

Emergency Procedures Description Attachment

NASA DFRC 2007 Fire Mission
UAS COA Application Attachment

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NASA Dryden Flight Research Center (DFRC) has procured from General Atomics – Aeronautical Systems Incorporated, an MQ-9 Reaper aircraft and a Ground Control Station (GCS). DFRC has assigned the number “NASA 870” to the aircraft and renamed it “Ikhana” (pronounced ee-kah-nah, a Native American word from the Choctaw Nation meaning intelligent, conscious, or aware).

The Ikhana UAS is complex electromechanical aircraft that depends on an engine driven generator to power the avionics and flight controls. In many systems, the aircraft has 2 and 3 levels of redundancy. Despite the redundancy, there are a few failure modes and emergencies that would prevent the aircraft from completing the planned mission.

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This attachment addresses two emergency situations and their constraints that would warrant landing the aircraft as soon as practical. The two emergency situations are: 1. Engine Failure, and 2. Generator Failure.

1. **Engine Failure** – In this scenario, aircraft flight time is limited by glide range and battery life.
2. **Generator Failure** – In this scenario, with the engine operating, aircraft flight time is limited by battery life.
3. **Additional Constraints** – A normal landing is accomplished via C-band line-of-sight (LOS) communication between the GCS and the aircraft. The GCS is located near the planned takeoff and landing location and near instantaneous command/control of the aircraft is possible. When the aircraft is beyond line-of-sight (BLOS) (also known as over-the-horizon, OTH), the aircraft is controlled via Ku-band satellite link. This link has a time delay inherent to satellite communication systems. Satellite communication time delays during a landing attempt to a BLOS/OTH ELS will likely result in a landing that is not “smooth”. It is for this reason that ELS are selected to reduce the risk of exposure to the general population and ground assets.

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4. **Pilot Actions During an Emergency** –
 - 4.1. The pilot will and flight crew will perform actions as specified in the MQ-9 Flight Manual (TO 1Q-9(M) A-1) and consistent with protecting public safety.

- 4.2. If the aircraft cannot reach a selected ELS, the pilot will position the aircraft in a remote location where the subsequent loss of the aircraft causes minimum hazard to population and ground assets.

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4.3. Real-time Emergency Landing Site (ELS) Selection –

- 4.3.1. The pilot will select an emergency landing site based on the nature of the emergency, aircraft position, real-time weather and other factors.
- 4.3.2. The pilot may select an appropriate emergency landing site that is hundreds of nm away depending on the nature of the emergency. The ELS may be in a different Zone than the aircraft is currently flying in, and includes the planned end-of-mission landing site – Edwards AFB, Ca. In other words, if the aircraft is flying in Zone B, the pilot may elect to go to the Amedee AAF ELS that is in Zone A.
- 4.3.3. Communication with ATC – The pilot will declare an emergency to ATC, and advise ATC of aircraft condition and pilot intentions. The pilot will maintain communication with ATC as conditions warrant.
- 4.4. **Flight Profile to Selected ELS -** The pilot will select a flight profile that is consistent with the emergency, with the safety of other aircraft in the NAS, and population on the ground.
- 4.4.1. The pilot will be assessing several factors during an emergency. Two of these are aircraft glide/range capability, and available electrical/battery power for the avionics and flight controls. The pilot will manage these factors and others in real-time (as defined by the particular emergency) to bring the aircraft in contact with the ground in as controlled a fashion as possible to protect other aircraft in the NAS and population on the ground.
- 4.4.2. In an emergency situation, the pilot will attempt to remain in Class A airspace (above FL180) or in active restricted airspace for as long is reasonable while proceeding to an appropriate emergency landing site.
- 4.4.3. The pilot will have detailed information on a selected set of generator failure and engine failure emergency landing sites available in the GCS. This information will aid the pilot in selecting an appropriate flight profile if one of those sites is selected. This information will be prepared in conjunction with the DFRC Range Safety Organization (RSO) and other DFRC personnel. This information can include location, preferred approach paths, population centers and keep-out areas, preferred lost link mission profiles/areas, initial lost link heading selections and identified hazards specific to those sites. Reference the “Range Safety Keep-out Zones and Population Centers” section of the following COA application attachment for further details: NASA 2007 Fire Mission - Mission and Lost Link Procedures Description Attachment.

5. **Engine Failure** - The TPE-331 engine installed in the aircraft is derived from a dependable family of turboprop engines that have a significant history.

5.1. **Glide capability** – Conservative L/D for the MQ-9 is 15:1. Assuming an altitude of 35,000 ft AGL, no thrust capability and a feathered prop, the aircraft has the capability to glide approximately 90 nmi.

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5.2. **Battery power capability** – As configured for the 2007 WSFM missions, the aircraft has at least 2 hours of battery power. It takes the aircraft less than 1 hour to glide from ~35,000 ft AGL, to sea level, allowing margin for electrically lowering the landing gear.

