ATTACHMENT 9

EMERGENCY PROCEDURES

1. INTRODUCTION

As a novel developmental aircraft, the A160 may experience in-flight emergencies due to system failures that warrant special landing procedures. The impact of these failures can be reduced with good failure identification tools, emergency landing procedures, emergency landing software, including autorotation control laws, and adequate flight crew training in emergency procedures.

The timeline for an emergency landing begins with identification of the failure. A160 operators have many tools at their disposal to quickly recognize critical problems, including extensive telemetry and special-purpose displays. The "Emergency Identification" section more fully describes these tools. After identifying a failure, the pilot in command is responsible for deciding the proper course of action. If an emergency landing is warranted, the pilot must choose the type of emergency landing, be it an expedited return home, an off-site landing, or an autorotation. The pilot will then execute the appropriate procedures to achieve this. The characteristics and procedures associated with each type of landing are described in the "Emergency Procedures" section. The final section is dedicated to autorotation. It describes the energy management problem, simulation of autorotation and current A160 autorotation control laws.

2. EMERGENCY IDENTIFICATION

A160 operating teams have many tools at their disposal to identify emergencies. They benefit from over 300 channels of telemetry, varying in update rate from 1 Hz to 1000 Hz. These channels include roughly 30 strain gauges, 40 temperature sensors, 15 accelerometers, 10 pressure sensors, 20 current and voltage sensors, 20 engine sensors, 20 navigation sensors, 20 sensors dedicated to actuators, and various communications health signals. All data are available to pilots and operators in real time and multiple detailed system-monitoring displays are available at designated engineering stations. The key displays are the pilots' head up display (HUD), several engineering displays, and analog and digital stripcharts.

Figure 1 shows a screenshot of the head up display. The most critical parameters for key subsystems are listed at the bottom of the window. Each parameter is highlighted in color in if it is outside of pre-specified bounds, yellow for marginal or red for serious. During normal flight, no items are highlighted, so the appearance of out-of-bounds signals is obvious. In addition to highlighted numeric displays, the HUD includes a text warning box in the center bottom of the screen. Text warnings are triggered for many more criteria than are available in the HUD numeric displays. During normal flight, no text warnings are displayed, so the appearance of such warnings is clear evidence of circumstances to monitor more precisely.

Figure 1: Pilot's Head Up Display Screenshot (typical)

