MD-10 Main Landing Gear
Flight Test Proposal

On July 28, 2006 the Left Main Landing Gear (LMLG) on FedEx flight 630, a McDonnell-Douglas (Boeing) MD-10-10F (N391FE), collapsed during the landing rollout at MEM. The NTSB Airworthiness Group, with representatives from the FAA, Boeing, FedEx, and ALPA, requests an in-service flight test program to investigate the loads imparted to the MLG during the landing sequence. The primary purpose is to validate the Finite Element Model (FEM) of the LMLG being developed by Boeing and to determine the MLG loads due to the installation of carbon brakes. During the on-scene portion of the investigation it was reported that MD-10 aircraft with carbon brakes have a higher incidence of brake "shudder" than those aircraft with the original steel brakes. The flight test should also allow the group to determine the impact, if any, that this "shuddering" has on the MLG loads.

LMLG Exam

Metallurgical examination of the failed LMLG cylinder was accomplished at the NTSB Materials Laboratory August 15-17, 2006. The origin of failure was located in the bore of the filler valve located on the aft side of the cylinder below the intersection with the drag brace (Figures 1 & 2). Metallurgical examination of the fracture revealed a small (0.130" long x 0.025" deep) pre-existing thumbnail region with a mixture of intergranular and transgranular separations on the outboard side of the valve bore. The thumbnail region was located underneath a layer of stray nickel-plating on the bore. The fracture on the inboard side of the bore initiated at a small (0.004" diameter, 0.002" deep) corrosion pit with a small area of transgranular separation around the pit. There was no plating present on the inboard side. Preliminary information indicates that the area of pre-existing fracture in the filler valve bore is not sufficient to cause failure of the MLG cylinder under normal operating loads.

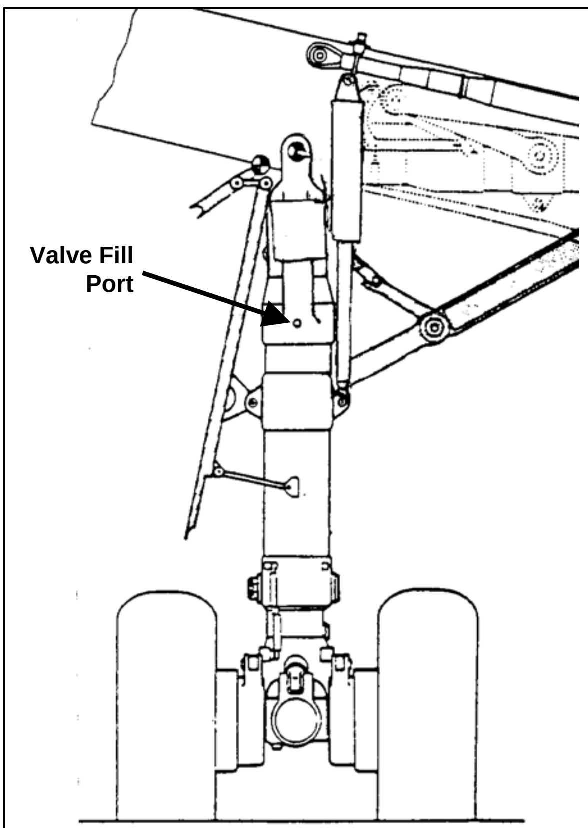


Figure 1 - Diagram of LMLG, looking FWD

Figure 2 - Close-up Photo of LMLG, Looking FWD

Scope of Test

Due to the small amount of pre-existing fracture, the nominal touchdown loads based on FDR data, pilot reports of "shudder" on carbon brake equipped airplanes, and the complex geometry of the MLG cylinder in the area of failure, the NTSB has requested that Boeing develop a Finite Element Model of the LMLG to determine the localized stresses in the area of the filler valve bore. In order to accurately represent the loads imparted to the gear and to validate the FEM, the NTSB is requesting that FedEx instrument an airplane for an in-service evaluation. The instrumentation will consist of strain gauges, accelerometers, pressure transducers, string potentiometers and data logging equipment described below. The aircraft to be modified should be a MD-10-10F configured with carbon brakes. It would be beneficial if the selected aircraft is one in which pilots have reported brake "shudder". In order to minimize the impact to the FedEx daily operations, the aircraft selected can be one that is currently scheduled for maintenance. Once the preliminary engineering work is completed, the installation of the equipment will require that the airplane be down for about 14 days. The intention is to then operate the airplane in revenue service for 30-60 days with little restriction. Data retrieval may require that the instrumented airplane land at certain airports periodically during the test time frame. Omni Test Services (OTS) has been selected to provide the instrumentation and installation on the selected airplane due to their experience with a similar flight test for Boeing and FedEx.

Instrumentation

The group has determined that in order to gather the needed data, the airplane should be equipped with 8 linear strain gauges, 3 rosette strain gauges, 3 accelerometers (or a tri-axial accelerometer), and 1 brake pressure transducer on each MLG. The airplane will also be equipped with 3 accelerometers (or a tri-axial accelerometer) near the airplane center-of-gravity, 2 brake pressure transducers, one each on the left and right brake systems, and two string potentiometers, one each on the left and right dual brake control valves (DBCV) to measure lever input position. For the purpose of calibration, a string potentiometer will be temporarily installed on the LMLG to measure the stroke. All of this data will be fed to the recording device supplied by OTS.

