

Interface Control Document

NASA 932 C-9B

Aircraft Operations Division

August 2005

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National Aeronautics and
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Lyndon B. Johnson Space Center
Houston, Texas

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APPROVAL AUTHORITIES

Original Signed By

John S. Yaniec
Lead, Reduced Gravity Program

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lyndon B. Johnson Space Center
Houston, Texas

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1.0 INTRODUCTION

The Reduced Gravity Program, operated by the National Aeronautics and Space Administration (NASA), Lyndon B. Johnson Space Center (JSC) in Houston, Texas, provides a “weightless” environment, similar to the environment of space flight.

1.1 Purpose

The purpose of this guide is to provide a guideline for existing and potential users of the JSC Reduced Gravity Program. This document provides detailed interface definition.

1.2 Scope

This work instruction applies to all users and potential users of the JSC Reduced Gravity Program.

1.3 Reference Documents

[AOD 33897, Experiment Design Requirements and Guidelines NASA 932 C-9B](#)

[Federal Standard W-C-596/90](#)

[Federal Standard W-C-596/91A](#)

[JPG-1700.1I, JSC Safety and Health Handbook](#)

[National Electrical Manufacturers Association \(NEMA\) L5-30P](#)

1.4 List of Acronyms

AC	Alternating Current
AOD	Aircraft Operations Division
DC	Direct Current
DIA	Diameter
DOT	Department of Transportation
FAA	Federal Aviation Administration
GFCI	Ground Fault Circuit Interrupter
Hz	Hertz
JSC	Johnson Space Center
MS	Military Specification
MSDS	Material Safety Data Sheet
NASA	National Aeronautics and Space Administration
NEMA	National Electrical Manufactures Association
NPT	National Pipe Thread
PSI	Pounds per Square Inch

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RGO	Reduced Gravity Office
SCFM	Specific Cubic Feet per Minute
USAF	United States Air Force
VAC	Volts Alternating Current
VCR	Video Cassette Recorder
VDC	Volts Direct Current

2.0 FACILITIES PROVIDED

This section describes the NASA facilities available to reduced gravity researchers, and users of the C-9B.

The reduced gravity environment is achieved by flying a modified Boeing C-9B jet through a series of parabolic maneuvers. This results in short periods of less than one “g” acceleration. The lengths of these reduced gravity periods depend on the “g” level required for the specific test. Listed below are typical lengths for various maneuvers:

Negative-g	1/10 max	15 seconds
Zero-g	0-g	23 seconds
Lunar-g	1/6-g (.16)	30 seconds
Martian-g	1/3-g (.38)	40 seconds

These maneuvers may be flown consecutively (i.e., roller coaster fashion), or separated by enough time to alter the test setup. Each parabola is initiated with a 1.8-g pull-up and terminated with a 1.8-g pull-out. Normal missions, lasting approximately two hours, consist of 40 parabolic maneuvers, and originate and terminate at Ellington Field in Houston, Texas. Changes to the normal mission profile can be made to ensure more efficient test operations. These changes include number of parabolas performed, g level adjustments (i.e., .16, .38, .1, .5), and length of breaks between parabolas or sets of parabolas. Requests for operations away from Ellington Field will be considered on an individual basis addressing the benefit to NASA, fiscal soundness, scientific merit, airspace accessibility, and overall Reduced Gravity Program schedule impact.

The C-9B aircraft test area is equipped with electrical power, portable compressed gas racks, an overboard vent, accelerometer data, and photo lights. NASA JSC can provide photographers for still photography and video coverage. An S-band video downlink with two-way audio capability may also be requested. Limited peer to peer wireless intercom is also available upon request. Workspace is available on the ground for buildup and checkout of test equipment to ensure its operation before installation in the airplane.

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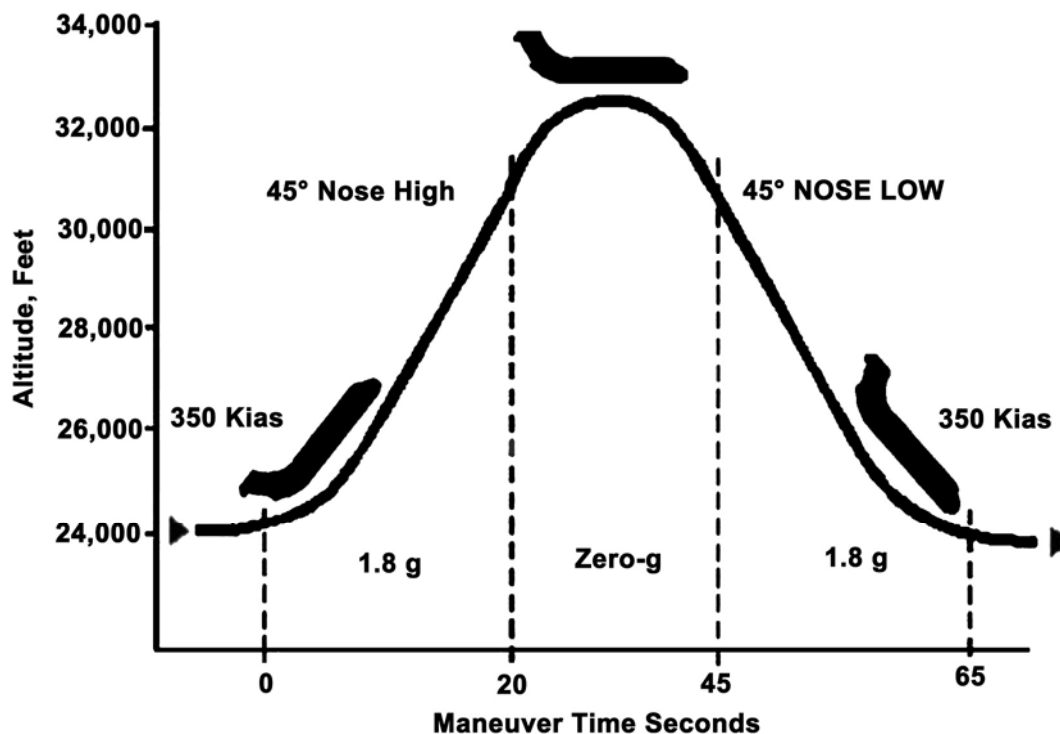
Figure 1. C-9B Aircraft

