be found Chapter 6 above. Certification on another platform or by another regulatory agency on a similar platform (like the DLR “HALO” G-550) does NOT transfer

between platforms, but the basic documentation should be similar. The certification process, which is payload specific and not instrument or rack specific, must be completed prior to the start of sensor integration on the G-V. Therefore, all certification documentation must be submitted to the RAF engineering staff 2 month prior to the scheduled upload. Failure to submit the required documentation by this deadline will result in the removal of this instrument from the research payload. Instrument providers may be required to rebuild structural and electrical components or replace unsuitable materials as part of the certification process. Project specific payload flight testing will be conducted just prior to deployment to the field site.

#### 7.4.2 C-130

Participation in any program on this platform only requires notification of key integration and support needs and successful completion of a structural, materials, power and wiring review by RAF staff. There are no formal documentation deadlines beyond the initial submission of the facility request, although some basic documentation will be needed for the facility records. Drawings and documentation should be available for submittal to the RAF Aeronautical Engineering upon request. Project specific payload flight testing will be conducted just prior to deployment to the field site.

### 7.5 Feasibility Review of Proposed Campaigns

The process for requesting one of the NSF/NCAR aircraft platforms in support of a scientific field project and the deadlines for filing such a request can be found on the EOL web site (<http://www.eol.ucar.edu/deployment/request-info/forms/request-forms-for-nsf-lower-atmospheric-observing-facilities>). As per standard practice, information on all User supplied equipment to be included in a specific research payload must be provided as part of the EDO as well as the formal request. Any special instrument integration requirements should be noted at this time. Prior to a scientific review by NSF and the OFAP panel, EOL conducts a very specific “feasibility review” to determine if the research payload is supportable and if the requested flight operations can be supported in a safe manner.

In the EDO and Facility Request feasibility review processes, field program payload requests will be evaluated on the basis of “required” versus “optional” sensors. During the interactive communications prior to the submission of a formal request for support, PI’s will be asked to denote which instruments are “required” to meet the scientific goals of their project. If a New Instrument (EOL or User supplied sensor) is included in the list of required instrumentation for an EDO and this instrument has not completed the functionality flight testing the RAF will communicate with the PIs and the NSF to determine a course of action that may include:

- Delaying the research project until the flight and performance testing or the required instrument is completed,
- Investigating the possibility of involving an equivalent instrument with existing performance history,
- Investigating whether or not the instrument is justified as "required" for the field project.

If an EOL supplied New Instrument is included in a Facility Request as "required" or "essential" and has not completed the functionality flight testing by the time of the OFAP meeting discussing the request, the request will be deemed "Unfeasible". In the event that any User supplied New Instrument on the required list cannot meet the GV certification and safety requirements, RAF will inform NSF that the sensor is not "airworthy" and recommend that the field project be re-evaluated for feasibility and scientific merit with that sensor omitted from the research payload. Failure of an "optional" sensor to comply with the stated requirements would result in the removal of that system from the overall research payload without impact on the overall project feasibility.

## 7.6 Flight Test Opportunities

A key component of ensuring that new instrumentation is ready for research deployments without compromising the compressed project deployment timelines will be the inclusion of annual flight test programs into the RAF schedule. Scheduled flight test opportunities are open to all NSF supported instrument developers so that they can comply with the new requirements on New Instrument flight testing. Space is limited and will be allocated based on system readiness and on association with an NSF funded research project. EOL plans to continue with some form of annual flight test program (based on the example of the IDEAS programs). Depending on community need and available intervals in the RAF deployment schedule, more than one test program may be scheduled in a particular year. The platform chosen for any specific flight test program (GV or C-130) will vary, depending upon availability. For more information on how to participate in one of these flight test program contact the RAF Facility Manager.



## **Chapter 8 Insurance – Liability Coverage, Bodily Injury, Property Damage**

Aircraft operations conducted by UCAR/NCAR personnel are insured – to the extent of the policy coverage – for legal liability arising from third-party claims.

This coverage extends to instrumentation installed on the aircraft as part of NSF-approved flight operations. UCAR also is insured for legal liability involving operation of motor vehicles and general liability hazards.

All UCAR/NCAR staff members are covered by the UCAR Travel Accident Policy as stated in the UCAR Benefits Manual.

Non-UCAR staff should check with their home institution for workers compensation coverage, medical and life insurance coverage, for possible insurance exceptions related to flying in a public aircraft operation.