Each MLG will be instrumented in accordance with Appendix 1. The strain gauges will be applied to the MLG outer cylinder (P/N ARG7002) using a cyano-acrylic adhesive supplied by OTS and will measure the local stresses in the general area of the filler valve, on the forward side of the cylinder opposite to the filler valve, and below the side brace attach point on the inboard and outboard surfaces. Corrosion protection will be applied to the stripped areas where the strain gages are installed. The MLG accelerometers will be installed at the base of the MLG piston in a recess above the truck beam pivot on the outboard side using PR1422 adhesive and tape and will measure the 3-axis motion of the MLG piston during the landing sequence. The airplane accelerometer will be installed immediately forward of the central avionics compartment (CAC) access door at the lower centerline of the airplane for recording the 3-axis motion of the CG. The MLG brake pressure transducers will be installed downstream of the MLG anti-skid manifolds in the most convenient position to measure brake pressure at the brake input. The airplane brake pressure transducers will be installed between the brake control valves and the anti-skid valves in the most convenient position to measure brake pressure input to the anti-skid manifolds. The string potentiometers will be installed on brackets attached to the dual brake control valves to measure the brake pedal input to the valves.

From the MLG wheel wells, the wiring will be routed through the pressure feed-thru to the CAC, where the test recording equipment will be mounted.

Calibration of the installed instrumentation will be performed using engine thrust per the procedure in Appendix 2 prior to releasing the airplane into service.

Data Logging Equipment

Four boxes will be installed in the aircraft CAC area for recording the selected parameters; two for signal conditioning, one recording box, and one power distribution box. The total weight of the boxes is 18.25 pounds. The signal conditioning boxes each have dimensions of 10 x 17 x 2 inches and will output analog data to the recording box. The recording box has dimensions of 8.5 x 11 x 3.5 inches. The recording device has an internal memory card for storing data that will need to be removed every week for data download. The power distribution box has dimensions of 3 x 5 x 2 inches. All of the boxes will be mounted in the CAC in a fixture designed and fabricated by FedEx.

This test equipment will require electrical power (28volts) and a triggering signal input from the aircraft. It can operate on a range of 18 to 30 volts (DC) but only requires 2.5 Amps of power. Power will come off of the non-essential Ground Servicing bus in the CAC and a 5-amp circuit breaker will be installed in the cockpit. A 16-gage wire will be routed from the recorder in the CAC to the ADAS in the Avionics bay to carry the triggering signal.

Data Acquisition & Timing

The only segment of the MD-10 flight spectrum that is of interest is touchdown through brake applications. The test recorder will be installed to collect data from the strain gages, accelerometers, pressure transducers, and string potentiometers that are installed on the airplane (50 total channels) at a rate of 200 samples per second. To conserve storage capacity, the recorder will be triggered to start collecting data at a Radio Altitude of 50 ft and stop collecting when the airplane slows to 60 knots indicated airspeed.

The triggering input will be a digital signal from the Auxiliary Data Acquisition System (ADAS), within the Digital Flight Data Acquisition Unit (DFDAU). The ADAS will monitor the aircraft flight mode and the triggering parameters and provide a discrete output signal to the test equipment. The ADAS has an operator-programmable feature that is independent of the DFDAU software and hardware. A program will need to be loaded onto the ADAS to define the discrete triggering signal and its output.

In addition to the data gathered from the installed instrumentation, airplane data from the existing flight recording (ADAS) system will be needed. Each landing recorded on the OTS system will have to be correlated with the corresponding airplane parameters such as, altitude, airspeed, heading, brake pedal position, control inputs, engine thrust, etc. The ADAS system installed on the airplane will record all of the needed data and is normally downloaded every 90 days. The list of parameters recorded by the ADAS recorder is listed in Appendix 3. During the installation of the instrumentation a new card will be put in the ADAS recorder to record the parameters during the flight test period. The recorded ADAS flight data will be downloaded at the same time as the test data (once per week).

Engineering

All necessary engineering to install the test equipment on the airplane will be the responsibility of FedEx including any DER approvals. Boeing will provide assistance where necessary. The FAA will be involved in the planning and installation in order to facilitate the approvals.

Maintenance

An Engineering document will schedule a periodic maintenance inspection of the installation for loose wires on the MLG or leaks of the brake lines. Maintenance will be directed to cut and cap any damaged wires. If necessary, the circuit breaker to the recording equipment may be pulled to deactivate the system in order to continue to operate the aircraft without interrupting revenue service.

FedEx Engineering and Maintenance Ops Control will coordinate and schedule a periodic replacement of the data storage card at a particular station. The data will be transmitted to OTS where preliminary reduction will be performed. OTS will then transmit the data to the NTSB where full reduction and analysis will be performed by the accident Airworthiness Group. The group will provide the data reduction criteria to be used by OTS, such as the recording parameters and the exceedance values to be considered.

Equipment Removal

At the end of the recording period, maintenance will be notified to power off the system and remove the recording device from the CAC. The aircraft may still operate in revenue service with the wiring installation until it is determined that enough data was gathered to support the investigation. Once the group is satisfied, the airplane can be scheduled in for maintenance, at which time all the wires and gages will be removed.

Project Mile Stones

11/06	Select A/C for installation
12/06	Develop Engineering
12/06	Instrument MLG and calibrate gages, Install Test data recorder, Return A/C into Operation.
12/06-2/07	Operate A/C and collect memory cards, Interpret results for any changes to installation.
3/07	Final data download, Temporarily deactivate equipment.
4/07	Airworthiness Group to interpret results.
5/07	Completely remove test equipment.