2.1 Aircraft

The Boeing C-9B is a two-engine, swept-wing aircraft similar to the Boeing DC-933. The United States Navy primarily operated these aircraft as transport. This particular C-9B (subsequently named NASA 932), was manufactured in November 1970. NASA obtained the current C-9B in November 2003 and modified it to support the Reduced Gravity Program. The predecessor to NASA 932, NASA 931, was put in service in 1995 and retired in October 2004, flew over 37,000 parabolas, and is now on display at the Pima Air and Space Museum in Pima, Arizona. Its predecessor, NASA 930, was obtained by NASA in 1973 and flew over 58,000 parabolas before it was retired in 1995. It is now on static display at the entrance to Ellington Field.

The C-9B is operated as a public aircraft within the meaning of the Federal Aviation Act of 1958, as amended. As such, it does not require or hold a current airworthiness certificate issued by the Federal Aviation Administration (FAA). The C-9B is not operated as a common carrier or as a military transport. Consequently, any individual manifested to board the C-9B should determine before boarding whether their personal life or accident insurance provides coverage under such conditions. Also, since the aircraft will be used under test conditions, all researchers and test subjects will be fully informed of the test plans and all risks, hazards, and discomforts inherent to such tests prior to flight.

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Figure 2. Parabola Diagram (for Reference Only)

2.1.1 Cabin Environment

Cabin pressure is maintained at approximately pressure altitude 8,000 feet (10.9 psia) during parabolic maneuvers. Loss of cabin pressurization could result in pressure as low as 2.8 psia; a factor that must be considered in the design of test equipment.

Normally, cabin temperature varies from 50 to 80 degrees Fahrenheit (F) in flight.

The temperature in the cabin is not controlled while the airplane is on the ground; however, a portable ground air conditioner is available during preflight operations. Keep in mind that the aircraft typically sits out on the ramp during the day and overnight during a flight week. Temperature ranges inside the cabin area are uncontrolled and can be as cold as 30°F during the winter months and as hot as 120°F in the summer. Researchers should make provisions for their experiment hardware to tolerate these conditions.

2.1.2 Cabin Dimensions

Approximately 45 feet of cabin length is available for test purposes. A floor plan schematic is shown in [Figure 3](#). A cross sectional view of the cabin is shown in [Figure 4](#). Test equipment is usually loaded through the cargo door that is 78 inches high and 135 inches wide. Because of the door actuation mechanism, an area 6 inches tall and 10 inches wide is unusable at the top left corner of the door. A diagram of the cargo door is shown in [Figure 5](#). A photograph showing the cargo door during loading operations is shown in [Figure 6](#).

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NOTE

Research equipment installation is prohibited on cross-hatched areas.