## **Appendix A**

### **NSF/NCAR GV Intercommunications System (ICS) Operating Instructions**

#### **Overview**

The Intercommunications System (ICS) installed on N677F consists of eight Audio Control Panels (ACP) and four 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:

- HOT MIC
- 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:

HOT MIC  
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 then 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:

VHF2 Audio  
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:

SATCOM Audio  
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:

SATCOM Audio  
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

### Research Aviation Facility (RAF)

#### Medical Information for Airborne Research

Prepared with the assistance of Dr. Warren Jensen, FAA Senior Medical Examiner, Director of Aeromedical Research, University of North Dakota, (UCAR OGC Review August 03)

The following information should assist you in identifying potential problems that could interfere with your ability to participate in research in NCAR/NSF aircraft. The information contained herein is in no way designed to be comprehensive. If you have any concerns about your ability to fly on NCAR/NSF aircraft, please consult your physician.

There is a possibility that you may be in situations that would require you to take care of yourself including such activities as evacuating the aircraft, dealing with turbulence, opening doors, and wearing an oxygen mask. It is important to identify conditions that may interfere with your performance of such duties. If you feel you cannot perform any duty or feel there may be an issue that could affect any aspect of your participation, do not continue without first consulting your physician.

The following medical conditions and policies could affect your safety and ability to participate in research in NCAR/NSF aircraft. Should you feel that you possess any of the conditions listed below or if you are unable to comply with any of the policies listed, you should NOT participate in NCAR/NSF aircraft at this time.

1. Any medical condition that would not allow you to continuously walk for 10 minutes or up two flights of stairs.
2. Any medical condition that would inhibit your ability to be able to lift 40 pounds.
3. Interruption of your normal activities because of difficulty breathing, conditions such as asthma, or other lung/heart problems that interrupt your normal activities.
4. Ear or sinus problems when flying.
5. Motion sickness when flying.
6. Problems with hearing and speech that would interfere with the ability give and receive instructions in a room with moderate background noise.
7. Taking any medication that gives side effects of drowsiness or difficulty in maintaining alertness.
8. Any condition, illnesses or injuries that would interfere with the ability to perform duties on research flights and to evacuate the aircraft if necessary.
9. Any condition, illnesses or injuries that might require the assistance of a RAF crewmember.
10. RAF policy limits flying for 24 hours after immunizations, dental work, and SCUBA diving.
11. Pregnancy beyond the 20th week as well as any other concerns related to the health of a pregnant mother or baby.
12. RAF policy prohibits carrying any person suffering effects from alcohol consumption on a flight, regardless of when it was consumed, and also restricts flight if alcohol has been consumed within 8 hours prior to flight.

### 13. Symptoms of upset stomach, gas, or diarrhea prior to flight

## Appendix C

Approved wiring and non wire materials

August 10, 2012

**RAF recommends using MIL-W-22759 wire for all Single Conductor Wire applications as listed in Advisory Circular AC 43.13-1B Table 11-11 “Open Wiring”, specifically MIL-W-22759/16. These wire types meet FAA flammability requirements. Wires listed in Table 11-12 “Protected Wiring” of the same Advisory Circular are NOT acceptable for use outside of a metal enclosure.**

### Multiconductor Cable

Type	Part Number	Manufacturer	ID	Supplier
STP-12	12-TE-1925(2)STJ	Thermax	677F-1	All Cable
STP-12	CA 1888	Cal Wire	57449	California Wire
STT-12	12-TE-1925(3)STJ	Thermax	677F-1C	All Cable
STT-12	CME4-03-STW-1219	Astro Ind	75866	Electrospec
STT-14	14-TE-1927(3)STJ	Thermax	677F-2	All Cable
STT-14	CME4-03-STW-1419	Astro Ind	75867	Electrospec
STP-16	16-TE-1929(2)STJ	Thermax	59633	ElectroSpec
STP-16	CME4-02-STW-1619	Astro Ind	58575	ElectroSpec
STT-16	16-TE-1929(3)STJ	Thermax	677F-3	All Cable
STT-16	CME4-03-STW-1619	Astro Ind	75860	Electrospec
STT-18	18-TE-1930(3) STJ	Thermax	677F-9B	All Cable
STT-18	CME4-03-STW-1819	Astro Ind	75868	Electrospec
STP-18	CME4-02-STW-1819	Astro Ind	75857	Electrospec
STP-18	18-TE-1930(2)STJ	Thermax	81173	Electrospec
STP-20	20-TE-1932(2)STJ	Thermax	677F-4	All Cable
STP-20	CME4-02-STW-2019	Astro Ind	75858	Electrospec
STT-20	20-TE-1932(3)STJ	Thermax	90408	All Cable
STT-20	CME4-03-STW-2019	Astro Ind	90408	Electrospec
STP-22	22-TE-1934(2)STJ	Thermax	89728	All Cable
STP-22	CME4-02-STW-2219	Astro Ind	75859	Electrospec
STT-22	22-TE-1934(3)STJ	Thermax	57449	All Cable
STT-22	CME4-03-STW-2219	Astro Ind	75862	Electrospec
STT-24	24-TE-1936(3)SXE	Thermax	677F-6	All Cable
STT-24	24-TE-1936(3)STJ	Thermax	75865	All Cable
STT-24	CME4-03-STW-2419	Astro Ind	75861	Electrospec
STQ-24	24-TE-1936(4)STJ	Thermax	677F-7	All Cable
STQ-24	CME4-04-STW-2419	Astro Ind	75863	Electrospec
ST5-24	24-TE-1936(5)STJ	Thermax	81173	Electrospec
STQ-26	26-TE-1938(4)STJ	Thermax	677F-2C	All Cable
STQ-26	CME4-04-STW-2619	Astro Ind	75864	Electrospec
TWX	M17/176-00002	Thermax	677F-14	All Cable
HEAD1	YQ-27540	Belden	677F-16	Buck Research
HSDQ	89728	Belden	677F-17	Belden
Multi conductor	342239-39/C	Electronics cable	87901	Electronics cable