Responsibilities

NTSB: Crookshanks
Overall Project Coordination and Oversight
Final Approval
Data Analysis

BOEING: Steelhammer
Calibration plan
Data analysis

OMNI-TEST SERVICES: Ingram
On-Site Installation of Instrumentation
On-Site Ops Check & Calibration
Parts: Recording Equipment, Strain Gages, Accelerometers, Pressure Transducers, String Potentiometers, and all necessary items for installation.
Data processing and follow-on support

FEDEX SYSTEMS ENGR: Cole
Project Coordination and Approval
Certification Issues & Supporting Documentation, Coordination
Flight Department Coordination for Crew Notification
Maintenance Program & Maintenance Alert
On-Site Support for Ops Check
Non-inventory Parts: Pressure Transducers, Connectors

FEDEX LAX ENGR: Springer
EA Preparation & Installation
Structural Analysis for Recording Installation
EA Attachments – Block Diagram, Installation Drawings
Wiring Installation & EA Work Steps
Coordination with Hangar MX and QA.
Parts: Wiring & clamps
Parts: Standard Parts for Pressure Transducer Installation

FEDEX AVIONICS ENGR: Massoud
Substantiation Analysis for Power Requirement
Certification of Test Equipment
DER Approval for Avionics Installation

FAA: Brown
FSDO Approval
Certification Issues

Appendix 1
MLG Instrumentation

MLG Input Signals – Recorded in OmniTest box

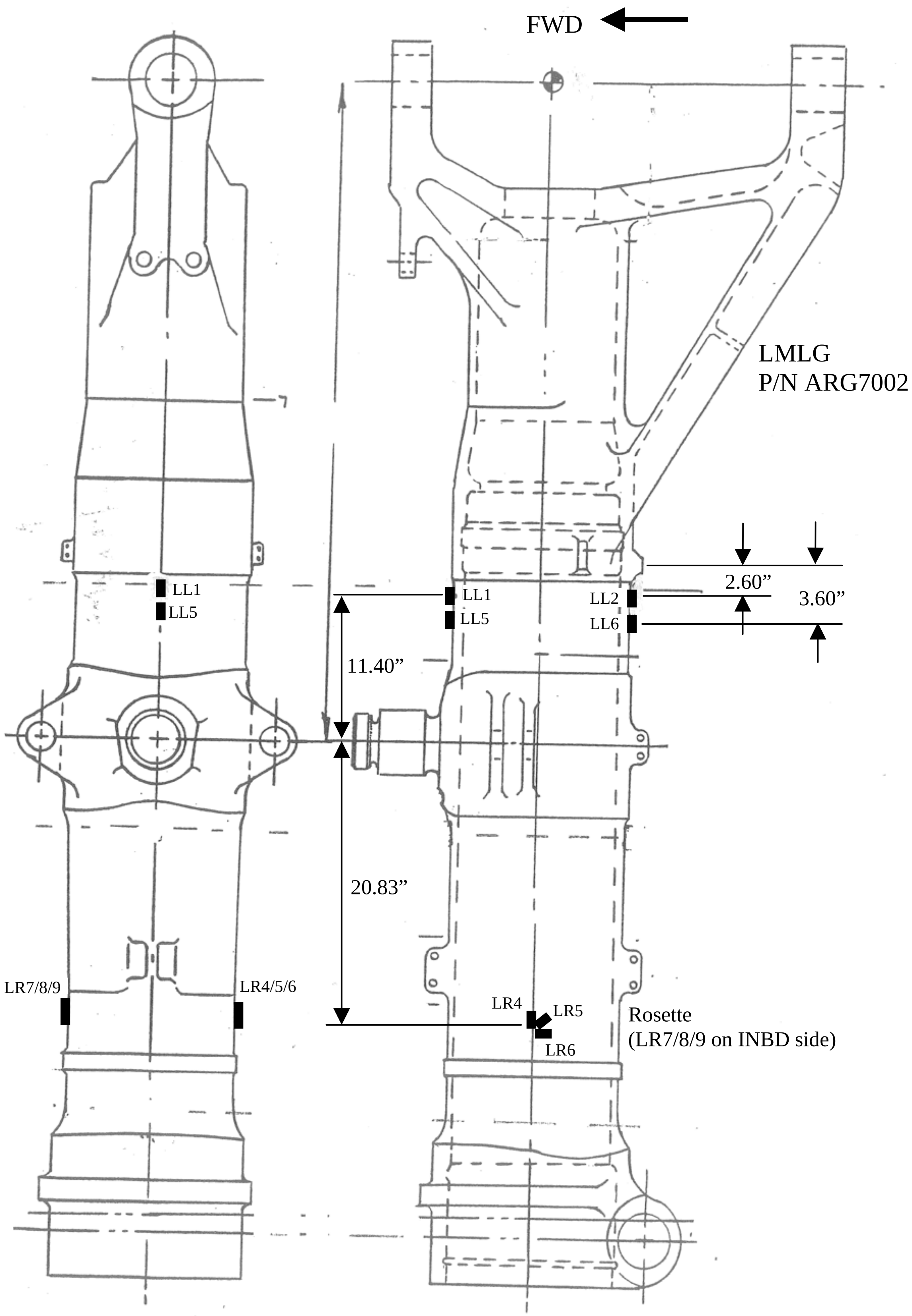
	Identity	Parameter	Scale Range
1.	LL1	Strain 1	+7000/-7000 micro-in/in
2.	LL2	Strain 2	+7000/-7000 micro-in/in
3.	LL3	Strain 3	+7000/-7000 micro-in/in
4.	LL4	Strain 4	+7000/-7000 micro-in/in
5.	LL5	Strain 5	+7000/-7000 micro-in/in
6.	LL6	Strain 6	+7000/-7000 micro-in/in
7.	LL7	Strain 7	+7000/-7000 micro-in/in
8.	LL8	Strain 8	+7000/-7000 micro-in/in
9	LR1/2/3	Rosette 1 (3 channels)	+7000/-7000 micro-in/in
10.	LR4/5/6	Rosette 2 (3 channels)	+7000/-7000 micro-in/in
11.	LR7/8/9	Rosette 3 (3 channels)	+7000/-7000 micro-in/in
12.	LA1	Accel X	-25/+25 G's
13.	LA2	Accel Y	-25/+25 G's
14.	LA3	Accel Z	-25/+25 G's
15.	LP1	Brake Pressure	0 - 3000 psi
16.	RL1	Strain 1	+7000/-7000 micro-in/in
17.	RL2	Strain 2	+7000/-7000 micro-in/in
18.	RL3	Strain 3	+7000/-7000 micro-in/in
19.	RL4	Strain 4	+7000/-7000 micro-in/in
20.	RL5	Strain 5	+7000/-7000 micro-in/in
21.	RL6	Strain 6	+7000/-7000 micro-in/in
22.	RL7	Strain 7	+7000/-7000 micro-in/in
23.	RL8	Strain 8	+7000/-7000 micro-in/in
24	RR1/2/3	Rosette 1 (3 channels)	+7000/-7000 micro-in/in
25.	RR4/5/6	Rosette 2 (3 channels)	+7000/-7000 micro-in/in
26.	RR7/8/9	Rosette 3 (3 channels)	+7000/-7000 micro-in/in
27.	RA1	Accel X	-25/+25 G's
28.	RA2	Accel Y	-25/+25 G's
29.	RA3	Accel Z	-25/+25 G's
30.	RP1	Brake Pressure	0 - 3000 psi
31.	SP1	LMLG Stroke	0 – 10 in
32.	SP2	Left DBCV position	0 – 2 in
33.	SP3	Right DBCV position	0 – 2 in