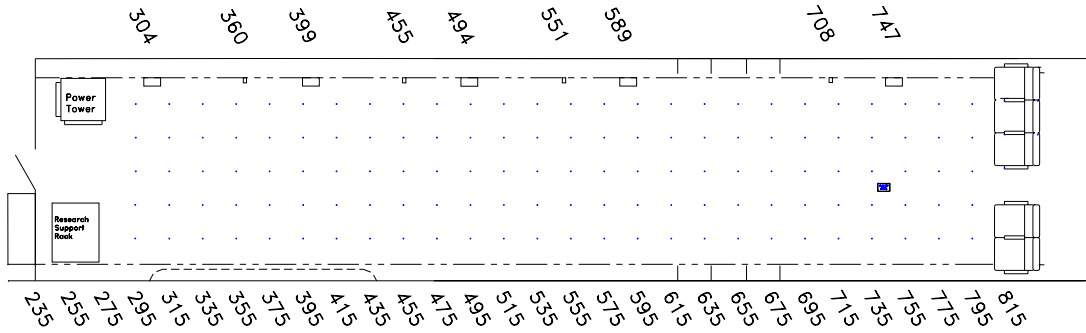
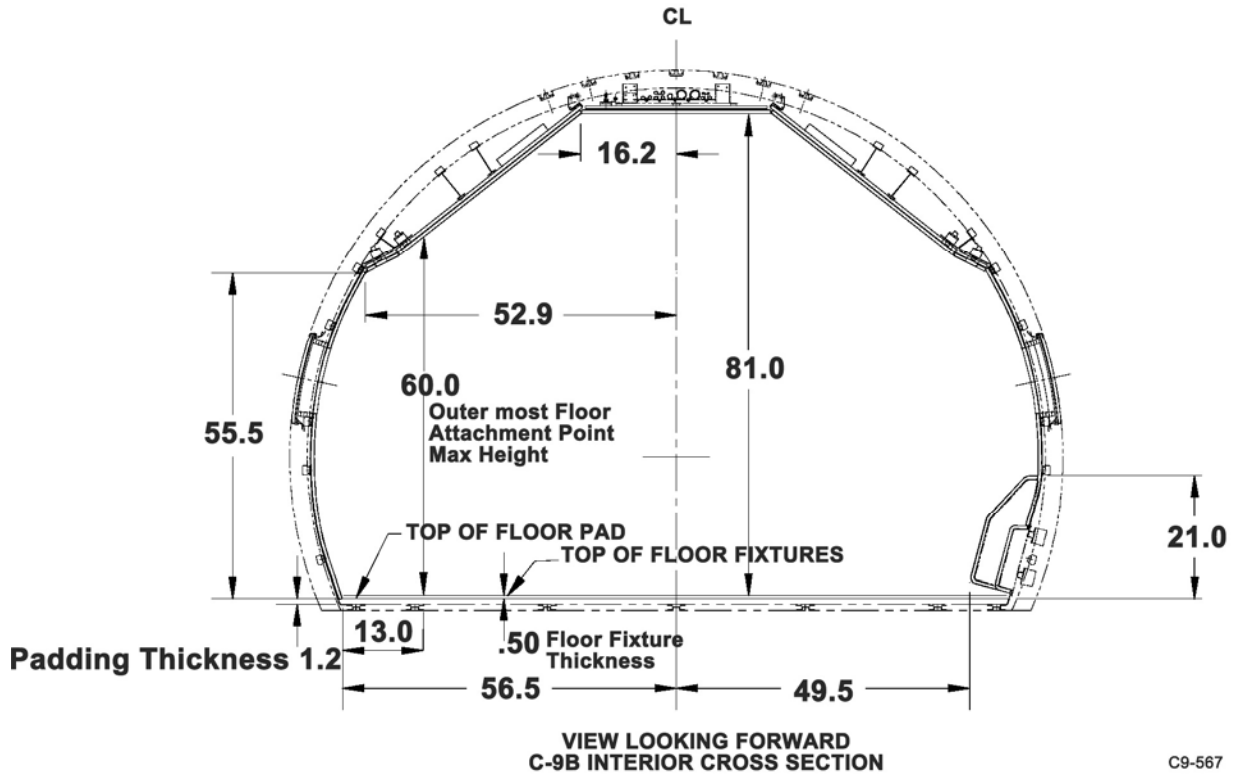


Figure 3. Aircraft Floor Layout



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Figure 4. Cross-Section of Fuselage

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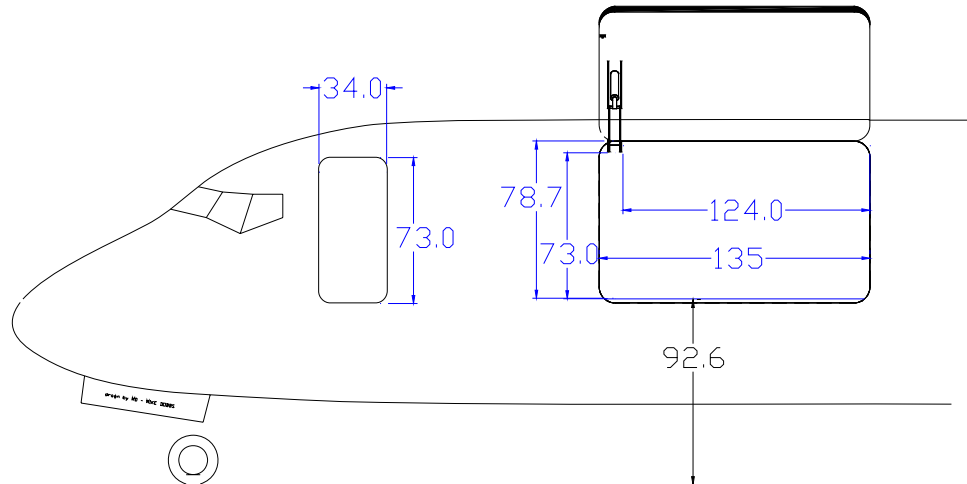


