NASA DC-8
Flying Laboratory Aircraft

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The Basic Aircraft

- History:
  - Built in 1968
  - Acquired by NASA in 1985
  - Modified 1985-87

- Aircraft Description:
  - Douglas DC-8-72
  - Fuselage Length: 157 ft
  - Wingspan: 148 ft
  - Engines: 4 ea CFM56-2-C1 High Bypass Turbofan Jet
  - Crew: 2 Pilots, 1 Flight Engineer, 1 Navigator, 2 Mission Dir., 2 Safety Techs, 1 Data System Mngr.

DC-8
Large Capacity, Long Range and Endurance

Capabilities
- Ceiling 42,000 ft.
- Duration 11 hours
- Range > 5,000 nautical miles
- Payload 30,000 lbs

Mission Support Features
- Shirtsleeve environment for up to 41 researchers
- Worldwide deployment experience
- Extensive modifications to support in-situ and remote sensing instruments
  - zenith and nadir viewports
  - wing pylons
  - modified power systems
  - 19 inch rack mounting

DC-8 Viewing Ports

Zenith, Nadir, and 62 ° Ports:

Zenith no. 1 Sta. 330 C/L 16 x 18.0

Nadir no. 2 Sta. 420 C/L 37.25 x 30.0

Nadir no. 7 Sta. 1200 C/L 37.25 x 30.0

62 ° no. 1 Sta. 470 LH 16 x 21.25

62 ° no. 3 Sta. 1090 LH 16 x 21.25

62 ° no. 4 Sta. 1130 LH 16 x 21.25

Nadir no. 5 Sta. 1130 LH 16 x 21.25

62 ° no. 8 Sta. 1310 RH 16 x 21.25

Nadir no. 9 Sta. 1310 RH 16 x 21.25

Modified 8 deg Passenger Window Ports:

8 ° Sta. 330 LH 16 x 18

8 ° Sta. 450 LH 16 x 18

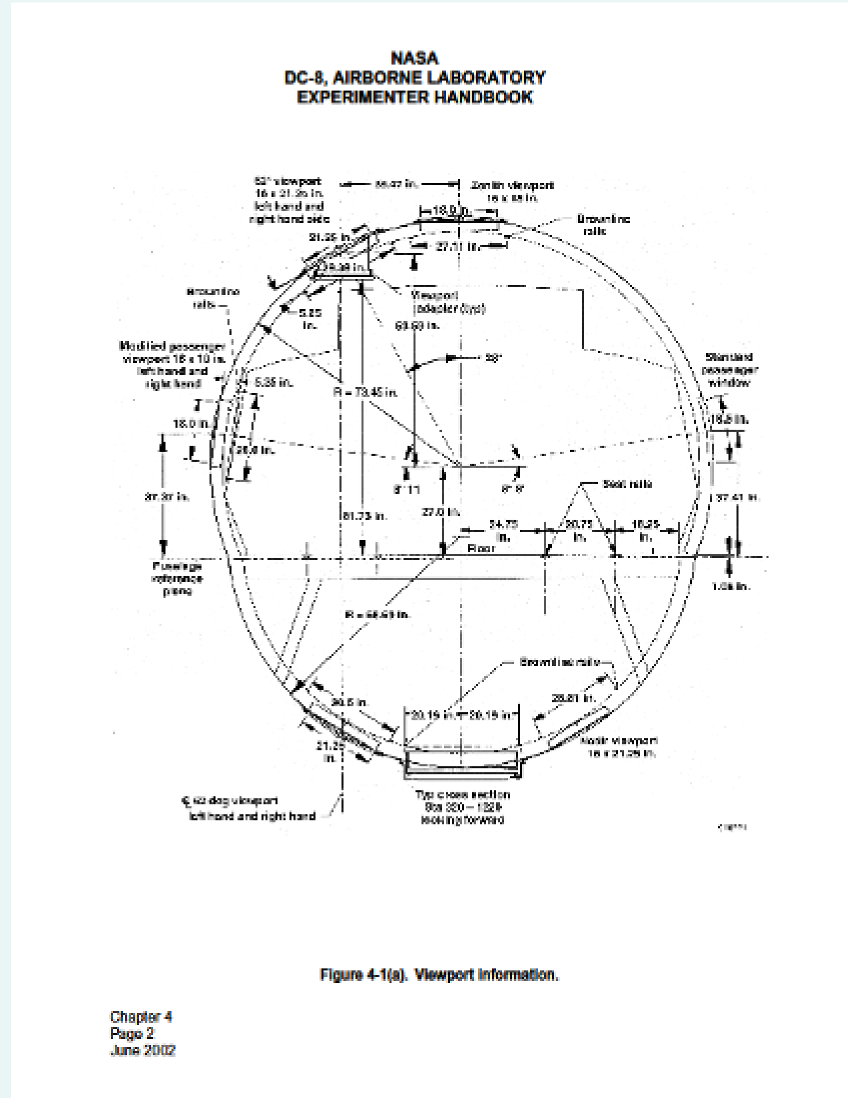
8 ° Sta. 530 RH 16 x 18

8 ° Sta. 570 L&R 16 x 18

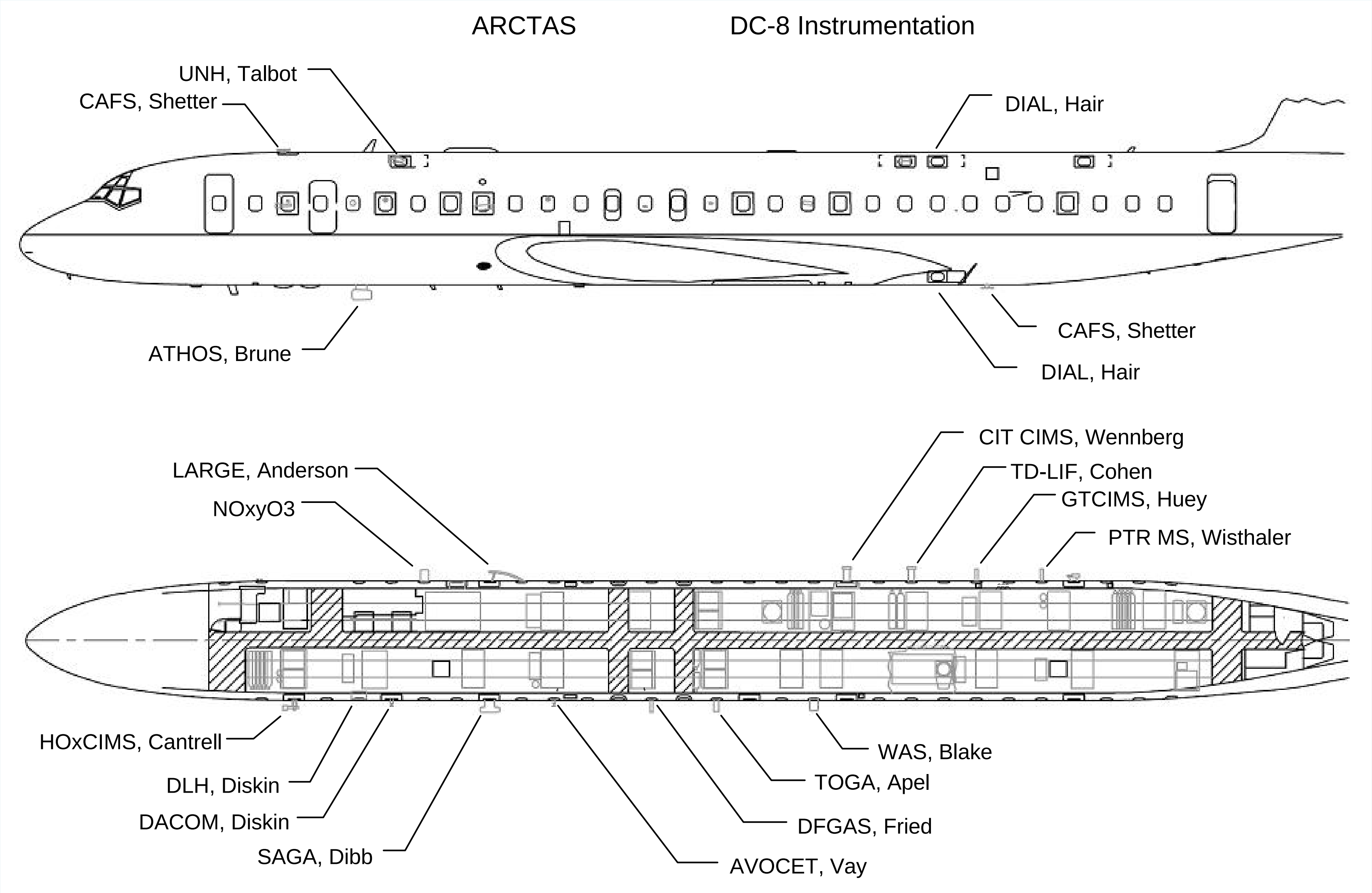
8 ° Sta. 890 LH 16 x 18

8 ° Sta. 1010 L&R 16 x 18

8 ° Sta. 1290 L&R 16 x 18

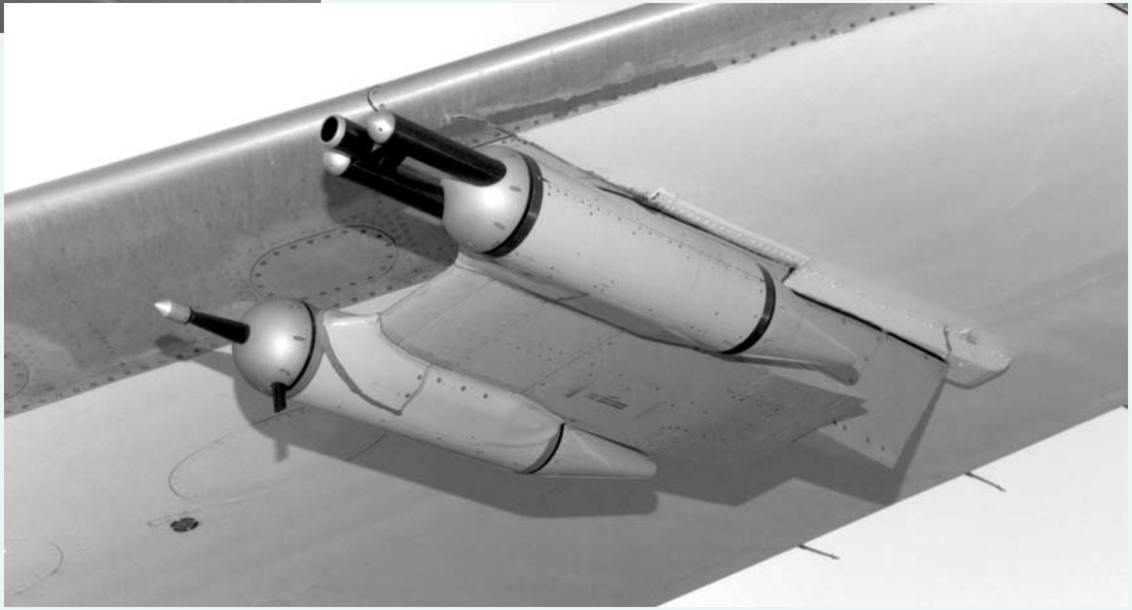


DC-8 Viewing Ports



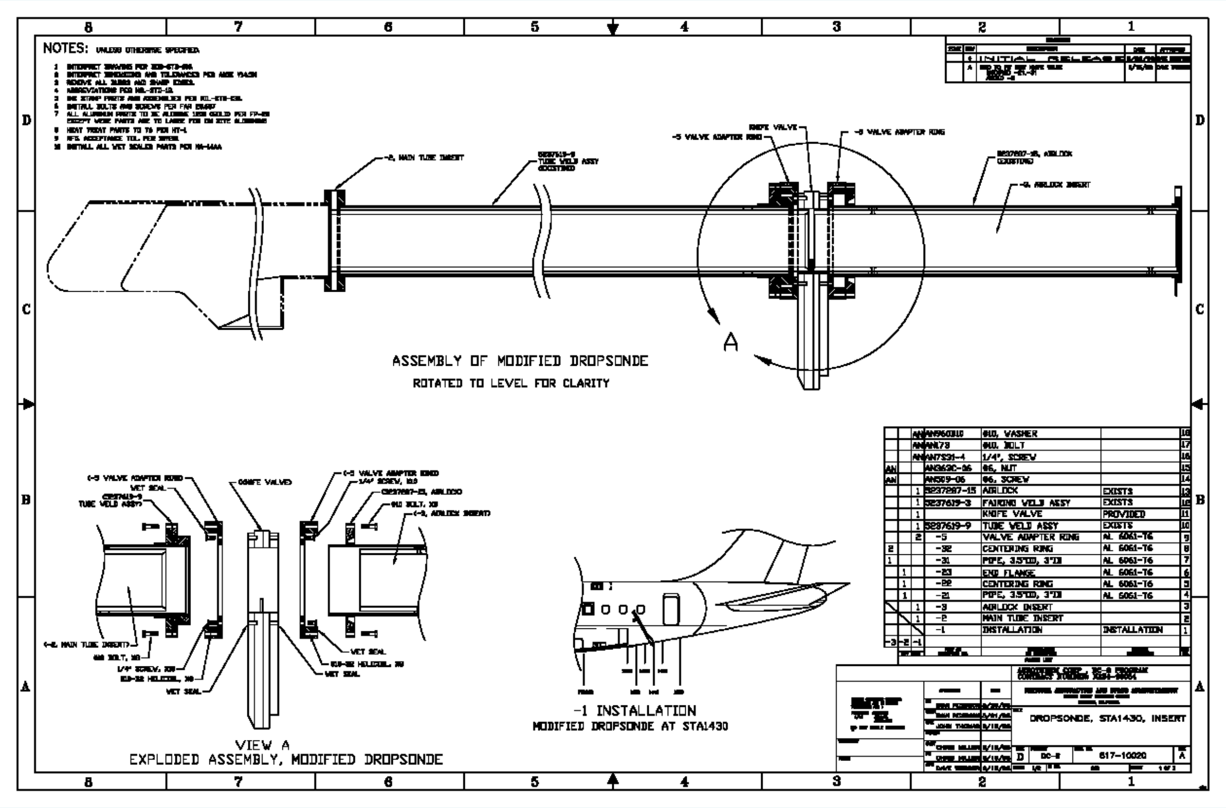
DC-8 Under Wing Pylons

Each pylon is designed to accommodate an equipment package with a maximum weight of 100 lb.



Electrical power, signal, and nitrogen gas connections exist at each pylon and extend to a connector panel at station 670 on both left hand and right hand sides of the aircraft.

Dropsonde System



Accommodates dropsondes up to 20" length and 2.875" & 3.75" diameter

Optical Grade Windows

Stock full-aperture (16 in. (40.6 cm) diameter) window materials include:
-Borosilicate crown glass (BK-7)
-UV grade fused silica.

Other optical materials (all less than full aperture in size):
-High-density polyethylene
-IrTran
-Germanium
-Pyrex.

Instrument Electrical Power

The following aircraft electrical power is supplied to the experimenters:

- 400 Hz (±1%), 115 volt (±1%), single-phase AC power, of which a nominal 40 kVA total is available

- 60 Hz (±0.1%), 115 volt (±1%), single-phase AC power, of which a nominal 40 kVA total is available

- Limited 220 volt capability

- 28 volt DC power supplies operating from 400 Hz power

- Outlet stations are spaced along both walls of the main cabin and in the cargo areas

Cabin Equipment Installations

•Accommodated by 19” racks and mountings to Brownline seat rails
•Equipment can also be located in forward & aft cargo bays that are accessible in flight

Recent System Upgrades

Aircraft and Facility Upgrades

New 1-F Flight Management System
New Terrain Awareness Warning System to meet FAA requirements
New Digital Aircraft Flight Recorder to meet FAA requirements
New Navigation Units with FM Immunity to meet European Standards
New Digital COMM / NAV Control Panels
New IRIDIUM air/ground communications for Flight Crew
Wing tip probe upgrades