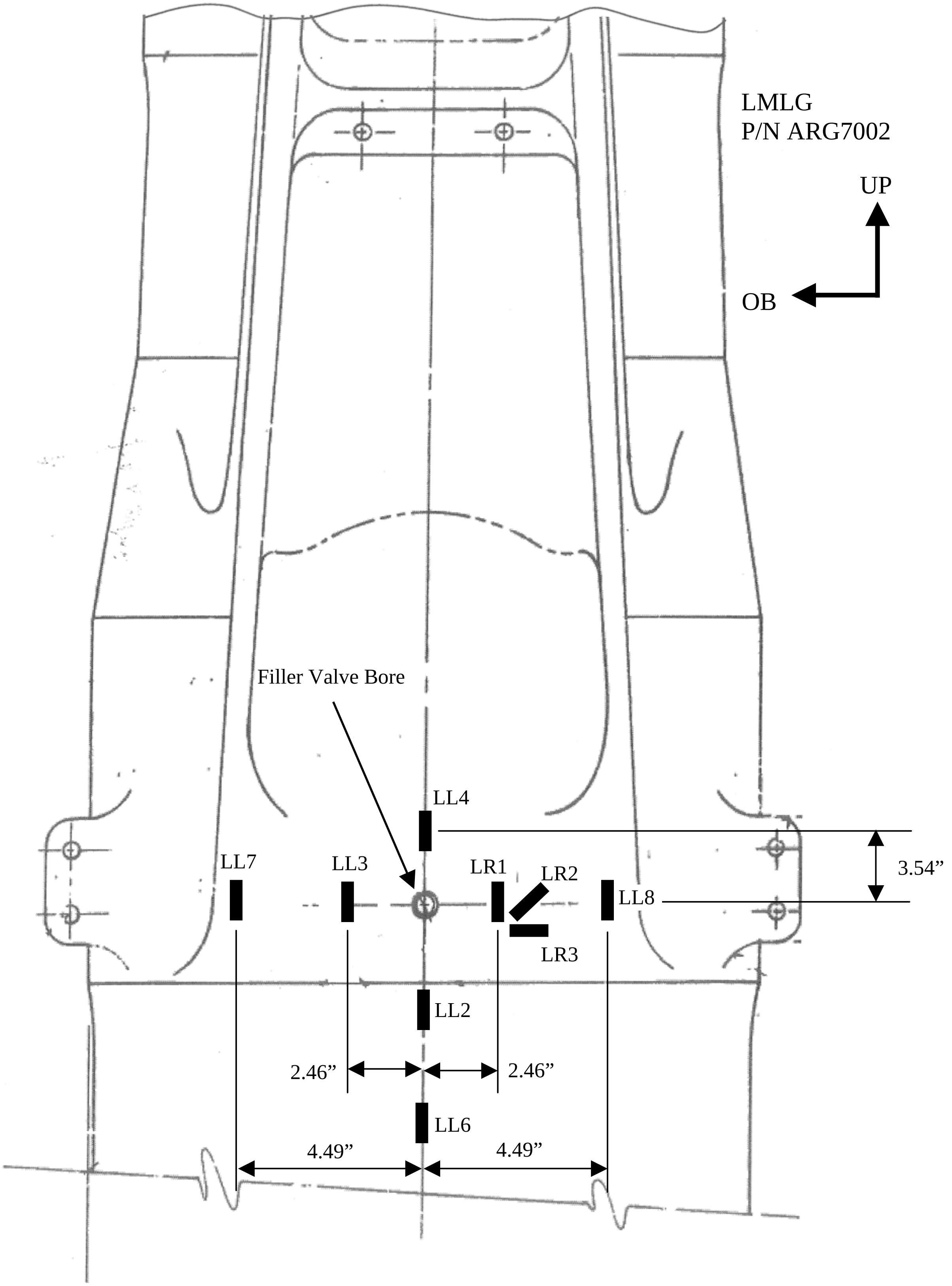
Items 1-15 are on the LMLG and items 16-30 are on the RMLG. The LMLG schematics are shown below, RMLG is opposite. The brake pressure transducers are not shown on the schematics but should be installed between the brake control valves and the anti-skid manifolds in the most convenient location. Item 31 is a temporary installation on the LMLG for the purposes of calibration and is not shown on the schematics. Items 32 and 33 are not shown on the schematics and will be installed as required on the DBCV's.