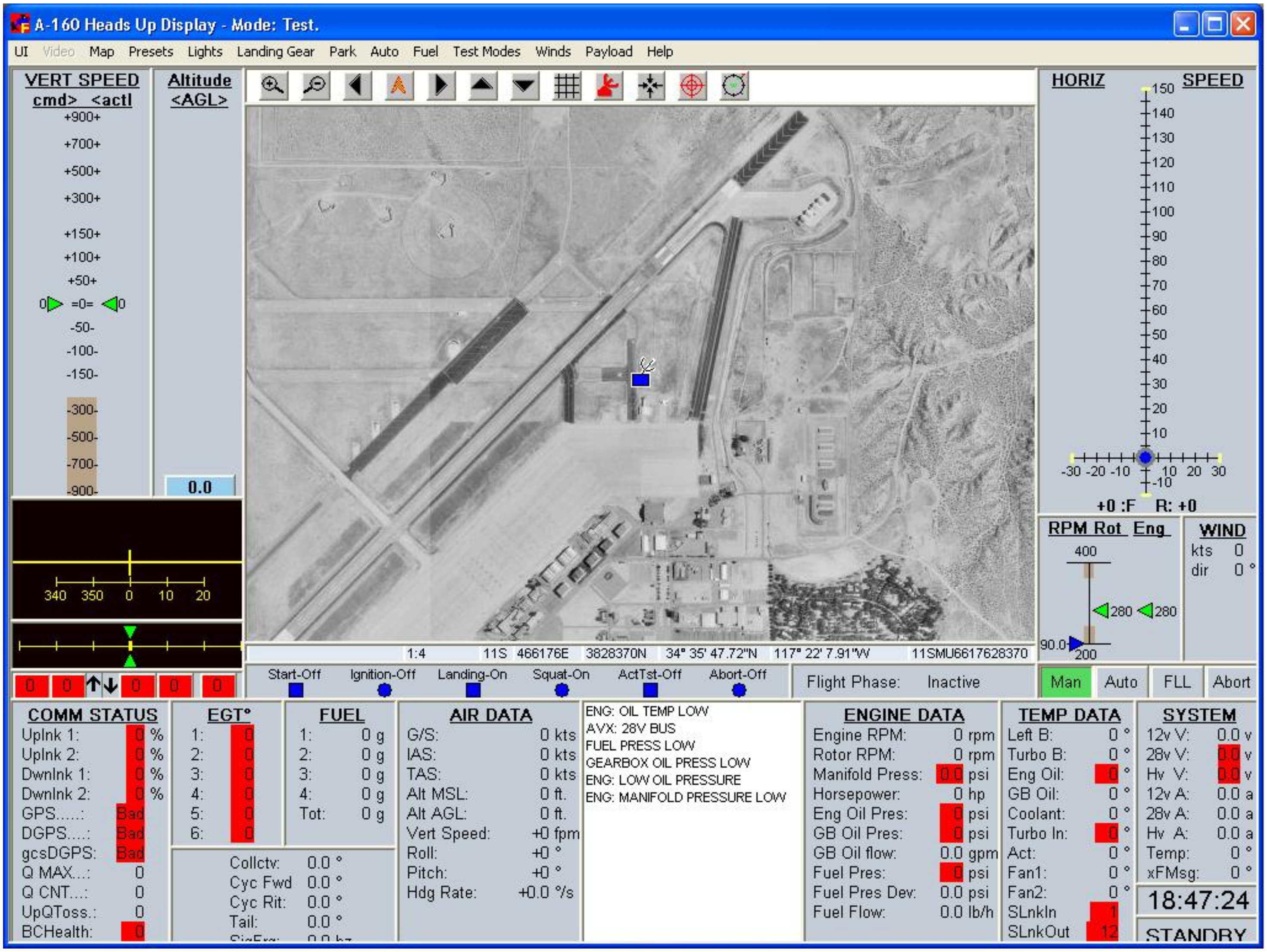
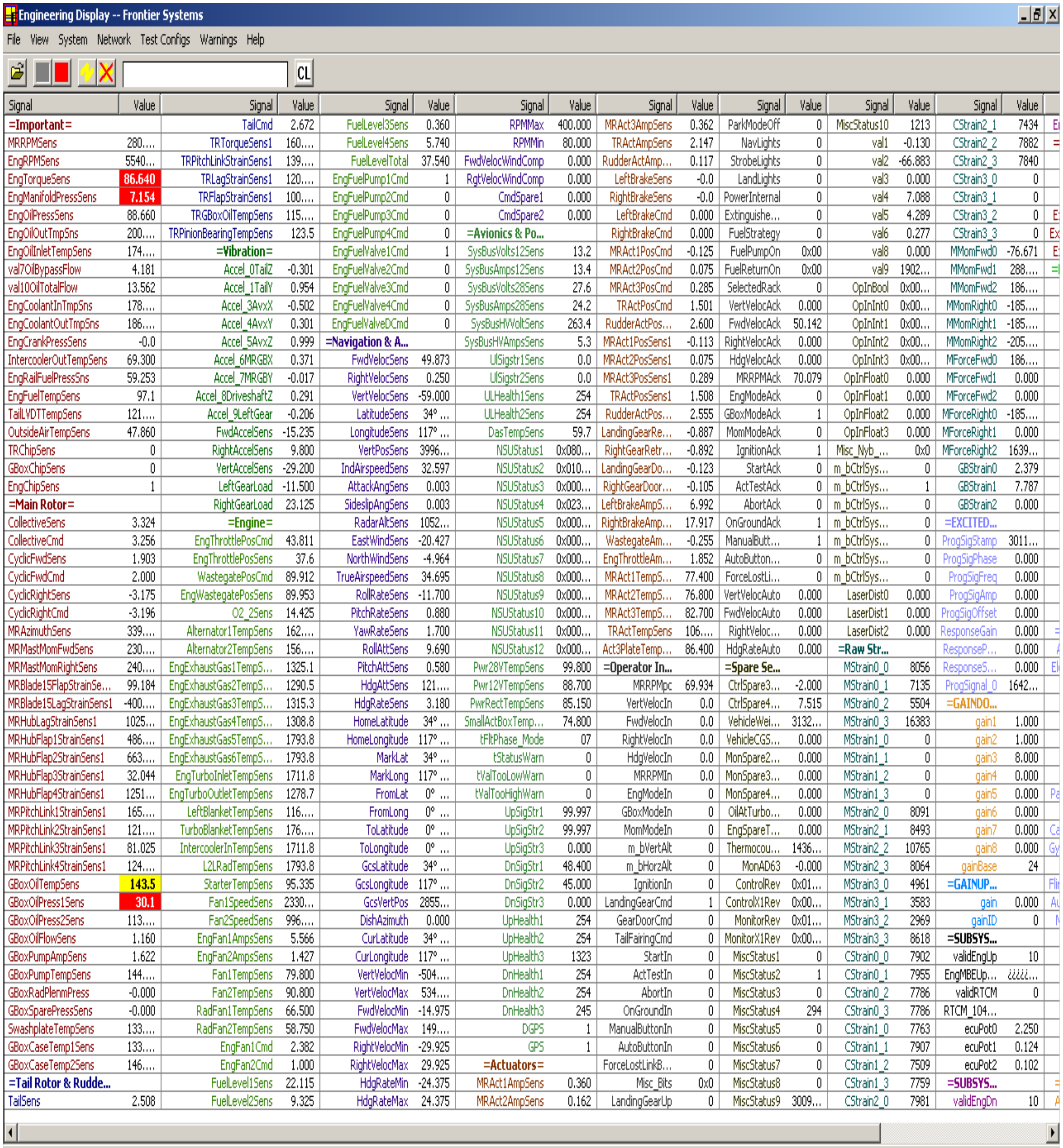