Figure 5. Cargo Door Dimensions in Inches



Figure 6. Cargo Door Operations

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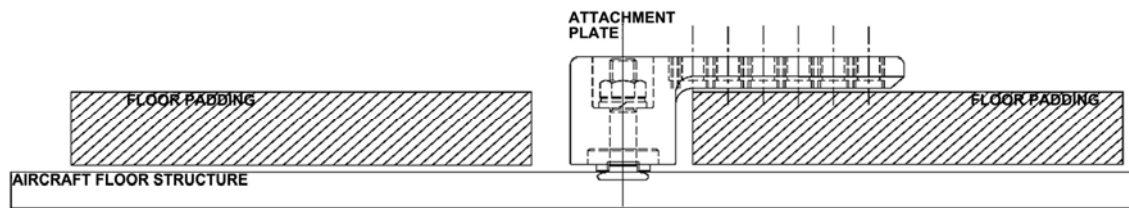
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2.1.2.1 Floor Attachment Hardware

Table 1. Floor Attachment Hardware

Restraint	WLL	Width	Length	Fixed Length
CGU-1/B (strap)	#5000	2 in	18 ft	12 in
S0203-0338-B (strap)	#1200	1.5 in	12 ft	14 in
104410P (strap)	#260	1 in	12 ft	8 in
AN-6 Steel Bolts	#5000	3/8 in	1/2 to 4 in	N/A

Aluminum floor plates are used to bolt equipment directly into the aircraft floor beams (bypassing the floor foam), and to load bolts in single shear at each floor attachment location. The maximum amount of weight allowed to rest on one plate, in a 1 g environment, is 400 lbs/plate (i.e., 2,400 lbs/plate is allowed in a 6 g down load case). See [Figure 7](#).

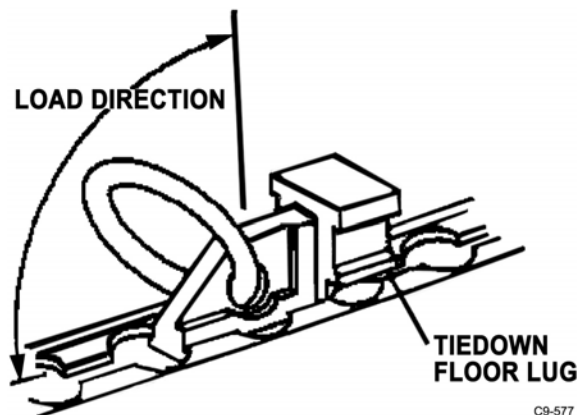


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Figure 7. Floor Attachment Plate Assembly (Installed)

Floor attachment holes are centered on a 20-inch \pm 0.005-inch square pattern. See [Figure 3](#).

Allowable floor loading is 200 lbs/ft² (for the in-flight load case, not for ground loading) without proper floor shoring. See [Figure 8](#).



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Figure 8. Cargo Strap Anchor, Tie Down #5000

No contiguous equipment or structure, greater than 8 feet in length, shall be rigidly secured along the length of the aircraft deck.

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2.1.3 Cabin Provisions

The aircraft is equipped with 20 seats aft of the test section. There is one lavatory for critical use, similar to passenger aircraft. The interior walls of the cabin are covered with foam padding for the protection of personnel and equipment.

2.1.4 Electrical Power and Interface

Four types of electrical power are available, as shown in [Table 2](#). The 115 VAC is distributed into two buses (A and B bus). Each experiment will be allotted a portion of the power budget at the time the aircraft is loaded. Special arrangements can be made for experiments with unusually high power requirements.

Table 2. Total Electrical Test Power

Power Type	Total Current Available
28 Volts DC	50 Amps
115 Volt AC, 400 Hz, Single Phase	10 Amps
115 Volt AC, 60 Hz, Three Phase	30 Amps
115 Volt AC, 60 Hz, Single Phase	60 Amps

Aircraft electrical power is distributed via five power distribution panels. These panels are located along the lower sidewall of the test cabin at fuselage stations 304, 399, 494, 589, and 747. A mechanical drawing and a photograph of a power distribution panel are depicted in [Figure 9](#). The following sections will explain the mechanical interface to each type of electrical power.