Data Acquisition and Display System Upgrades

REVEAL data acquisition system
IRIDIUM based satcom system
X-chat capability with ground
New gigabit ethernet based data display system
Backward compatibility with RS-232 data stream
High resolution LCD displays
Dedicated Mission scientist station
Digital video system

Systems descriptions and equipment installation requirements can be found in the Experimenter Handbook:

http://www.nserc.und.edu/PDFs/ExperimenterHandbook.pdf

Platform Data

•Currently we distribute a UDP packet at 1Hz containing the following thru REVEAL:

- UNS 1-B Latitude and Longitude
- GPS Altitude (MIDG-II), Pressure Altitude, Radar Altitude
- True Air Speed, Indicated Air Speed, Mach Number, Vertical Speed
- True Heading, Track Angle, Drift Angle, Pitch Angle, Roll Angle, Slip Angle, Attack Angle
- Static Air Temp, Dew Point, Total Air Temp, Static Pressure, Dynamic pressure, Cabin Pressure.
- Wind Speed, Wind Direction, Vert Wind Speed
- Solar Zenith Angle, Aircraft Sun Elevation, Sun Azimuth, Aircraft Sun Azimuth
- GPS_Vertical_Speed (MIDG-II)
- ADC_Baro_Altitude
- Potential Temp, Cabin Temp, Cabin Humidity
- Acceleration_X, Acceleration_Y, Acceleration_Z
- Time stamp (both IRIG and NTP available for clock synchronization)

• New AIMMS-20 high precision/rate system in work (see B/U slides)

Platform Science Data Comm.

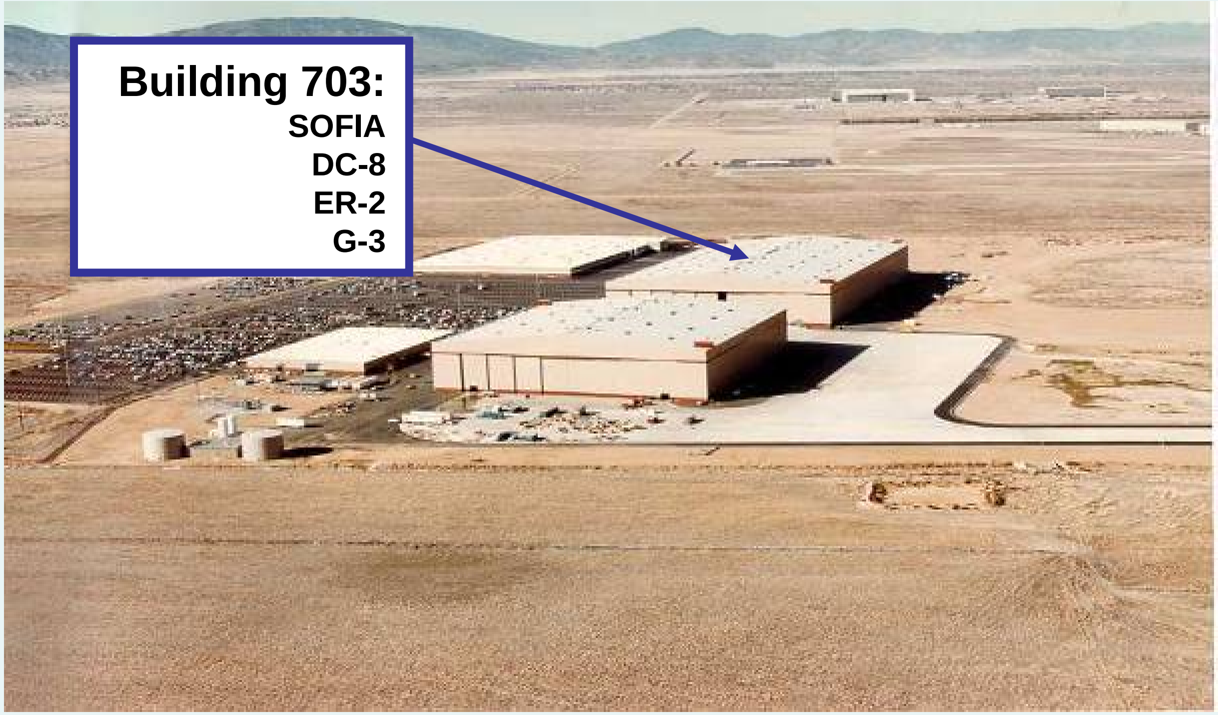
- Iridium system is 2400 bps per channel, with the 4-channel system supporting up to 9600 bps