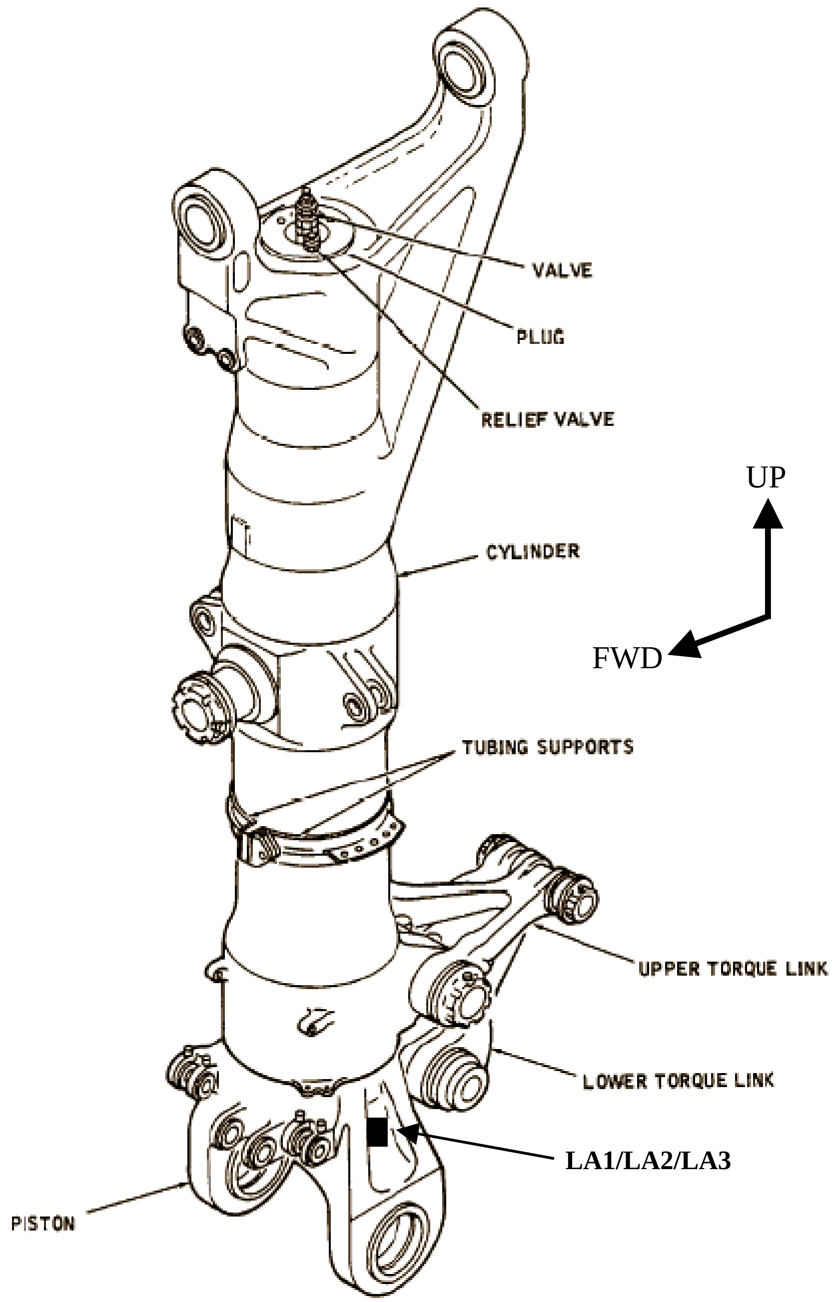
Airplane Input Signals – Recorded in OmniTest box

34.	CGA1	Accel X	-4/+4 G's
35.	CGA2	Accel Y	-4/+4 G's
36.	CGA3	Accel Z (vertical)	-4/+4 G's
37.	P3	Brake Pressure	0 - 3000 psi
38.	P4	Brake Pressure	0 - 3000 psi

Items 34-38 are not shown on the schematics. The airplane accelerometers are to be installed near the airplane center of gravity. The brake pressure transducers are to be installed in the brake lines between the anti-skid manifolds and brake assemblies in the most convenient location.


FWD
LMLG
P/N ARG7002
LL1
LL5
LL1
LL5
LL2
LL6
2.60”
3.60”
11.40”
20.83”
LR7/8/9
LR4/5/6
LR4
LR5
LR6
Rosette
(LR7/8/9 on INBD side)


LMLG
P/N ARG7002
UP
OB
Filler Valve Bore
LL4
LL7
LL3
LR1
LR2
LL8
3.54”
LR3
LL2
2.46”
2.46”
LL6
4.49”
4.49”