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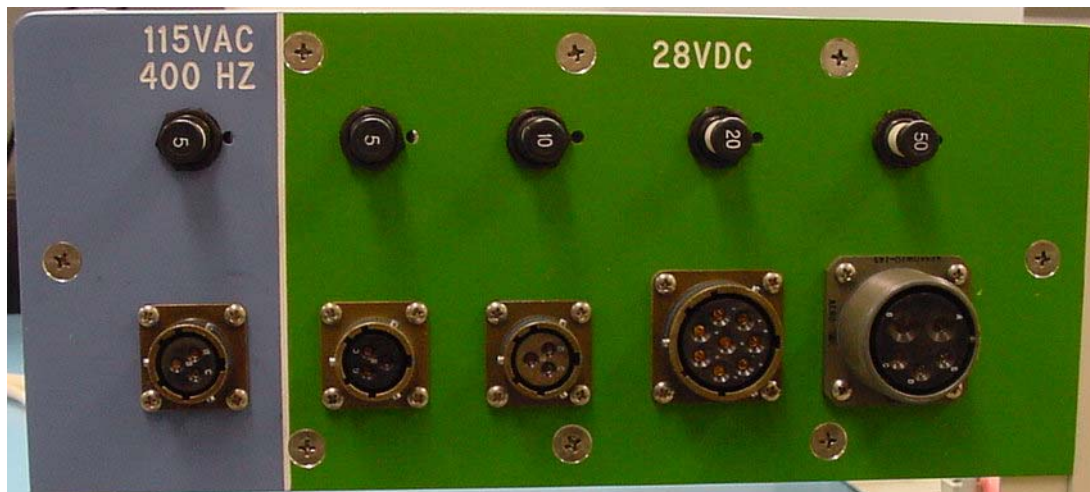
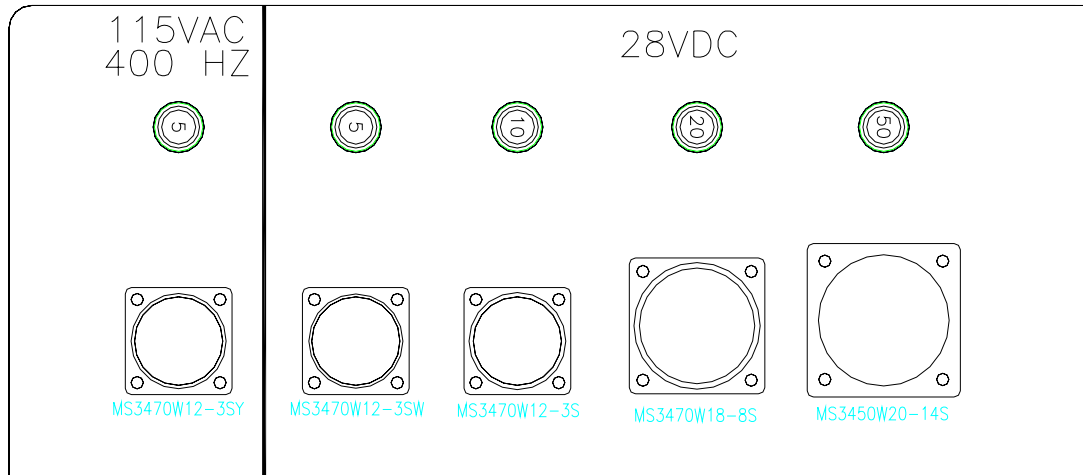


Figure 9. Power Distribution Panel DC Side

115 VAC, 400 Hz, 1p

One cannon receptacle, MS3470W12-3SY ([Figure 9](#)), supplies raw 115 VAC aircraft power at 400 Hz. This receptacle has a dedicated 5 Amp circuit breaker on the local power distribution panel. Researchers may use the 400 Hz outlet when it is available; however, it is the responsibility of the researchers to protect their own equipment from electrical faults. Every electrical cable from a power distribution panel should include a current limiting device on the experiment.

Experimenters must use wire sizes in accordance with “Minimum Wire Gauges” ([AOD 33897](#), Table 2) and will find the mating cannon plug in [AOD 33897](#).

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28 VDC

Each power distribution panel provides interfaces for 5, 10, 20, and 50 Amp circuits. All 28 Volt interfaces are standard Military Specification (MS) cannon connectors ([Figure 10](#)).

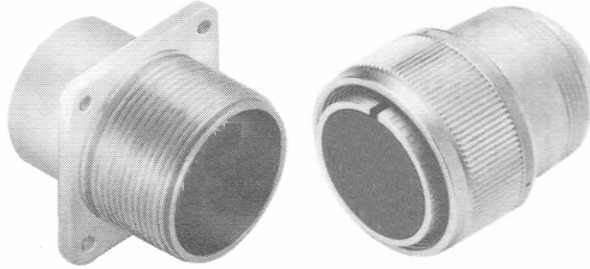


Figure 10. MS Cannon Receptacle (Left) and Plug (Right)

Power Panel 28 VDC Interfaces

One cannon receptacle ([Figure 9](#)) supplies 28 VDC at a maximum 5 Amps (MS3470W12-10S).

Researchers will find the mating cannon plug in [AOD 33897](#).

HOT	A
GROUND	B

Connector Pin Out

One cannon receptacle ([Figure 9](#)) supplies 28 VDC at a maximum 10 Amps (MS3470W12-3S).

Researchers will find the mating cannon plug in [AOD 33897](#).

HOT	A
GROUND	B

Connector Pin Out

One cannon receptacle ([Figure 9](#)) supplies 28 VDC at a maximum 20 Amps (MS3470W18-8S).

Researchers will find the mating cannon plug in [AOD 33897](#).

HOT	A
GROUND	B

Connector Pin Out

One cannon receptacle ([Figure 9](#)) supplies 28 VDC at a maximum 50 Amps (MS3450W20-14S).