- New INMARSAT system capable of up to 432kbps
    - Buy by bandwidth service

DC-8 Located At DAOF Palmdale, CA

Dryden Aircraft Operations Facility

Dryden Aircraft Operations Facility



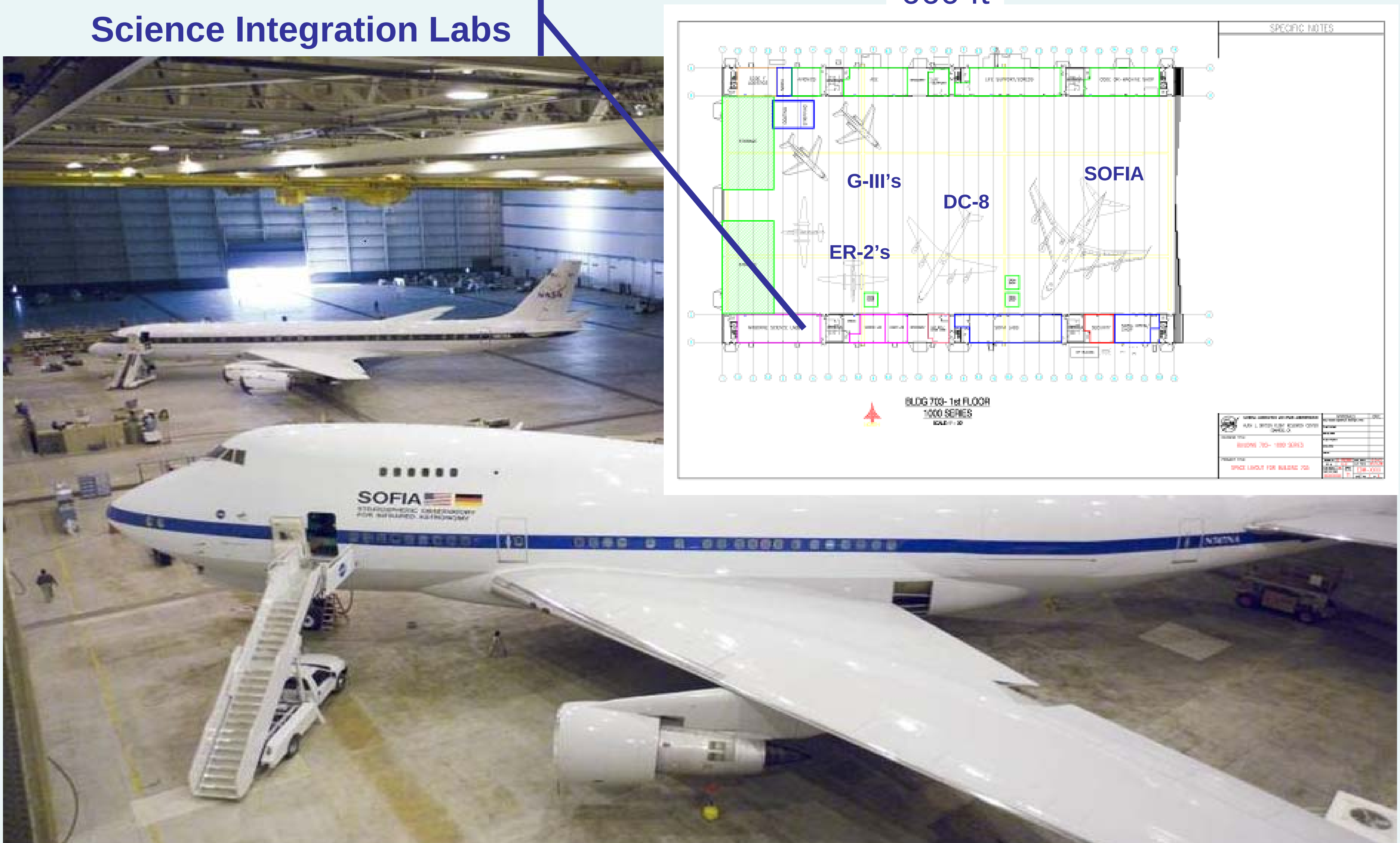
Palmdale Site 9 complex provides for :

- **Efficient consolidated operations of platform aircraft**
- **Easy access for visiting science teams**
- **Access to Air Force Plant 42 airfield**
  - **Two 12,000 ft runways**

DAOF Layout

Science Integration Labs

660 ft



Substantial Ground Support Infrastructure

2” 100PSI H_2O Main

440VAC/200amp Receptacles

120VAC/20amp Receptacles

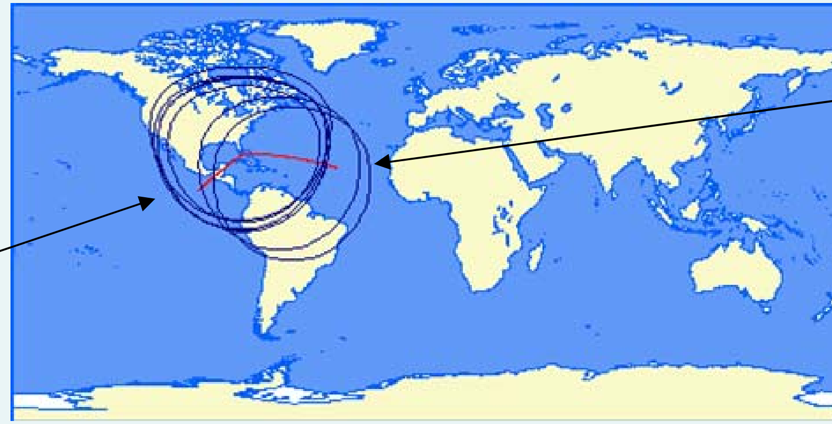
DC-8 GRIP Support

GRIP Support – Transit Time

From	To	Initial Heading	Distance	Time
KJAX (30°29'39"N 81°41'16"W)	KMIA (25°47'36"N 80°17'26"W)	164° (S)	291 nm	0:40
KHST (25°29'18"N 80°23'01"W)	KMIA (25°47'36"N 80°17'26"W)	15° (N)	19 nm	0:03
KRSW (26°32'10"N 81°45'19"W)	KMIA (25°47'36"N 80°17'26"W)	119° (SE)	91 nm	0:12
KFLL (26°04'21"N 80°09'10"W)	KMIA (25°47'36"N 80°17'26"W)	204° (SW)	18 nm	0:02
TISX (17°42'06"N 64°48'06"W)	KMIA (25°47'36"N 80°17'26"W)	301° (NW)	990 nm	2:15
TBPB (13°04'29"N 59°29'33"W)	KMIA (25°47'36"N 80°17'26"W)	305° (NW)	1400 nm	3:11
Total:			2808 nm	6:23