Figure 2 shows a screenshot of the engineering station Health Monitoring Display, a comprehensive searchable numeric display of every telemetry signal, including over 300 channels varying in update rate from 1 Hz to 1000 Hz. These include roughly 30 strain gauges, 40 temperature sensors, 15 accelerometers, 10 pressure sensors, 20 current and voltage sensors, 20 engine sensors, 20 navigation sensors, 20 actuator sensors, and various communications health signals. Parameter values that are outside of pre-determined safe limits are highlighted, yellow for marginal or red for serious. Since this screen continuously displays all telemetry data, a more comprehensive picture of overall vehicle health is available, including subsystem details if an emergency arises, allowing assessment of potential emergency procedures. It also supports vehicle health projections based on signal values and trends.

Figure 2: Health Monitoring Display Screenshot (typical - A160 with Subaru engine)



Engineering Display -- Frontier Systems

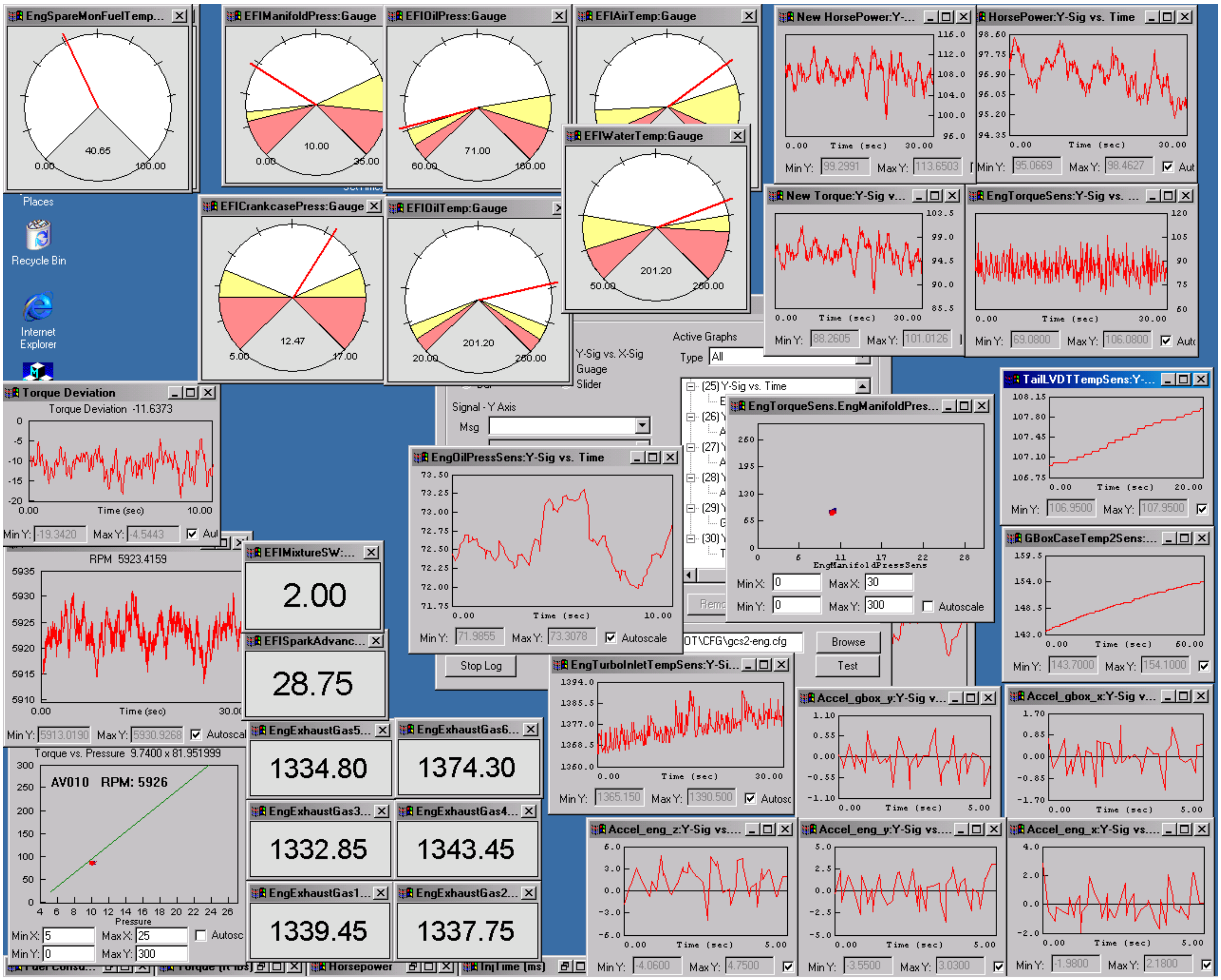
File View System Network Test Configs Warnings Help