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6. **Generator Failure** – Although this failure is commonly referred to as the “generator failure” since there is only 1 generator on the aircraft, it can also refer to any failure(s) in the power system that prevents the electrical power provided by the generator from being distributed to the avionics system (the majority of the power distribution is redundant). With a generator failure, the on-board aircraft battery system provides the electrical power capability that indirectly determines aircraft range. Since the aircraft engine is still operating nominally, the batteries are providing electrical power for the flight computers, other avionics, fuel pumps, and landing gear deploy servos to operate. When the battery capacity is no longer sufficient to power this equipment, the pilot will not be able to control the aircraft.

6.1. **Aircraft Range Capability** - The underlying assumption for this class of failures is that the aircraft is relying completely on the on-board batteries for electrical power. Once the battery capacity (in minutes) is determined, then the aircraft range depends on the maximum speed that the aircraft can sustain.

6.1.1. **Pre-mission Aircraft Range Capability Determination** - Since the Ikhana battery capacity, and the pod/pylon flutter speed have not been determined (see below), the aircraft range cannot be absolutely determined at this time, a conservative 400 nm range capability will be used for planning purposes.

6.1.2. **Real-time Aircraft Range Capability (during emergency situation)** - During an emergency situation, the pilot will use the pre-mission aircraft range as a starting point for determining the capability of the aircraft during the emergency. The pilot will have to take into account the nature of the emergency, day-of-flight winds, aircraft position, and other factors.

6.1.3. **Battery Capacity** – The aircraft normally flies with a 2 sets of 3 batteries each (total of 6 batteries). To increase battery capacity for this failure scenario, the aircraft has been modified for the 2007 WSFM to carry 2 sets

of 7 batteries (total of 14 batteries). This same modification was performed for Altair® during the 2006 WSFM for the same reason.

- 6.1.3.1. **Airborne Test (Ikhana)** – Prior to the first 2007 WSFM, the nominal aircraft power draw in a representative SatCom configuration at altitude will be identified.
- 6.1.3.2. **Ground Test (Ikhana)** – Prior to the first 2007 WSFM, a ground test of the Ikhana aircraft to determine battery capacity with 14 batteries installed will be performed. A measure of conservatism will be applied to the ground test results.
- 6.1.3.3. **Ground Test (Altair®)** – In preparation for the 2006 WSFM, a ground test with Altair® was performed. This ground test demonstrated a 3 hour 50 minute battery capacity for Altair® with 14 batteries installed. Heater draws on the batteries due to thermal conditions at altitude could not be included in this ground test.
- 6.1.3.4. **Rule of Thumb (Altair®)** – 14 batteries provide the aircraft with more than 2 hours of electrical power, with the SPMA and required avionics operating, and margin to electrically lower the landing gear. This rule adds some conservatism to power draw tests performed on an 8/16/2006 Altair® 2006 WSFM checkout flight.
- 6.1.4. **Maximum Airspeed** – The aircraft is limited in airspeed by its V_{ne} (never exceed speed), and by the flutter speed of the attached pod/pylon.
 - 6.1.4.1. **Aircraft V_{ne}** – The aircraft V_{ne} is 230 KIAS/249 KTAS. Maximum sustained speed in level flight is in the 140 – 150 KIAS range. Best glide speed is based on aircraft weight and is flown at +2° AOA.
 - 6.1.4.2. **Pod/Pylon flutter speed** – Although the pylon from the 2006 WSFM on Altair® is being reused, a different pylon is being built for the 2007 WSFM on Ikhana.
 - 6.1.4.2.1. **2007 pod/pylon flutter speed** – Since the pylon is in design, is not yet manufactured, and a ground vibration test (GVT) has not been performed nor analyzed, this speed has not been determined yet. The assumption is that it will not be less than the 2006 pod/pylon flutter speed, and it is hoped to be as high as 200+ KIAS.
 - 6.1.4.2.2. **2006 WSFM pod/pylon flutter speed** – 120 KIAS.

7. **Emergency Landing Sites (ELS)** – NASA DFRC has a desire to attempt to land the aircraft in an emergency situation.

7.1. In an emergency situation, it is desired to attempt to land the aircraft at a suitable landing site, only if this can be accomplished without an unacceptable increase of risk to people.

7.2. **Pre-mission Emergency Landing Site Selection** – Although the NASA DFRC and General Atomics rules for pre-mission selection of an ELS may change, the full set is currently the following:

7.2.1. Verbal FAA HQ UAS restriction: No airfields with an active Commercial or General Aviation presence. Private airfields by definition have a General Aviation presence.

7.2.2. NASA DFRC restriction: No military airfields unless the controlling authority has been briefed on the aircraft, mission and risks and that authority approves designation as an Emergency landing site for these missions.

7.2.3. NASA DFRC restriction: The DFRC Range Safety Office or local Range Safety Office must analyze each airfield and determine acceptable runways, approach corridors, lost link plans and orbit points (as applicable) with respect to surrounding populations.