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Researchers will find the mating cannon plug in [AOD 33897](#).

HOT	A
GROUND	B

Connector Pin Out

The mechanical connections are similar. The power distribution panel receptacles are female. Experimenters must provide the mating male plug connector. Experimenters must use wire sizes in accordance with “Minimum Wire Gauges” ([AOD 33897](#), Table 2) and will find the mating cannon plug in [AOD 33897](#).

NOTE

Power cords used to reach this 50 Amp outlet should be 10 feet in length.

115 VAC, 60 Hz, Single phase, 30A & 20A

Three 115 VAC 60 Hz 20A circuits, and one 30A circuit, are provided at each power panel. Research hardware interfaces to these via 6-foot long GFCI protected single receptacle pigtails as shown in [Figure 11](#), having 30A twist loc (HUBBELL 2611, NEMA 15-30P) and 20A flat prong (HUBBELL 53CM69C, NEMA 5-20R) standard type residential outlets.



Figure 11. 115 VAC 60 Hz Connectors (30A and 20A)

Experimenters must use wire sizes in accordance with “Minimum Wire Gauges” ([AOD 33897](#), Table 2) and will find the mating cannon plug in [AOD 33897](#).

115VAC, 60Hz, 3p

One outlet per panel will supply 20 A, 115 VAC, 60 Hz, 3 P power via GFCI protected Pigtail ([Figure 12](#)) terminated in a single 5-pin twist loc receptacle (HUBBELL 2813, NEMA L21-30R).

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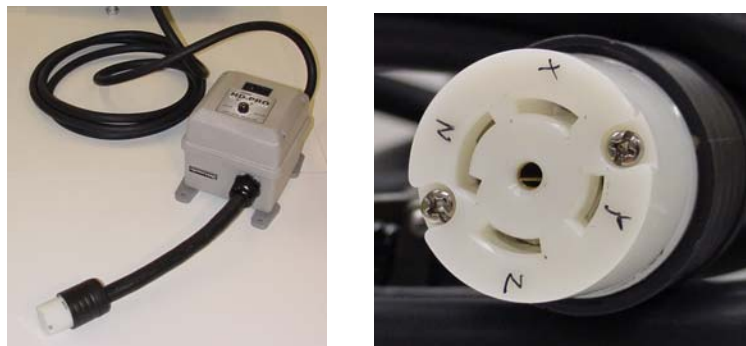


Figure 12. 115 VAC 60 HZ 3 ph GFCI protected Pigtail

2.1.5 Aircraft Lighting

The aircraft cabin contains 28 LED photo-lights (14 down each side-overhead). These lights have been specially designed to provide sunlight-quality illumination (color temp of 5,600 K). Because of the unique design of the assemblies, daylight camera film may be used in the cabin and a flashbulb is typically not required.

A switch in the cockpit controls the intensity setting of all cabin photo lights. There are two possible illumination levels: all assemblies on, and half of the assemblies on. The lights will be set to full illumination during the reduced gravity portion of the parabolas. During all other phases of flight (including takeoff, landing, parabola pull-up, and pull-out) the lights will remain at half-illumination or off.

Each of the lights may be turned off individually. When a given fixture is turned off, it will remain off during all phases of flight regardless of the cockpit switch position.

2.1.6 High Pressure Gas System

High pressure gas systems are allowed for use on the C-9B through compliance with all safety guidelines. All pressurized gas systems must receive approval through the pressure vessel certification procedure documented in this User's Guide (see [AOD 33897](#), section 2.3).

Per customer request, the Reduced Gravity Office (RGO) will provide the following high pressure gas and "K-bottle" handling equipment:

1. Nitrogen K-bottle (volume 228 ft³ at 2200 psig)
2. Helium K-bottle (volume 212 ft³ at 2200 psig)
3. Argon K-bottle (volume 248 ft³ at 2200 psig)
4. Breathing air K-bottle (volume 233 ft³ at 2200 psig)
5. K-bottle ground handling carts
6. In-flight, 9g rated, K-bottle mounting rack

Researchers should ensure the gas bottles shipped to the RGO are 9 inches in diameter and 55 inches in length if RGO bottle racks are used.

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All bottles must be Department of Transportation (DOT)–certified and current or meet pressure system requirements for a pressure vessel.

All regulators and gauges must be properly calibrated and have current certification tags.

All gas systems must have appropriate-sized relief valves installed at the regulators to prevent over-pressurization of the gas supply line, and current calibration (and tagged).

The RGO does not supply regulators to researchers.

Any high-pressure gas equipment must be approved for use by the RGO prior to its arrival at Ellington Field (see [AOD 33897](#), section 2.3).

2.1.7 Overboard Vent System

An overboard vent system is available on the aircraft for the venting of most gases. No liquid can be vented through this system due to freezing, which could occur at altitude.

There are four vent lines: two are multi-user lines ([Figure 13](#)), and the other two are dedicated lines for use with oxygen enriched, or reactive gases. The multi-use vent lines (1-inch DIA) have interface locations at FS 360, FS 455, FS 551, and FS 708 along the right side of the aircraft.