CL

Signal	Value	Signal	Value	Signal	Value	Signal	Value	Signal	Value	Signal	Value	Signal	Value	Signal	Value
=Important=		TailCmd	2.672	FuelLevel3Sens	0.360	RPMMax	400.000	MRAct3AmpSens	0.362	ParkModeOff	0	MiscStatus10	1213	CStrain2_1	7434
MRRPMSens	280....	TRTorqueSens1	160....	FuelLevel4Sens	5.740	RPMMin	80.000	TRActAmpSens	2.147	NavLights	0	val1	-0.130	CStrain2_2	7882
EngRPMSens	5540...	TRPitchLinkStrainSens1	139....	FuelLevelTotal	37.540	FwdVelocWindComp	0.000	RudderActAmp...	0.117	StrobeLights	0	val2	-66.883	CStrain2_3	7840
EngTorqueSens	86.640	TRLagStrainSens1	120....	EngFuelPump1Cmd	1	RgtVelocWindComp	0.000	LeftBrakeSens	-0.0	LandLights	0	val3	0.000	CStrain3_0	0
EngManifoldPressSens	7.154	TRFlapStrainSens1	100....	EngFuelPump2Cmd	0	CmdSpare1	0.000	RightBrakeSens	-0.0	PowerInternal	0	val4	7.088	CStrain3_1	0
EngOilPressSens	88.660	TRGBoxOilTempSens	115....	EngFuelPump3Cmd	0	CmdSpare2	0.000	LeftBrakeCmd	0.000	Extinguishe...	0	val5	4.289	CStrain3_2	0
EngOilOutTmpSns	200....	TRPinionBearingTempSens	123.5	EngFuelPump4Cmd	0	=Avionics & Po...		RightBrakeCmd	0.000	FuelStrategy	0	val6	0.277	CStrain3_3	0
EngOilInletTempSens	174....	=Vibration=		EngFuelValve1Cmd	1	SysBusVolts12Sens	13.2	MRAct1PosCmd	-0.125	FuelPumpOn	0x00	val8	0.000	MMomFwd0	-76.671
val7OilBypassFlow	4.181	Accel_0TailZ	-0.301	EngFuelValve2Cmd	0	SysBusAmps12Sens	13.4	MRAct2PosCmd	0.075	FuelReturnOn	0x00	val9	1902...	MMomFwd1	288....
val10OilTotalFlow	13.562	Accel_1TailY	0.954	EngFuelValve3Cmd	0	SysBusVolts28Sens	27.6	MRAct3PosCmd	0.285	SelectedRack	0	OpInBool	0x00...	MMomFwd2	186....
EngCoolantInTmpSns	178....	Accel_3AvxX	-0.502	EngFuelValve4Cmd	0	SysBusAmps28Sens	24.2	TRActPosCmd	1.501	VertVelocAck	0.000	OpInInt0	0x00...	MMomRight0	-185....
EngCoolantOutTmpSns	186....	Accel_4AvxY	0.301	EngFuelValveDCmd	0	SysBusHVVoltSens	263.4	RudderActPos...	2.600	FwdVelocAck	50.142	OpInInt1	0x00...	MMomRight1	-185....
EngCrankPressSens	-0.0	Accel_5AvxZ	0.999	=Navigation & A...		SysBusHVAmpsSens	5.3	MRAct1PosSens1	-0.113	RightVelocAck	0.000	OpInInt2	0x00...	MMomRight2	-205....
IntercoolerOutTempSens	69.300	Accel_6MRGBX	0.371	FwdVelocSens	49.873	UlSigstr1Sens	0.0	MRAct2PosSens1	0.075	HdgVelocAck	0.000	OpInInt3	0x00...	MForceFwd0	186....
EngRailFuelPressSns	59.253	Accel_7MRGBY	-0.017	RightVelocSens	0.250	UlSigstr2Sens	0.0	MRAct3PosSens1	0.289	MRRPMAck	70.079	OpInFloat0	0.000	MForceFwd1	0.000
EngFuelTempSens	97.1	Accel_8DriveshaftZ	0.291	VertVelocSens	-59.000	ULHealth1Sens	254	TRActPosSens1	1.508	EngModeAck	0	OpInFloat1	0.000	MForceFwd2	0.000
TailLVDTTempSens	121....	Accel_9LeftGear	-0.206	LatitudeSens	34° ...	ULHealth2Sens	254	RudderActPos...	2.555	GBoxModeAck	1	OpInFloat2	0.000	MForceRight0	-185....
OutsideAirTempSens	47.860	FwdAccelSens	-15.235	LongitudeSens	117° ...	DasTempSens	59.7	LandingGearRe...	-0.887	MomModeAck	0	OpInFloat3	0.000	MForceRight1	0.000
TRChipSens	0	RightAccelSens	9.800	VertPosSens	3996...	NSUStatus1	0x080...	RightGearRetr...	-0.892	IgnitionAck	1	Misc_Nyb_...	0x0	MForceRight2	1639...
GBoxChipSens	0	VertAccelSens	-29.200	IndAirspeedSens	32.597	NSUStatus2	0x010...	LandingGearDo...	-0.123	StartAck	0	m_bCtrlSys...	0	GBStrain0	2.379
EngChipSens	1	LeftGearLoad	-11.500	AttackAngSens	0.003	NSUStatus3	0x000...	RightGearDoor...	-0.105	ActTestAck	0	m_bCtrlSys...	1	GBStrain1	7.787
=Main Rotor=		RightGearLoad	23.125	SideslipAngSens	0.003	NSUStatus4	0x023...	LeftBrakeAmpS...	6.992	AbortAck	0	m_bCtrlSys...	0	GBStrain2	0.000
CollectiveSens	3.324	=Engine=		RadarAltSens	1052...	NSUStatus5	0x000...	RightBrakeAmp...	17.917	OnGroundAck	1	m_bCtrlSys...	0	=EXCITED...	
CollectiveCmd	3.256	EngThrottlePosCmd	43.811	EastWindSens	-20.427	NSUStatus6	0x000...	WastegateAm...	-0.255	ManualButt...	1	m_bCtrlSys...	0	ProgSigStamp	3011...
CyclicFwdSens	1.903	EngThrottlePosSens	37.6	NorthWindSens	-4.964	NSUStatus7	0x000...	EngThrottleAm...	1.852	AutoButton...	0	m_bCtrlSys...	0	ProgSigPhase	0.000
CyclicFwdCmd	2.000	WastegatePosCmd	89.912	TrueAirspeedSens	34.695	NSUStatus8	0x000...	MRAct1TempS...	77.400	ForceLostLi...	0	m_bCtrlSys...	0	ProgSigFreq	0.000
CyclicRightSens	-3.175	EngWastegatePosSens	89.953	RollRateSens	-11.700	NSUStatus9	0x000...	MRAct2TempS...	76.800	VertVelocAuto	0.000	LaserDist0	0.000	ProgSigAmp	0.000