cable		Specialist		Specialist
PMS Cable	6548PA	Belden	90355	Electrospec

### Special Wire

Type	Part Number	Manufacturer	ID	Supplier
C50	S44191	PIC	6870	PIC
C50	COAX316SON #RL0458338	Thermax	57436	All Wire
C50	S44193	PIC	6753	PIC
C50	S33141	PIC	2831	PIC
C50	S22089	PIC	7404	PIC
NET	E50824	PIC	6753	PIC
USB	USB2422	PIC	7161	PIC
FW(Fire-wire)	FAWM226C-008	Northwire	91904	Northwire
FW(Fire-wire)	FAWM226C-003	Northwire	91905	Northwire
Firewire	912406	Electronic Cable Spec	9972	Electro Spec
Fiber optic	S696T-02F-62X	DRAKA	9710	Glenair
Fiber optic	S696T-01-62X	DRAKA	9710	Glenair
Fiber optic	S696T-16-62X	DRAKA	9710	Glenair
Thermocouple	5TC-TT-T-24-36	Omega Engineering	87819	Omega Engineering
Thermocouple	WTT-6-60-TT	Omega Engineering	88169	Omega Engineering
Thermocouple	EI1110202/SA1-T-72	Omega Engineering	88169	Omega Engineering
Arinc Cable	422202	Carlisle	92196	ECS

### Flat Ribbon Cable ( Used in DSM)

Type	Part Number	Manufacturer	ID	Supplier
10 Pin conductors	F2807S-10-050-55	TEMP-FLEX Cable	677F-3C	Electro Spec.
20 Pin conductors	F2807S-20-050-55	TEMP-FLEX Cable	57449	Electro Spec.
26 Pin conductors	F3007S-26-025-85	TEMP-FLEX Cable	72286	Electro Spec
40 Pin conductors	F2807S-40-050-55	TEMP-FLEX Cable	57449	Electro Spec.
44 Pin conductors	F2807S-44-0394-55	TEMP-FLEX Cable	72286	Electro Spec
50 Pin conductors	F2807S-50-050-55	TEMP-FLEX Cable	677F-30B	Electro Spec.

### Coaxial Cable

Gauge	Type	Part Number	Manufacturer	ID	Supplier
18 AWG	RG-142 B/U	M17/158/00001	BELDEN	677F-31	BELDEN
20 AWG		S88207	PIC WIRE	9668	PIC WIRE & CABLE
26 AWG	75-OHM	Part#V76261	PIC WIRE	9626	PIC WIRE&CABLE