Figure 13. Multi-User Overboard Vent

The fittings on the multi-user vent line are male Army/Navy (AN) 16 fittings (1 inch); researchers must supply a female AN 16 fitting on the research equipment. (Parker Triplelok 37 degree Flared Tube Fitting)

For experiments requiring venting of oxygen-enriched gas or the requirement for a dedicated vent line, there are two dedicated vent ports located at FS 918. These two vent ports (1-inch DIA) do not have permanent lines attached. It is the responsibility of the researcher to have the correct AN fittings and flexible vent line to attach to either of the two ports dedicated to these vents. The distance from the vent ports to the front edge of the seats is 110 inches. The distance from the top fitting to the floor is 41 inches.

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NOTE

All vent line materials must be compatible with expected vent mixtures.

When the vent line is being utilized for an oxygen-enriched gas mixture, the vent line must meet the requirements for oxygen clean systems.

The dedicated vent port has a male 1-inch AN 16 fitting. The researcher will be required to have a 90 degree AN female fitting to attach to the aircraft male AN fitting at the window plug ([Figure 14](#)). The researcher is responsible for providing all of the appropriate fittings and hoses from the aircraft connection to their research equipment.



Figure 14. Dedicated Overboard Vent Ports

A simplified table of vent line flow rates is provided below:

Table 3. Volumetric Flow Rates

Location	Max Flow (SCFM) 36,000'	Min Flow (SCFM) 26,000'
Fwd Manifold	TBD (total*)	TBD (total*)
Aft Manifold	TBD (total*)	TBD (total*)
Dedicated Line	TBD	TBD

* Total refers to a combination of all experiment flows at that location including all flows introduced upstream at the forward manifold.

NOTE

These rates apply at the manifold/fitting only. Line losses in researcher equipment must be considered to determine flow rate at researcher's termination point.

A complete study of the volumetric flow rates through the overboard vent system will be performed and a copy available through the RGO.

The test cabin volume is approximately 4,700 cubic feet. The cabin air exchange rate is one cabin volume per 3.5 minutes.

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2.1.8 Aircraft G-Load Display

There are two display panels to show the real-time g-value and the parabola count for reference only. One display is mounted on the forward bulkhead facing aft and the other is mounted on the aft bulkhead facing forward. These values are not typically recorded in flight by the RGO.

2.1.9 Accelerometer Signal

Aircraft accelerometer signals Gx, Gy, and Gz are available for research use. The locations of the signal distribution boxes are shown in [Figure 15](#). Each signal distribution box is buffered to prevent interference with aircraft systems and other researchers.

Accelerometer signals are not typically recorded in flight by RGO.

Each signal is filtered with a normal cutoff frequency of 100 Hz. The RGO staff may independently adjust the cutoff frequency of each channel upon request. Changes to any cutoff frequency will affect the corresponding signal at every signal distribution box in the test cabin.

A male DB-15 connector and 10- to 15-feet of signal cable are required to connect to a signal distribution box. Pin designations are shown in [Figure 16](#) and [Table 4](#).



Figure 15. Signal Distribution Box

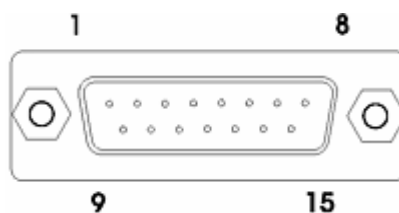


Figure 16. DB-15 Accelerometer Data Connector

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Table 4. Accelerometer Pin Designations

Measurement	Pin Number	Signal Value
Gx +	5	9.8 Volts/g
Gx -	9	Signal Ground, 0 Volts
Gy +	6	9.8 Volts/g
Gy -	10	Signal Ground, 0 Volts
Gz +	4	3.6 Volts/g
Gz -	11	Signal Ground, 0 Volts

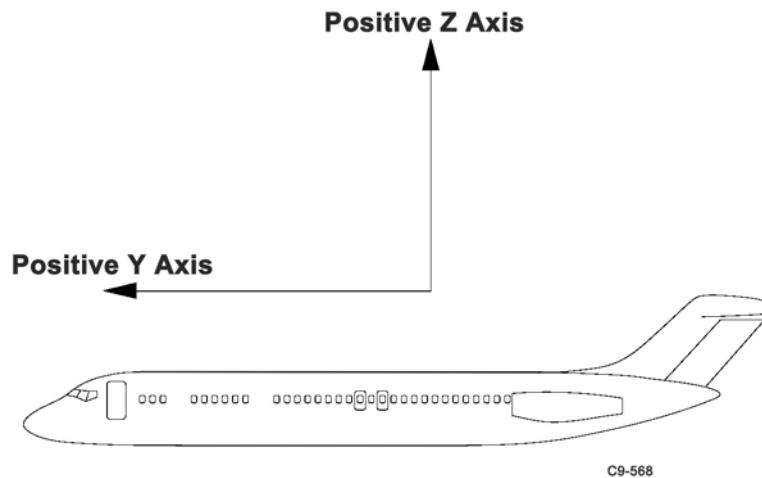


Figure 17. Aircraft Acceleration Vectors

2.1.10 On-Board Tools

The RGO maintains a toolbox with a collection of hand tools sufficient to install most test packages in the aircraft. No tools or loose equipment are allowed on the aircraft at any time without proper inventory control and specific authorization of the RGO. The toolbox and **all** tools are removed prior to flight. No tools are provided during flight. See [AOD 33897](#), section 2.10 for a description of permitted tools.