Left Main Landing Gear Accelerometers

Appendix 2
Calibration Procedures

Step No	Description	Remarks
1	Jack airplane up. Service the main gears with the airplane on jacks per AMM Chapter 11-16-01. Record air pressure and X dimension with weight on wheels.	To be done as part of C Check.
2	Zero out the strain gage readings	Will be done with weight on wheels prior to test. The pressure in the gear will not cause a significant strain in the cylinder.
3	Position the airplane at the run-up area (static position on level surface). Measure and record 'X' dimension of each main gear. Using the data recording system, record left MLG stroke and all strain gage readings.	Will provide the first calibration data point with V(gear) = Static weight on gear, and D(gear) = 0. An estimate of the weight and CG of the airplane will be used.
4	Obtain temperature and wind information from ATIS.	See note 5 for wind speeds.
5	Mechanic in the cockpit to apply brakes close to the full travel of the pedals.	Brakes must be applied firmly and continuously while the engines are on.
6	Start the wing engines. Set engine throttles to obtain 70% of N1 (see note 6). Stabilizing at this RPM, record the stroke on the left MLG and gage readings on the two gears for 10-15 seconds.	Compute and record thrust using the attached N1 vs. Thrust plots based on the ambient temperature (see note 7). Will provide the second calibration point. V(gear) = static wt on gear + delta due to thrust. D(gear) = Thrust
7	Repeat step 6 after increasing to 80% of N1.	Third data point
8	Repeat step 6 after increasing to 90% of N1.	Fourth data point.
9	Repeat step 6 after decreasing to 80% of N1.	Fifth data point.
10	Repeat step 6 after decreasing to 70% of N1.	Sixth data point. Engines should not be run for more than 5 minutes total time for steps 6-10.
11	Decrease throttle to idle. Allow engines to cool for 5 minutes at idle power.	
12	Turn engines off. Measure and record 'X' dimension of each main gear. Record left MLG stroke and the strain gauge readings on the data recording system.	

Notes:

1. Record all strain gauges; however, only gauge sets (LL1,LL2), (LL5, LL6), (RL1,RL2) and (RL5,RL6) will be used for loads calibration.
2. The calibrated gages will be used for estimation of vertical and drag loads on the gears only. Side loads will not be estimated.
3. Landing impact loads will not be estimated because calibration constants will apply only to gear position at or near static.
4. Engines to be run with bleed air and generators off.
5. Calibration should be performed preferably with cross wind less than 10 knots, and head wind not less than 10 knots. If prevailing conditions during the test are outside these limits, do not exceed the limitations of AMM Chapter 71-00-00 Figure 505A, page 510A (Preferred Wind Direction).
6. Synchronize the start of the data recording system with the system recording N1.
7. Use the attached N1 vs. Thrust calibration plots for the test airplane engines.
8. Follow the ground engine start procedures, and engine shutdown procedures listed in AMM 71-00-00.
9. Final weight and CG of the airplane to be measured after the calibration runs at the completion of the C Check.

DC/MD-10-10 CF6-6D Power Cals from GECA0106
40%, 70%, 98% N1 (98% chosen not exceed MPA for range of temperatures)
Static (0. M)
No ECS bleed

SEA LEVEL
Net Thrust - Wing Engine
Tamb °C
N1 ---- ---------- ---------- ---------- -------
40% ------ ---------- ---------- -----------—-
70% ------ - ---------- ---------- -----------—
98% ------ - ---------- ---------- -----------—

500 FT Pressure Altitude
Net Thrust - Wing Engine
Tamb °C
N1 ---- ---------- ---------- ---------- ------
40% ------ ---------- ---------- --------------
70% ------ - ---------- ---------- -------------
98% ------ - ---------- ---------- -------------

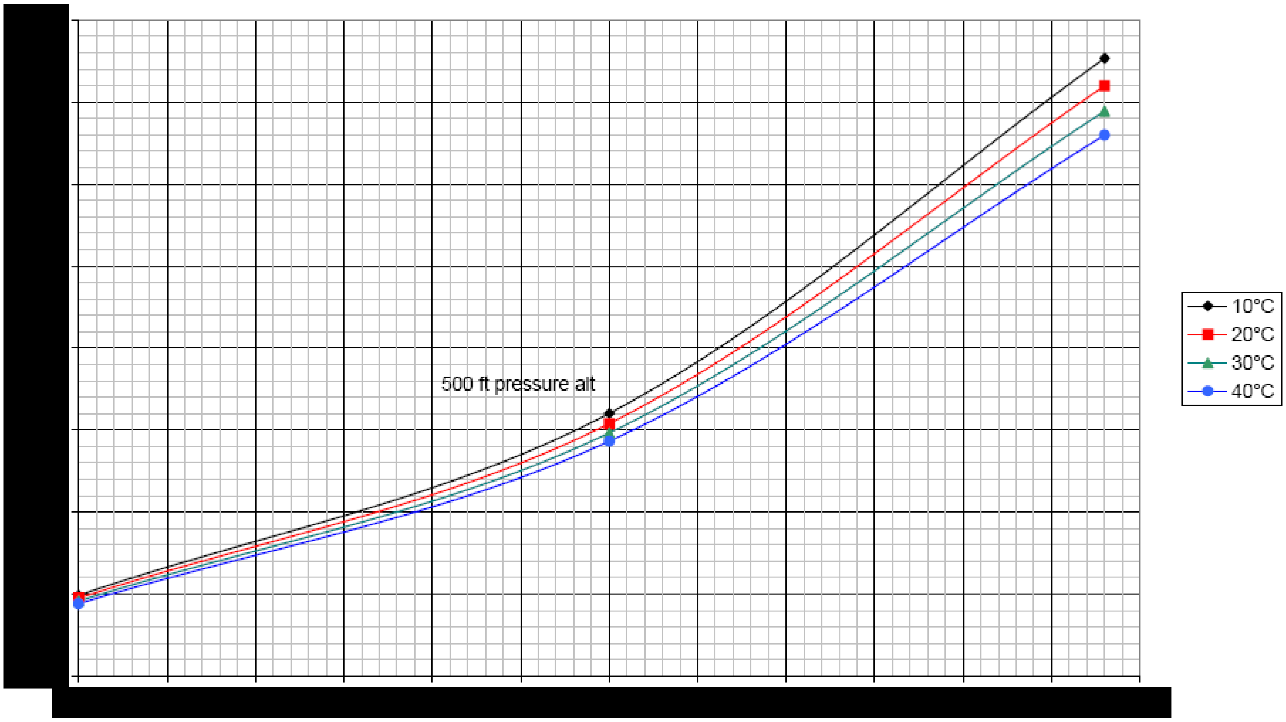
Use plots to locate intermediate temperature data points; interpolate between pressure altitudes as needed
Plots use wing engine data.