GRIP Support - Range

20N40W



10N100W

From	To	Initial Heading	Distance	Time
KFLL (26°04'21"N 80°09'10"W)	20°00'00"N 40°00'00"W	90° (E)	2243 nm	5:06
KFLL (26°04'21"N 80°09'10"W)	10°00'00"N 100°00'00"W	233° (SW)	1483 nm	3:22
Total:			3725 nm	8:28

Code	Source	Location
KFLL	FAA	*Fort Lauderdale [Fort Lauderdale/Hollywood Intl], FL, US*
KJAX	FAA	*Jacksonville [Intl], FL, US*
KMIA	FAA	*Miami [Intl], FL, US*
KHST	FAA	*Homestead [Homestead Air Reserve Base], FL, US*
KRSW	FAA	*Fort Myers [Southwest Florida Intl], FL, US*
TISX	FAA	*Christiansted [Henry E Rohlsen Airport], St. Croix, VI, US*
TBPB	DAFIF	*Bridgetown [Grantley Adams Intl], BB*

Range circles extend 1980nm from KJAX, KHST, KRSW, TISX , TBPB departure points and allow for two hours dwell time at perimeter of circle (4.5 hours out + 4.5 hours back + 2 hours dwell = 11.0 hours); Range circle extends 1760nm from KFLL departure point and allows for two hours dwell time at perimeter of circle (4.0 hours out + 4.0 hours back + 2 hours dwell = 10.0 hours);

GRIP Support - Range

Ft. Lauderdale to Barbados transit/ science flight

From	To	Initial Heading	Distance	Time
KFLL (26°04'21"N 80°09'10"W)	20°00'00"N 40°00'00"W	90° (E)	2243 nm	5:06
20°00'00"N 40°00'00"W	TBPB (13°04'29"N 59°29'33"W)	252° (W)	1196 nm	2:43
Total:			3439 nm	7:49

Code	Source	Location
KFLL	FAA	*Fort Lauderdale [Fort Lauderdale/Hollywood Intl], FL, US*
TBPB	DAFIF	*Bridgetown [Grantley Adams Intl], BB*

GRIP Support - Range

Ft. Lauderdale to Pacific region and Back

10N100W

From	To	Initial Heading	Distance	Time
KFLL (26°04'21"N 80°09'10"W)	10°00'00"N 100°00'00"W	233° (SW)	1483 nm	3:22
10°00'00"N 100°00'00"W	KFLL (26°04'21"N 80°09'10"W)	46° (NE)	1483 nm	3:22
Total:			2965 nm	6:44

Code	Source	Location
KFLL	FAA	*Fort Lauderdale [Fort Lauderdale/Hollywood Intl], FL, US*

Ft. Lauderdale – Average Temperatures

Month	Average Temp	Ave. Daily High Temp	Ave. Daily Low Temp	Record High Temp (year)	Record Low Temp (year)
June	81ºF / 27ºC	89ºF / 32ºC	72ºF / 22ºC	100ºF / 38ºC (1985)	40ºF / 4ºC (1983)
July	83ºF / 28ºC	91ºF / 33ºC	73ºF / 23ºC	101ºF / 38ºC (1981)	61ºF / 16ºC (1950)
Aug	83ºF / 28ºC	91ºF / 33ºC	74ºF / 23ºC	99ºF / 37ºC (1987)	61ºF / 16ºC (1976)
Sep	82ºF / 28ºC	90ºF / 32ºC	73ºF / 23ºC	99ºF / 37ºC (1973)	57ºF / 14ºC (1994)
Oct	78ºF / 26ºC	86ºF / 30ºC	70ºF / 21ºC	97ºF / 36ºC (1980)	44ºF / 7ºC (1996)