### Approved and Tested Non-Wire Materials

<b>Tubing</b>	<b>Part Number</b>	<b>Manufacturer</b>	<b>ID</b>	<b>Supplier</b>
1/4" Comp	SYNFLEX 1300-04403	SAINT-GOBAIN	677F-5C	SAINT-GOBIN
3/8" Comp	SYNFLEX 1300-06603	SAINT GOBAIN	677F-6C	SAINT-GOBIN
3/8" OD Conductive Silicone	3001788 #1851 (TSI #) VC-781 Solid Carbon- filled	VANGUARD	677F-7C	TSI
1/2" OD Conductive Silicone	3001789 (TSI #) VC-781 Solid Carbon- filled	VANGUARD	9800	TSI
1/8" OD Clear	22UHP .063X .125	AMETEK	677F-10C	AMETEK
1/8" OD Black	104-0125031-OTC	Parker Hannifin Corp	77918	Metron Tech. Central
1/4" OD Clear	TSFP5 .250125	SAINT-GOBAIN	677F-9C	SAINT-GOBIN
1/4" OD TEFLON, 22P	22P.156X.250	AMETEK	56210	AMETEK
1/4" OD Black	104-0250047-OTC	Parker Hannifin Corp	77919	Metron Tech. Central
3/8" OD TEFLON	UHP22.250X.375F	AMETEK	59056	AMETEK
3/8" OD Clear	UHP22.313X.375	AMETEK	91060	AMETEK
3/8" OD Clear	UHP22.250X.375H	AMETEK	72509	AMETEK
3/16" OD Clear	22P.125X.187	AMETEK	84286	VQS
3/16" OD Semi- Clear	5239K11	McMaster-Carr	89761	McMaster-Carr
5/16" OD Clear	AAC000012-CP	SAINT-GOBAIN	9800	SAINT-GOBAIN
5/16" OD Clear	AAC00025	SAINT-GOBAIN	151937-06	SAINT-GOBAIN
1/2" OD Clear	UAT500-062	AZTECH	72889	AZTECH CONTROL
ARMAFLEX Foam Insulator	APT03834	ARMACELL	75233	EJ Bartells or Armacell
DEGUSSA Foam Insulator	½" ROHACELL-110S	N/A	10032	SCION CORE SYS.
Insulation material OffWhite	207-782-7011	Insulsafe Textiles, Inc	89308	Insulsafe Textiles

<b>Wire Protection</b>	<b>Part Number</b>	<b>Manufacturer</b>	<b>ID</b>	<b>Supplier</b>
3/8" Black Sleeve	HTN0.38TB	TECHFLEX	677F-8C	TECHFLEX
1/2" Black Sleeve	HTN0.50TB	TECHFLEX	57449	TECHFLEX
1/4" Left Cut, Spiral Wrap	TSWTF-1/4-NT-L	PARKER	91785	PORT PLASTIC, INC.
1/4" Right Cut, Spiral Wrap	TSWTF-1/4-NT-R	PARKER	91786	PORT PLASTIC, INC.
3/8" Right Cut, Spiral Wrap	TSWTF-3/8-NT-R	PARKER	91784	PORT PLASTIC, INC.



3/8" Left Cut, Spiral Wrap	TSWTF-3/8-NT-L	PARKER	91787	PORT PLASTIC, INC.
1/2" Left Cut, Spiral Wrap	TSWTF-1/2-NT-L	PARKER	91783	PORT PLASTIC, INC.
1/2" Right Cut, Spiral Wrap	TSWTF-1/2-NT-R	PARKER	91788	PORT PLASTIC, INC.

Other	Part Number	Manufacturer	ID	Supplier
.125" Plastic Phenolic	FBGS.125N	ACCURATE	72813	ACCURATE PLAST.
Phenolic Insulator strip	8796K42	ARAMID	76178	McMaster Carr
Insulated Duo-Tape Low Watt Density	AWH-WWW-XXXDL	Amptek Company	V220288	Amptek Company
Insulated Duo-Tape Medium Watt Density	AWH-WWW-XXXDM	Amptek Company	V220287	Amptek Company
Insulated Duo-tape Low Watt Density	A401-NCAR0311-20	Amptek Company	90775	Amptek Company
Insulated Duo-tape Low Watt Density	A401-NCAR0311-21	Amptek Company	90775	Amptek Company
Insulsafe Textiles	P-100	ARAMID	V220289	Mc Master Carr
Arimid Strip 1" Wide	8796K72	Mc Master Carr	V219907	Mc Master Carr
Aerogel Pyrogel XT Insulation	PG XT 5MM-5	Pacor Inc	V219907	Pacor Inc
Spaceloft White Insulation	SL 5MM-XX	Pacor Inc	90859	Pacor Inc
Ultem 1000 Arimid Strip	Ultem 1000	Colorado Plastic	H219907	Colorado Plastic Prod
MP Graphite/Poly Foam 45 ILD 1/2"	Lot #Z574-595-MP45	Skandia Inc	91237	Skandia, Inc
MP Graphite/Poly Foam 65 ILD 1/2"	Lot #12660-MP65	Skandia Inc	91237	Skandia, Inc
MP Graphite/Poly Foam 45 ILD 1/2"	Lot #W1132-1142-MP45	Skandia Inc	91237	Skandia, Inc
Clear Plastic .125"	PCBFRCLSH00125 PALSUN FR	Professional Plastic	92077	Professional Plastics, Inc