CyclicRightCmd	-3.196	O2_2Sens	14.425	PitchRateSens	0.880	NSUStatus10	0x000...	MRAct3TempS...	82.700	FwdVelocAuto	0.000	LaserDist1	0.000	ProgSigOffset	0.000
MRAzimuthSens	339....	Alternator1TempSens	162....	YawRateSens	1.700	NSUStatus11	0x000...	TRActTempSens	106....	RightVeloc...	0.000	LaserDist2	0.000	ResponseGain	0.000
MRMastMomFwdSens	230....	Alternator2TempSens	156....	RollAttSens	9.690	NSUStatus12	0x000...	Act3PlateTemp...	86.400	HdgRateAuto	0.000	=Raw Str...		ResponseP...	0.000
MRMastMomRightSens	240....	EngExhaustGas1TempSens	1325.1	PitchAttSens	0.580	Pwr28VTempSens	99.800	=Operator In...		=Spare Se...		MStrain0_0	8056	ResponseS...	0.000
MRBlade15FlapStrainSe...	99.184	EngExhaustGas2TempS...	1290.5	HdgAttSens	121....	Pwr12VTempSens	88.700	MRRPMpc	69.934	CtrlSpare3...	-2.000	MStrain0_1	7135	ProgSignal_0	1642...
MRBlade15LagStrainSens1	-400....	EngExhaustGas3TempS...	1315.3	HdgRateSens	3.180	PwrRectTempSens	85.150	VertVelocIn	0.0	CtrlSpare4...	7.515	MStrain0_2	5504	=GAINDO...	
MRHubLagStrainSens1	1025...	EngExhaustGas4TempS...	1308.8	HomeLatitude	34° ...	SmallActBoxTemp...	74.800	FwdVelocIn	0.0	VehicleWei...	3132...	MStrain0_3	16383	gain1	1.000
MRHubFlap1StrainSens1	486....	EngExhaustGas5TempS...	1793.8	HomeLongitude	117° ...	tFltPhase_Mode	07	RightVelocIn	0.0	VehicleCGS...	0.000	MStrain1_0	0	gain2	1.000
MRHubFlap2StrainSens1	663....	EngExhaustGas6TempS...	1793.8	MarkLat	34° ...	tStatusWarn	0	HdgVelocIn	0.0	MonSpare2...	0.000	MStrain1_1	0	gain3	8.000
MRHubFlap3StrainSens1	32.044	EngTurboInletTempSens	1711.8	MarkLong	117° ...	tValTooLowWarn	0	MRRPMIn	0.0	MonSpare3...	0.000	MStrain1_2	0	gain4	0.000
MRHubFlap4StrainSens1	1251...	EngTurboOutletTempSens	1278.7	FromLat	0° ...	tValTooHighWarn	0	EngModeIn	0	MonSpare4...	0.000	MStrain1_3	0	gain5	0.000
MRPitchLink1StrainSens1	165....	LeftBlanketTempSens	116....	FromLong	0° ...	UpSigStr1	99.997	GBoxModeIn	0	OilAtTurbo...	0.000	MStrain2_0	8091	gain6	0.000
MRPitchLink2StrainSens1	121....	TurboBlanketTempSens	176....	ToLatitude	0° ...	UpSigStr2	99.997	MomModeIn	0	EngSpareT...	0.000	MStrain2_1	8493	gain7	0.000
MRPitchLink3StrainSens1	81.025	IntercoolerInTempSens	1711.8	ToLongitude	0° ...	UpSigStr3	0.000	m_bVertAlt	0	Thermocou...	1436...	MStrain2_2	10765	gain8	0.000
MRPitchLink4StrainSens1	124....	L2LRadTempSens	1793.8	GcsLatitude	34° ...	DnSigStr1	48.400	m_bHorzAlt	0	MonAD63	-0.000	MStrain2_3	8064	gainBase	24
GBoxOilTempSens	143.5	StarterTempSens	95.335	GcsLongitude	117° ...	DnSigStr2	45.000	IgnitionIn	0	ControlRev	0x01...	MStrain3_0	4961	=GAINUP...	
GBoxOilPress1Sens	30.1	Fan1SpeedSens	2330...	GcsVertPos	2855...	DnSigStr3	0.000	LandingGearCmd	1	ControlX1Rev	0x00...	MStrain3_1	3583	gain	0.000
GBoxOilPress2Sens	113....	Fan2SpeedSens	996....	DishAzimuth	0.000	UpHealth1	254	GearDoorCmd	0	MonitorRev	0x01...	MStrain3_2	2969	gainID	0
GBoxOilFlowSens	1.160	EngFan1AmpsSens	5.566	CurLatitude	34° ...	UpHealth2	254	TailFairingCmd	0	MonitorX1Rev	0x00...	MStrain3_3	8618	=SUBSYS...	
GBoxPumpAmpSens	1.622	EngFan2AmpsSens	1.427	CurLongitude	117° ...	UpHealth3	1323	StartIn	0	MiscStatus1	0	CStrain0_0	7902	validEngUp	10
GBoxPumpTempSens	144....	Fan1TempSens	79.800	VertVelocMin	-504....	DnHealth1	254	ActTestIn	0	MiscStatus2	1	CStrain0_1	7955	EngMBEUp...	¿¿¿¿...
GBoxRadPlenmPress	-0.000	Fan2TempSens	90.800	VertVelocMax	534....	DnHealth2	254	AbortIn	0	MiscStatus3	0	CStrain0_2	7786	validRTCM	0
GBoxSparePressSens	0.000	RadFan1TempSens	66.500	FwdVelocMin	-14.975	DnHealth3	245	OnGroundIn	0	MiscStatus4	294	CStrain0_3	7786	RTCM_104...	
SwashplateTempSens	133....	RadFan2TempSens	58.750	FwdVelocMax	149....	DGPS	1	ManualButtonIn	0	MiscStatus5	0	CStrain1_0	7763	ecuPot0	2.250
GBoxCaseTemp1Sens	133....	EngFan1Cmd	2.382	RightVelocMin	-29.925	GPS	1	AutoButtonIn	0	MiscStatus6	0	CStrain1_1	7907	ecuPot1	0.124
GBoxCaseTemp2Sens	146....	EngFan2Cmd	1.000	RightVelocMax	29.925	=Actuators=		ForceLostLinkB...	0	MiscStatus7	0	CStrain1_2	7509	ecuPot2	0.102
=Tail Rotor & Rudde...		FuelLevel1Sens	22.115	HdgRateMin	-24.375	MRAct1AmpSens	0.360	Misc_Bits	0x0	MiscStatus8	0	CStrain1_3	7759	=SUBSYS...	
TailSens	2.508	FuelLevel2Sens	9.325	HdgRateMax	24.375	MRAct2AmpSens	0.162	LandingGearUp	0	MiscStatus9	3009...	CStrain2_0	7981	validEngDn	10