Ft. Lauderdale – DC-8 Takeoff Performance

NASA DRYDEN RESEARCH CENTER 3 MAR 09 KFLL-2 *OPSDATA SERVICES*

--KFLL--/--FLL--
FT LAUDERDALE-HOLLYW
FT LAUDERDALE, FL
VAR 03 W

ELEV. 9FT
MAX TEMP 120F
CFM56-2-C1

FLAPS 23

DC-8-72
TAKE OFF PERFORMANCE
A/C PACKS OFF

RUNWAY NO		09L	13	27R	31		
F	PERF LMT					N1%	C
0	350.0	348.6	X308.9	347.6	X308.4	84.9	-17
10	350.0	347.1	X306.8	345.7	X306.4	85.8	-11
20	350.0	345.4	X304.6	343.7	X304.3	86.7	-6
30	350.0	343.6	X302.3	341.6	X302.2	87.6	0
40	350.0	341.6	X299.8	339.3	X299.8	88.5	4
45	350.0	340.5	X298.6	338.2	X298.7	89.0	7
50	350.0	339.5	X297.3	337.0	X297.5	89.4	10
55	350.0	338.6	X296.3	336.0	X296.5	89.9	13
60	350.0	337.5	NA	334.6	NA	90.3	16
62	350.0	336.8	NA	334.1	NA	90.5	17
64	350.0	336.2	NA	333.5	NA	90.7	18
66	350.0	335.5	NA	332.9	NA	90.8	19
68	350.0	334.9	NA	332.4	NA	91.0	20
70	350.0	334.2	NA	331.8	NA	91.2	21
72	350.0	333.5	NA	331.1	NA	91.3	22
74	350.0	332.8	NA	330.5	NA	91.5	23
76	350.0	332.1	NA	3[illegible].9	NA	91.7	24
78	350.0	331.4	NA	329.3	NA	91.8	26
80	350.0	330.6	NA	328.6	NA	92.0	27
82	350.0	329.9	NA	327.9	NA	92.2	28
84	350.0	329.1	NA	327.2	NA	92.3	29
86	350.0	328.3	NA	326.6	NA	92.5	30
88	350.0	325.7	NA	324.1	NA	92.3	31
90	350.0	323.7	NA	322.1	NA	92.2	32
92	350.0	322.0	NA	320.2	NA	92.0	33
94	350.0	320.2	NA	318.4	NA	91.8	34
96	346.9	318.5	NA	316.5	NA	91.7	36
98	343.6	316.7	277.7	314.7	277.7	91.5	37
100	340.3	315.0	276.1	312.8	276.1	91.3	38
102	336.9	313.2	274.6	311.0	274.6	91.2	39
104	333.6	311.5	272.9	309.1	273.0	91.0	40
106	330.5	309.3	270.8	306.8	271.1	90.9	41
108	327.4	307.1	268.8	304.6	269.1	90.7	42
110	324.3	304.8	266.7	302.3	267.0	90.6	43
112	321.2	302.2	264.7	299.8	264.9	90.4	44
114	318.0	299.6	262.6	297.5	262.8	90.3	46
116	314.9	297.2	260.5	295.1	260.7	90.1	47
118	311.8	294.8	258.5	292.8	258.6	90.0	48
120	308.7	292.4	256.7	290.5	256.7	89.8	49
RUNWAY LENGTH		9000	6930	9000	6930		
RUNWAY SLOPE		0.0	0.0	0.0	0.0		
HEADWIND CORR		414	502	461	484		
TAILWIND CORR		2502	NA	2476	NA		
LIMITED BY		OBST	OBST	OBST	OBST		
LEVEL OFF HT		1000	1000	1000	1000		

APPLY PERFORMANCE CORRECTION AS REQUIRED

DATED: 03/03/09

Ft. Lauderdale – DC-8 Takeoff Performance

- How long can I fly out of Ft. Lauderdale?

Assume that we takeoff in early morning with cool 74 deg F temperature
and a maximum allowable takeoff weight of 330,000 lbs

Aircraft empty weight =	155,000 lbs
Payload weight =	30,000 lbs
Fuel weight =	145,000 lbs
Total TO weight =	330,000 lbs

145,000 lbs fuel / 12,500 lbs fuel burn per hour = 11.6 hours
Less 1.5 hour reserve fuel = ~10 hours

St. Croix & Barbados have longer runways so we may be able to achieve the 11 hour flights from those locations

Frequency & Duration of Flights

- Duty day maximum = 14 hours
- Rest period minimum = 12 hours
- Maximum flight hours in 7 days = 40 hours
- Flight day = any day aircraft flies or maintenance crews complete preflight
- No fly day = aircraft made available to experimenters but does not fly
- Down day = no activity or support at aircraft
- Must schedule a down day within each 10 day (flight days + no fly days) period

- Typical flight day = aircraft available 3 hours prior to flight + flight hours + aircraft available for 1 hour after flight

  - Minimum time required prior to flight is 1.5 hours for preflight; any additional hours are as required by science team

  - Minimum time after flight is 1 hour for post flight activity; any additional hours are as required by science team

Frequency & Duration of Flights

- Plan on staffing to support 10 hour flight day with bursts to 11 hours in length
  - 3 hour preflight + 10 hour flight + 1 hour post flight = 14 hr duty day
  - 3 hour preflight + 11 hour flight + 1 hour post flight = 15 hr duty day
    - Only when flying out/in to home base (3 additional techs at home base)

- Always plan on 12 hr rest period for aircraft operations personnel

- Planning on additional technician staff and 2 navigators to support operations

Flight Planning

Example GRIP DC-8 Suitcase Flight Schedule (120 Flt Hrs) Aug/Sep 2010

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
15 Travel day 5.0 hr KPMD-KFLL	16 No fly day unpacking/ inst. checks	17 No fly day unpacking/ inst. checks	18 Science Flight Day 10 hr	19 Science Flight Day 10 hr	20 Science Flight Day 10 hr	21 No fly day inst. checks
22 No fly day inst. cheks	23 No fly day inst. cheks	24 Down Day (Aircraft Unavailable)	25 Science Flight Day 11 hr (includes suitcase transit)	26 Science Flight Day 8 hr	27 Science Flight Day 10 hr	28 Science Flight Day 11 hr (includes suitcase transit)
29 No fly day inst. checks	30 No fly day inst. checks	31 No fly day inst. checks	1 No fly day inst. checks	2 No fly day inst. checks	3 Down Day (Aircraft Unavailable)	4 No fly day inst. checks
5 Science Flight Day 11 hr (includes suitcase transit)	6 Science Flight Day 8 hr	7 Science Flight Day 10 hr	8 Science Flight Day 11 hr (includes suitcase transit)	9 No fly day packing (Aircraft Available)	10 No fly day packing (Aircraft Available)	11 Travel day 5.0 hr KFLL-KPMD
12	13	14	15	16	17	18