2.1.11 On-Board Storage Containers

The RGO has three storage containers for use on the aircraft by researchers. Two smaller containers and one large container pictured in [Figure 18](#).

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Figure 18. On-Aircraft Storage Containers

The interior dimensions and take-off/landing weight limits are:

- Small container: 20-1/2 x 19 x 19-1/2 inches (L x W x H), 100 lbs.
- Larger container: 46-1/2 x 22 1/2 x 17-1/2 inches (L x W x H), 150 lbs.

2.2 Ground Facilities

This section describes the NASA ground facilities that are provided to C-9B researchers by the Aircraft Operations Division.



Figure 19. Ground Facilities

2.2.1 Reduced Gravity Office

Building 993 at Ellington Field provides visiting researchers with a 1,760 square foot high bay work area. This air-conditioned workspace is available for test equipment buildup and checkout.

The high bay is equipped with 5-foot, 7-foot, and 10-foot workbenches for researcher use.

Available electrical power includes 115 VAC, 60 Hz, 20 Amp; 115 VAC, 3 phase, 20 Amp, 400 HZ; 28 VDC, 20 Amp. Access to the work area includes two 12- by 12-foot roll-up doors.

The building also has an adjacent conference room containing computers, telephones, a VCR, 8-mm video equipment, and video monitors.

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Figure 20. Building 993 High Bay Work Area

2.2.2 Computers, Network Access, Printers, and Phones

The computers and the network access are provided by the RGO for OFFICIAL business ONLY. Phones are provided in the conference room. All long distance calls must be made collect or third party. Incoming calls or faxes for the researcher should be to the following numbers:

Main Office: 281-244-9874
Conference Room: 281-244-9005
Fax: 281-244-9500

2.2.3 Normal Duty Hours

The RGO operates Monday through Friday from 7:30 am to 4:00 pm. Researcher access to the High Bay is limited to these hours unless prearranged with the RGO. Access to the aircraft is from 7:30 am to 4:00 pm during flight days.

2.2.4 Equipment and Material Storage

Very limited storage space is available in Building 993. Requests for space must be prearranged with the RGO. All chemicals will be stored in the chemical storage locker located in the High Bay of Building 993. Any chemical stored in this locker shall be clearly marked with the name of the researcher, the date it was placed in the locker, and the experiment title. Material Safety Data Sheet (MSDS) paperwork should be given to RGO personnel for filing in a 3-ring binder located on top of the chemical storage locker. It is the responsibility of the researcher to notify RGO personnel when a chemical is removed after completion of an experiment.

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NOTE

Building 993 is not equipped with an approved vent hood for chemical mixing.

2.2.5 Cryogenic Storage and Supply System

A cryogenic storage and supply system is available to provide a source of breathing air or nitrogen. The cryogenic system has a 1/2-inch standard AN fitting with a variety of available adapters. Contact the RGO **six weeks** prior to flight to address any needs in this category.

2.2.6 Crane and Scale

Building 993 is equipped with an overhead crane that spans the distance between the two overhead doors. It has a capacity of 2,000 pounds. The maximum distance from the floor to the crane hook on the crane is 97 inches. Only certified JSC or Ellington Field personnel shall operate the crane (see [JPG-1700.1I, JSC Safety and Health Handbook](#)).

2.2.7 Forklift

Forklifts are available for the unloading and loading of research equipment, (6SX 30) 4,900 lb. capacity at 188-inch lift.

The forklift is equipped with a loading platform for ease of operation when moving multiple pieces of equipment. This loading platform has a ramp on the front that enables research equipment with wheels to be rolled on and off the platform. Only certified JSC or Ellington personnel shall operate the forklift (see [JPG-1700.1I](#)).



Figure 21. Forklift with Lifting Platform

2.2.8 Ground Tools

The High Bay of Building 993 provides a complete toolbox for researcher use while at the RGO. The High Bay facility also includes a 20-gallon air compressor 135 psi max (5.7 scfm @ 90 psi / 4.9 scfm @ 135 psi), shop vacuum, bench vice, power available.

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2.2.9 Loading Assistance Tools

Loading assistance tools are available for researcher use, including:

- Lift Platform (for the forklift)
- J-Bars
- Roller Pipe (schedule 40 PVC)
- Lifting Straps
- Lifting Pipe
- Furniture Dolly (24- by 44-inches)

It is the researcher's responsibility to ensure that their research hardware has been designed with the proper handholds, lifting bars, and wheels (if required) to allow for safe and easy loading and unloading of the aircraft (see [AOD 33897](#), section 2.10).

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