The most flexible display is SigView, shown in Figure 3. SigView provides real-time-configurable time history, cross-plot, FFT, gauge, slider, and numeric displays of any telemetry signal with configurable time scale and data smoothing. The team configures a display appropriate to the flight's objectives before takeoff, allowing detailed monitoring of test-specific failure modes. The team may add displays during flight to investigate anomalies.

Figure 3: SigView Screenshot (typical)



Three analog stripcharts and one digital stripchart are also available in a typical flight test. The stripcharts are used to examine the dynamic behavior of critical signals, such as speeds, loads, and temperatures. Previous stripcharts are kept in the ground control station so that previous and current behavior can be compared.

Flight Crew Qualifications, Training, and Simulator Practice

Valid engineering judgments by skilled and well-trained teams play a prominent role in emergency operations. The A160 flight-test team engineers have extensive ground testing experience and most have been involved in the design and development of the A160 flight systems. This provides an in-depth understanding of the entire system and facilitates the rapid identification, evaluation, and reaction to a system anomaly and potential emergency situation.

The flight crews have been trained in several ways. Initially, the crew members have trained in flight operations on an A160 flight simulator. Additional hours have been logged in the past with the Maverick UAS, an unmanned modification of the Robinson R-22 aircraft. Before flying the A160, flight crew are trained in the co-pilot seat under supervision of a qualified A160 pilot.