Only run engine in accordance with ground run limitations in AMM 71-00-00.
Do not use cockpit TAT to approximate Tamb unless TAT probe is aspirated.

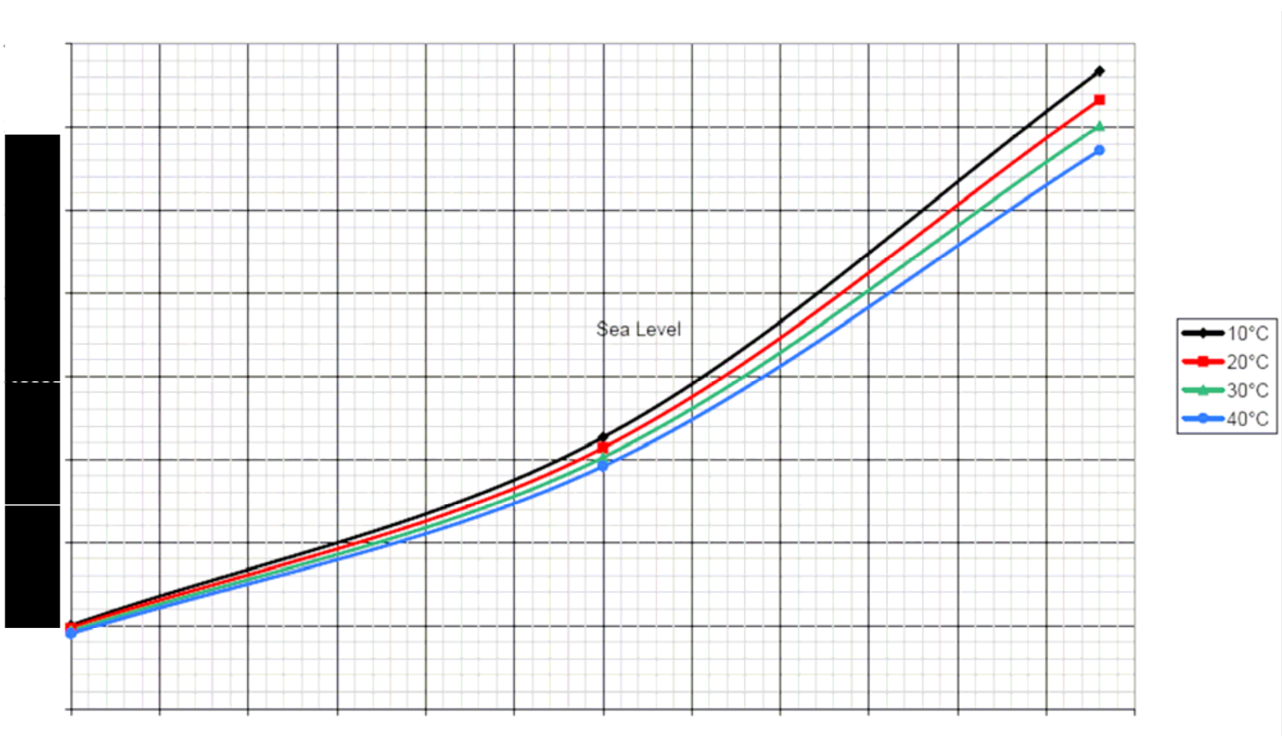
DC-10-10 CF6-6D reference data (STA and FRP refs are approximate)
Wing engine Nozzle cant 2 deg outward from fuselage CL (i.e. fwd thrust vector points inward towards fuselage), 0.9 deg downward from FRP (i.e. fwd thrust vector points up)

Engine CL position 112" below FRP
Fan nozzle exit STA 1219

DC/MD-10-10 CF6-6D
Net Thrust per Engine (500 ft Pressure Alt)
Function of Ambient Temperature



DC/MD-10-10 CF6-6D
Net Thrust per Engine (Sea Level)
Function of Ambient Temperature