Suitcase flight crew:
Pilots(2) + FE(1) + Nav(2) + MD(2) + Data Mgr(1) + Techs(4) = 12
Allows for up to 38 science team members

LN2 Carriage Capability

- We have available two 35 liter dewars that we have carried in the main cabin
  - We have had as many as three 35 liter dewars on flights

- We also have three 4 liter dewars

Backup Slides

AIMMS-20 System

With regard to frequency, accuracy, and resolution:

Time Frequency:
Up to 20Hz, as time is sent out at the same rate as the position/velocity messages from the GPS boards. Accuracy: similar to what one expects from GPS processor, rated at 20ns! However, practically speaking, you have transfer delays: GPS board -> GPS module digital board -> CAN bus -> CPM processor, which are variable. This would put a limit of probably 1ms or so on it. The resolution in time on the standard output is limited by single-precision floating point representation for the output in decimal hours. This is limited to approximately 0.00001 hours, or 36ms, as a result. If high-performance time-tagging is ever required, we could provide 1ms accuracy / resolution, but as things stand, I'd say we're probably good to 50ms (consistent with 20Hz rate).

Pressure:
Output frequency is programmable up to 40Hz. Precision limited by thermal bias and hysteresis. Those are typically within 100Pa. Accuracy is limited by this + sensor calibration uncertainly and nonlinearity, which adds about another 50Pa. Absolute accuracy will depend also on position error characterization, which will have an uncertainty of 20 Pa or so. All combined, static pressure accuracy should be +/- 200Pa. Resolution is limited by 14bit ADC, which works out to about 6-7Pa.

Temperature:
Like all air-data parameters, the output rate is programmable up to 40Hz. The frequency response of the thermistor is much lower than this, so there is little point in setting it this high. We usually run it at a few Hz only. Resolution is 14-bit. For your probe, we'd extend the range to further than the -30C we normally use down to -50C. With dynamic heating of 20C, this puts the static temperature sensed at 200m/s -70C. The resolution works out to approximately 0.01C. Calibration accuracy is +/- 0.05C, but uncertainty in the recovery factor means total confidence in absolute accuracy probably around 0.2C (this is being verified by Tom Ratvatsky this week at NASA Glenn).

Wind vector (u,v,w) Frequency:
Real-time output of 5Hz standard, but could be extended to 20Hz assuming the differential pressure data is updated at this rate as well. Resolution in the output is 0.01 m/s, this is supported by resolution in constituent data (ground speed, TAS, flow angles). Accuracy is dominated by ability to calibrate out position errors. We can achieve consistency to the level of about 0.5 m/s on wind box calibration checks, so this is my confidence in total accuracy.

Position (GPS altitude, lat, long) Frequency:
20Hz. Resolution is currently limited by single-precision floating point accuracy for latitude / longitude, which works out to 7 significant figures. Typically, this means latitude / longitude resolution is 0.00001 deg. Accuracy is governed by the GPS system: whether WAAS is active or not, and PDOP due to constellation geometry. If WAAS / SBAS available, accuracy is good 1.2m RMS. Without SBAS, accuracy is 2-3 times worse than this.

AIMMS-20 System

With regard to frequency, accuracy, and resolution:

Attitude (pitch, roll, heading):
Output frequency is user-programmable. It is based on IMU integrated rates, which are available up to the IMU output rate, which is currently 40Hz. This can be increased to a maximum of 100Hz. Resolution on angles is 0.01 deg. With fore/aft antenna geometry, roll is determined exclusively by gyro integration anchored by g-vector sensed predominantly by the y-accelerometer. Absolute thermal bias stability of the IMU accelerometers is about 3mg, which is translates into about 0.17 deg. for accuracy. Pitch and heading accuracy limited by carrier-phase stability over the antenna baseline. With 20m antenna separation (105 wavelengths of L1 carrier), and observed phase offset estimation stability of approx. 0.1 wavelengths for your installation during maneuvers means angular accuracy 0.001 rad or 0.06 deg. was being achieved on the GPS phase calculations. Precision is limited by gyro and accelerometer noise, and phase noise on the GPS signals. Precision should be a few times better, approaching 0.01 deg.

Angle of Attack Yaw angle:
Output frequency user-programmable up to 40Hz. Flow angles are measured by 5-hole probe with 20Pa combined thermal bias/span stability, nonlinearity, hysteresis and calibration accuracy. At 200m/s, this uncertainty translates is 0.01 deg. precision. Absolute flow angle accuracy will be governed by how well the position error effects are calibrated out from the flight data. This is usually achieved to within 0.1 deg.

True airspeed:
Output frequency user-programmable up to 40Hz. True airspeed accuracy governed by pitot-static accuracy of 20Pa, which at 200m/s translates into roughly 0.1 m/s, subject again to accuracy of position-error characterization. Precision is limited by noise and resolution on the pitot-static channel, which is about an order of magnitude better than the total accuracy, so we're looking at limit of about 1 cm/s.

Aircraft velocity (eastward, northward, vertical):
Output frequency available up to the output rate on the IMU, which is 40Hz but can be extended up to a maximum of 100Hz. Accuracy limited by GPS, which is spec'd by the Novatel boards at 0.03 m/s. Precision is governed by IMU noise / integration error, which will be down around 0.01 m/s level.

Vertical acceleration:
Vertical acceleration output rate limited by IMU output rate of 40Hz (up to max 100Hz). Accuracy (thermal bias stability, non-linearity) is approximately 3mg, noise (precision) is approx. 1mg.