3. EMERGENCY PROCEDURES

Once the need for emergency landing is identified, the pilot in command must decide what type of landing to execute. The pilot has the option of expediting a standard landing that returns to the launch site (currently Southern California Logistics Airport in Victorville, CA), landing off-site, or if there is a drive system, engine, or tail rotor control failure, commanding an autorotation. This section describes each landing and the associated procedures. During flight, pilots have access to detailed checklists for each procedure.

3.1 Expedited Landing

A160 emergency procedures recommend that the operator expedite a standard landing when it is not prudent to continue flight, but when losing the aircraft is not imminent. Examples of this situation are slowly rising system temperatures that trend towards exceeding limits or the loss of a non-flight critical sensor like a torque sensor or exhaust gas temperature sensor. In such a case, the pilot begins executing the standard landing procedure immediately, while initiating focused attention on the anomaly. Standard landings approach the Warrior Ramp, the normal take off and landing site at Southern California Logistics Airport (SCLA), from the northeast (assuming normal winds) at 40 kts and 200 ft/min. Below is the checklist for standard landings:

MANUAL LANDING

- ❑ Call to Tower: Inbound to Land.................................... COMPLETE
- ❑ Call Ground Crew: Inbound to Land COMPLETE
- ❑ RPM SET FOR APPROACH
- ❑ Map Landing Location SET
- ❑ "Takeoff Preset" horsepower (250 hp) SET
- ❑ Altimeter RESET
- ❑ Wind Compensation OFF
- ❑ Wind Speed and Direction CHECK
- ❑ Payload Mode (if landing by EO/IR) FIXED
- ❑ Altitude DESCEND TO 3205 MSL (350 AGL)
- ❑ Airspeed 40 KTS
- ❑ Landing Gear DOWN
- ❑ Landing Switch LANDING
- ❑ FLIGHT PHASE: **LANDING** CONFIRM
- ❑ Approach Path SET
- ❑ At 6000' range 3205 MSL (350 AGL)

- ❑ Descent Rate 200 FPM
- ❑ Landing Gear CONFIRM DOWN
- ❑ Landing Area CLEAR
- ❑ Weight on Wheels Warning CHECK
- ❑ Cross Landing Threshold 50 FEET
- ❑ FLIGHT PHASE: **TAXI** CONFIRM ON GROUND CONTACT
- ❑ Squat Switch ACTIVATE IF NO TAXI
- ❑ Landing Switch DISENGAGE

3.2 Off-site Landing

If there is an immediate risk of losing control of the aircraft, A160 emergency procedures recommend that the pilot execute an off-site landing. Examples of this situation are unexpected increases in vibrations or loss of generators requiring running on batteries for a lengthy period. In an off-site landing, the pilot brings the A160 to a hover over a safe landing spot at an altitude high enough to maintain the telemetry link. The pilot then engages the "abort" autonomous flight plan which executes a 200 ft/min hover descent and touchdown, even if the datalink is lost. If link is still lost, the A160 after touchdown automatically shuts down the engine, fuel pumps, and cooling fans.

A team of flight test engineers explored the Victorville desert that the A160 flies over to determine safe landing locations. They generated the map in Figure 4, which is posted in the ground control station. SCLA is located at the bottom of the map. The A160 flies in the triangular section north of the airport that is outlined in light purple, but avoids flying over red "avoid" areas. A160 operations avoid these areas because of inhabited structures or significant terrain variations. These areas must also be avoided in an off-site landing. Except where marked, the desert is quite open and flat, allowing landings in many locations.

Below is the checklist for off-site landing descent:

OFF SITE LANDING

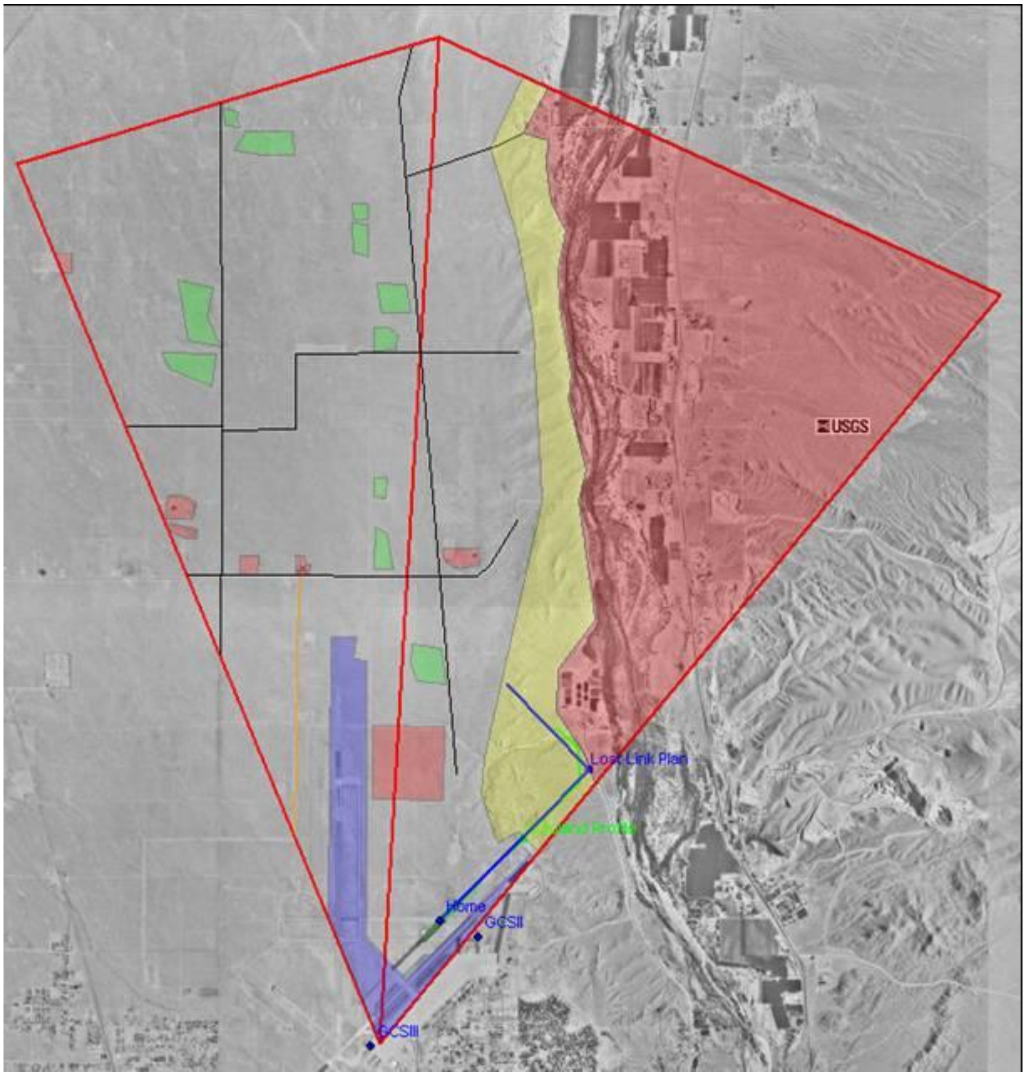
- ❑ Airspeed .... 40 KTS
- ❑ Descent Rate ....200 FPM
- ❑ RPM .... SET FOR APPROACH
- ❑ Wind Compensation.. OFF
- ❑ "Takeoff Preset" horsepower (300 hp) .... SET
- ❑ Landing Gear .... DOWN
- ❑ Landing Switch .... LANDING
- ❑ FLIGHT PHASE: **LANDING**............................ CONFIRM
- ❑ Approach Path and Landing Site .... SET
- ❑ At ~200 feet AGL .... SLOW TO HOVER
- ❑ Abort Switch .... ENGAGE
- ❑ Call to Tower: "Landing off site" .... COMPLETE
- ❑ Call to Ground Crew: "Landing off site"........ COMPLETE

Likely loss of datalink descending below 2850 MSL

"Abort" automation will shut off aircraft after touchdown

- ❑ Aircraft Location.. RECORD
- ❑ Locate Aircraft .... COMPLETE
- ❑ Safe and Shutdown Aircraft............................. COMPLETE

Figure 4: A160 Operating Area and Landing Zones (Green areas are optimal emergency landing sites)



3.3 Autorotation

In the case of engine or other drive system failure, the A160 must execute an autorotation. By virtue of the A160 RPM control architecture, the A160 automatically enters and maintains autorotation upon loss of drive torque. The pilot must then enable the touchdown logic using a panel switch, identify a safe landing location, and guide the aircraft to that location. The autorotation timeline below provides a summary of autorotation events. .

- Loss of power
- A160 automatically enters and maintains autorotative descent
- Operator enables autorotation switch.
    - A160 autonomously controls RPM to 280
    - Disallows lost link flight plan
    - Operator maintains control of speed and heading
        - Commands efficient airspeed ~60 kts
        - Navigates toward safe landing spot
- At ~200 ftAGL

    - A160 autonomously begins increasing rotor RPM to 405 to store maximum energy
    - A160 autonomously starts cyclic flare
- At ~100 ftAGL, A160 autonomously zeros heading rate and sideslip
- At ~30 ftAGL, A160 autonomously starts collective flare
- Just after touchdown, A160 autonomously shuts down engine, fuel pumps and cooling fans.

Below is the checklist for autorotation:

AUTOROTATION

- ❑ Forward Speed to 60 kts (if advisable) .... SET
- ❑ Autorotation Switch .... ENGAGE
- ❑ Landing Site .... PICK
    - Steering is still operator controlled
    - Forward speed can be adjusted down to change glide path

After touchdown:

- ❑ Call to Tower: Off site landing .... COMPLETE
- ❑ Call Ground Crew: Off site landing................. COMPLETE

The brevity of the checklist is meant to allow completion in the limited time available before the A160 reaches the ground. To this end, the touchdown logic enabled by the autorotation switch automates several tasks, such as lowering the landing gear.