Appendix 3
FOQA Recorder Parameters

A/P Engage-1
A/P Engage-2
A/T Climb Thrust
A/T Engaged-1
A/T GA Thrust
A/T TO Thrust
AC Bus-1
AC Bus-2
AC Bus-3
Aileron Pos-LIB
Aileron Pos-LOB
Aileron Pos-RIB
Aileron Pos-ROB
Air Cond Pack Flow-1
Air Cond Pack Flow-2
Air Cond Pack Flow-3
Air Data Source Select-Capt
Air Data Source Select-F/O
Airspeed
Altitude Select
Altitude, Baro
Altitude, Baro Set
Altitude, Radio
Angle of Attack
Anti-Ice Wing
Anti-Ice-1
Anti-Ice-2
Anti-Ice-3
APU Bleed Valve
APU Eng Fire
APU N1
APU N2
Auto Slat Extend
Below RA Minimum
Bleed Air
Brake Pedal Pos-Left
Brake Pedal Pos-Right
Cabin Altitude
Cabin Altitude Warning
Cabin Smoke
Cargo Heat-Aft
Cargo Heat-Fwd
Center of Gravity
Control Column Pos
Control Wheel Pos-CAPT
Control Wheel Pos-F/O
Date
Day
DC Bus-1 Off
DC Bus-2 Off
DME Distance
DME Frequency
Drift Angle
EGT Exceedence
EIS Source Select-Capt
EIS Source Select-F/O
Elevator Pos-LIB
Elevator Pos-LOB
Elevator Pos-RIB
Elevator Pos-ROB
ENG EGT
Eng Fire
ENG N2
ENG Thrust
Engine Out
Flap Handle Pos
Flap Pos-LIB
Flap Pos-LOB
Flap Pos-RIB
Flap Pos-ROB
Flaps Disagree
Flt Dir Active-1
Flt Dir Source Select-Capt
Flt Dir Source Select-F/O
Flt Path Angle
Flt Path Angle Select
FMA-1 Roll Armed
FMA-1 Roll Flash
FMA-1 Roll Mode
FMA-1 Speed Flash
FMA-1 Speed Protect
FMA-1 Speed Speed Mode
FMA-2 A/P Mode
FMA-2 A/T Mode
FMA-2 GND PROX
FMA-2 Land Armed
FMA-2 Land Mode
FMA-2 Prof
FMA-2 Vert Alert
FMA-2 Vert Flash
FMA-2 Vertical Mode
FMA-3 Speed Display
FMA-4 Roll Display
FMA-5 Vertical Display
FMS Source Select-Capt
FMS Source Select-F/O
Fuel Flow
Fuel Pressure
Fuel Qty - Ballast
Fuel Switch Off
Fuel Switch On
Glideslope Deviation
GPS Time
GPWS Caution
GPWS Caution Displayed
GPWS Failure
GPWS Mode 5 Visual
GPWS Terrain Awareness Available
GPWS Terrain Awareness INOP
GPWS Terrain Caution
GPWS Terrain Displayed-Capt
GPWS Terrain Displayed-F/O
GPWS Terrain Override
GPWS Terrain Warning
GPWS Too Low Terrain
GPWS Warning
GPWS Warning Displayed
GPWS WX Displayed-Capt
GPWS WX Displayed-F/O
Gross Weight
Ground Speed
Heading Select
Headwind Shear
High Stage Open Relay Valve Closed
Hydraulic Pressure
Hydraulic Pressure Low
Hydraulic Quantity
ILS Frequency
ILS Source Select-Capt
ILS Source Select-F/O
IRS Source Select-Capt
IRS Source Select-F/O
Landing Gear Down/Locked
Landing Gear Lever
Landing Gear Unsafe
Lateral Acceleration
Localizer Deviation
Longitudinal Acceleration
MACH
MACH Select
Mag Heading
Marker Beacon
Master Caution
Master Warning
N1 Exceedence
ND APPR Mode Select
ND CRS DEV IND Source Fail
ND HDG Fail
ND HDG Miscompare
ND Map Fail
ND Map Mode Select
ND No Plan Mode
ND Plan Mode Select
ND Position Miscompare
ND VOR Mode Select
ND WX Radar Off
Nose Gear Compressed
Oil Pressure
Oil Pressure Low

Oil Quantity
Oil Temperature
Overspeed
PFD ALT Fail
PFD Alt Miscompare
PFD ATT Fail
PFD ATT Miscompare
PFD CAS Fail
PFD FLT DIR Fail
PFD FPA Select
PFD HDG Fail
PFD HDG Miscompare
PFD HP Select
PFD IAS Miscompare
PFD MACH Fail
PFD MACH Select
PFD Mag/True Select
PFD Meters Select
PFD Track Select
PFD VERT SPD Fail
Pitch Attitude
Pitot Htr
Pneumatic ISO VLV 1-2 Closed
Pneumatic ISO VLV 1-2 Open
Pneumatic ISO VLV 1-3 Closed
Pneumatic ISO VLV 1-3 Open
Predictive Windshear Alert
Predictive Windshear Warning
Present Position Lat/Long
Roll Attitude
Rudder Pedal Pos
Rudder Pos-Lower
Rudder Pos-Upper
Slat Position
Slats Disagree
Speed Select
Spoiler Armed
Spoiler Position
Spoilers Extended
Stabilizer Out of Trim
Stabilizer Position
Stick Shaker
System Display Select
Tailwind Shear
TCAS Altitude Matrix
TCAS Combined Control
TCAS Display Control
TCAS Display Matrix
TCAS Down Advisory
TCAS Intruder Sense Level
TCAS Intruder Vertical Sense
TCAS RI Field
TCAS SL Control
TCAS SL Standby
TCAS Up Advisory
TCAS Vertical Control
Throttle Above 13.5 DEG
Throttle Below 3 DEG
Thrust Limit Mode
Thrust Reverser Deployed
Thrust Reverser Stowed
Total Air Temp
Total Fuel Qty
Total Pressure
True Airspeed
True Heading
UTC
Vert Speed Select
Vertical Acceleration
Vertical Speed
VOR Course Select
VOR Frequency
VOR Omnibearing
VOR Source Select-Capt
VOR Source Select-F/O
Wind Direction
Wind Speed
XMTR Keying HF-1
XMTR Keying HF-2
XMTR Keying SATCOM-1
XMTR Keying SATCOM-2 - SPARE
XMTR Keying VHF-1
XMTR Keying VHF-2
XMTR Keying VHF-3
Zero Fuel Weight