### Single Conductor Wire

Type	Part Number	Manufacturer	ID	Supplier
10 AWG RED	M16878/4 BMG-9	Thermax	677F-3B	All Cable
10 AWG WHT	M16878/4 BMG-2	Thermax	677F-11B	All Cable
10 AWG BLK	M16878/4 BMG-0	Thermax	677F-21B	All Cable
12 AWG WHT	M16878/4 BLE-2	Thermax	677F-12 B	All Cable
12 AWG RED	M16878/4 BLE-9	Thermax	677F-4 B	All Cable

12 GAW BLK	M16878/4 BLE-0	Thermax	677F-22 B	All Cable
14 AWG WHT	M16878/4 BKE-2	Thermax	677F-13 B	All Cable
14 AWG RED	M16878/4 BKE-9	Thermax	677F-2B	All Cable
14 AWG BLK	M16878/4 BKE-0	Thermax	677F-23 B	All Cable
16 AWG WHT	M16878/4 BJE-9	Thermax	677F-8	All Cable
16 AWG BLK	M16878/4 BJE-0	Thermax	677F-9	All Cable
16 AWG RED	M16878/4 BJE-2	Thermax	677F-14 B	All Cable
18 AWG RED	M16878/4 BHE-9	Thermax	677F-1B	All Cable
18 AWG WHT	M16878/4 BHE-2	Thermax	677F-15 B	All Cable
18 AWG BLK	M16878/4 BHE-0	Thermax	677F-24 B	All Cable
20 AWG WHT	M16878/4 BGE-9	Thermax	677F-10	All Cable
20 AWG BLK	M16878/4 BGE-0	Thermax	677F-11	All Cable
20 AWG RED	M16878/4 BGE-2	Thermax	677F-16 B	All Cable
22 AWG WHT	M16878/4 BFE-9	Thermax	677F-12	All Cable
22 AWG BLK	M16878/4 BFE-0	Thermax	677F-13	All Cable
22 AWG BLUE	M16878/4 BFE-6	Thermax	677F-28 B	All Cable
22 AWG RED	M16878/4-BFE-2	Thermax	57401	All Cable
22 AWG ORG	M16878/4-BFE-3	Thermax	57401	All Cable
22 AWG YEL	M16878/4 BFE-4	Thermax	57401	All Cable
22 AWG BRWN	M16878/4 BFE-1	Thermax	677F-29 B	All Cable
24 AWG WHT	M16878/4 BEE-9	Thermax	677F-5B	All Cable
24 AWG RED	M16878/4 BEE-2	Thermax	677F-17 B	All Cable
24 AWG BLK	M16878/4 BEE-0	Thermax	677F-25 B	All Cable
26 AWG WHT	M16878/4 BDE-9	Thermax	677F-6B	All Cable
26 AWG RED	M16878/4 BDB-2	Thermax	677F-18 B	All Cable
26 AWG BLK	M16878/4 BDB-0	Thermax	677F-26 B	All Cable
28 AWG RED	M16878/4 BCB-2	Thermax	677F-19 B	All Cable
30 AWG WHT	M16878/4 BBB-9	Thermax	677F-8B	All Cable
30 AWG RED	M16878/4 BBB-2	Thermax	677F-20 B	All Cable
30 AWG BLK	M16878/4 BBB-0	Thermax	677F-27 B	All Cable
22 AWG BLK	178-8679	Teledyne Reynolds	73141	

### Obsolete Part Numbers

wire protection	part number	manufacturer	id	supplier
1/4" Left Cut, Spiral Wrap	401-025030-N00000L	PARKER	677F-11C	PORT PLASTIC, INC.
1/4" Right Cut, Spiral Wrap	401-0250030-N00000R	PARKER	90710	PORT PLASTIC, INC.
3/8" Right Cut, Spiral Wrap	401-0375030-N00000R	PARKER	677F-12C	PORT PLASTIC, INC.
3/8" Left Cut, Spiral Wrap	401-0375030-N00000L	PARKER	677F-13C	PORT PLASTIC, INC.
1/2" Left Cut, Spiral	401-0500030-	PARKER	677F-	PORT PLASTIC, INC.

Wrap	N00000L		14C	
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**Wire Type Abbreviations:**

STP	- Shielded Twisted Pair
STT	- Shielded Twisted Triple
STQ	- Shielded Twisted Quad
TWX	- Twinax Cable
HEAD1	- Special Dew Point Cable
HSDQ	- High-Speed Data Quad
C50	- 50-Ohm Coaxial Cable
NET	- GigaBit Network Cable