7.3. **Emergency Landing Sites** – Representative lists of emergency landing sites is included at the end of this document. Although these lists are current as of 2/14/2007, they will be modified and updated as new information is received. They are included here only to demonstrate to the FAA that DFRC is faithfully following the stated rules for emergency landing site selection. The lists presented are copies (slightly reformatted) of the latest status from the 2006 WSFM emergency landing site lists. Sites that were removed from consideration for the 2006 WSFM may be added back into consideration for the 2007 WSFM as conditions may have changed. The sites on the lists are analyzed continuously by the DFRC Range Safety Office (RSO) and DFRC Operations for desirability and appropriateness so that the pilot has a current list of “acceptable” alternatives in the event of an emergency. The lists will be updated (additions and deletions) as new sites are analyzed and new information becomes available on the sites listed.

7.3.1. **Generator Failure ELS Graphic Representations** – Reference Figure 1 - 400 nm circles on Generator Failure ELS to see the coverage of the Overall COA and 3 zones

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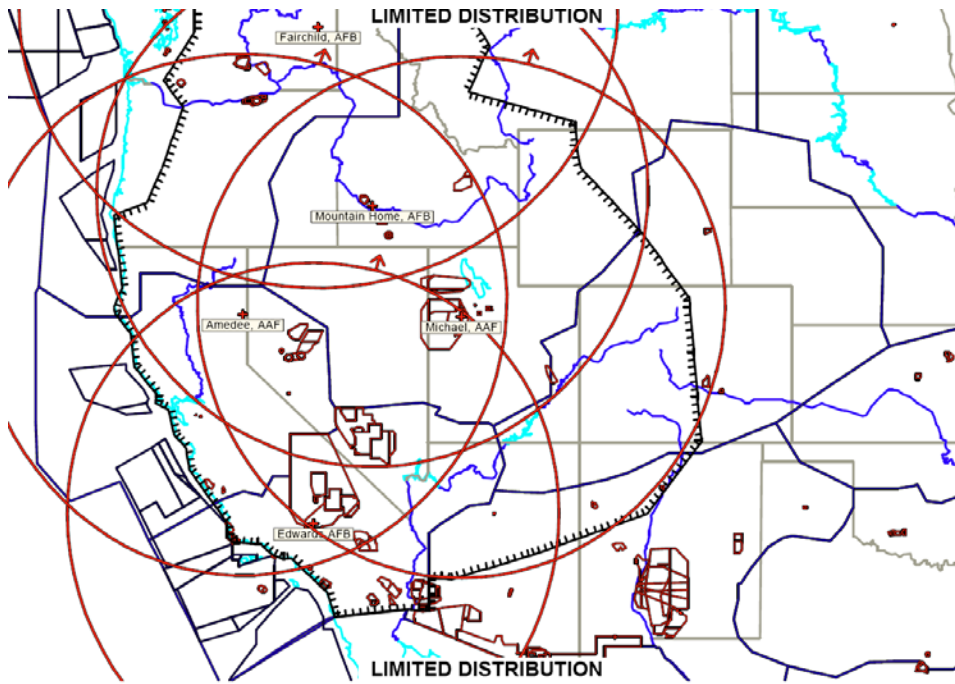


Figure 1 – 2/14/07 400 nm circles on Generator Failure ELS

7.3.2. **Engine Failure ELS Graphic Representations** – Reference Figures 2 through 4 for graphic representations of the engine failure circles to see coverage of the zones.

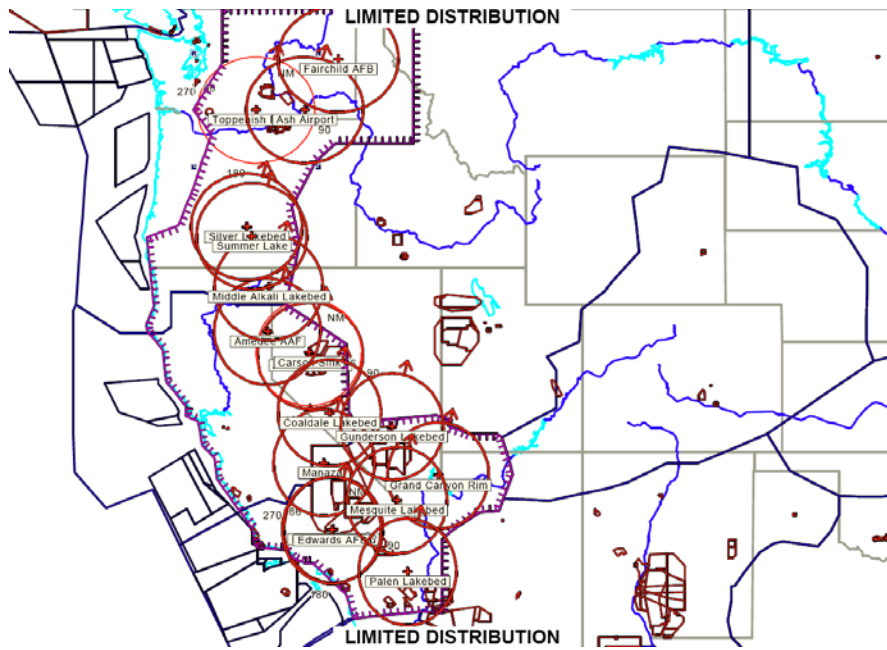


Figure 2 – 2/14/07 Engine Failure nm circles on Zone A Engine Failure ELS

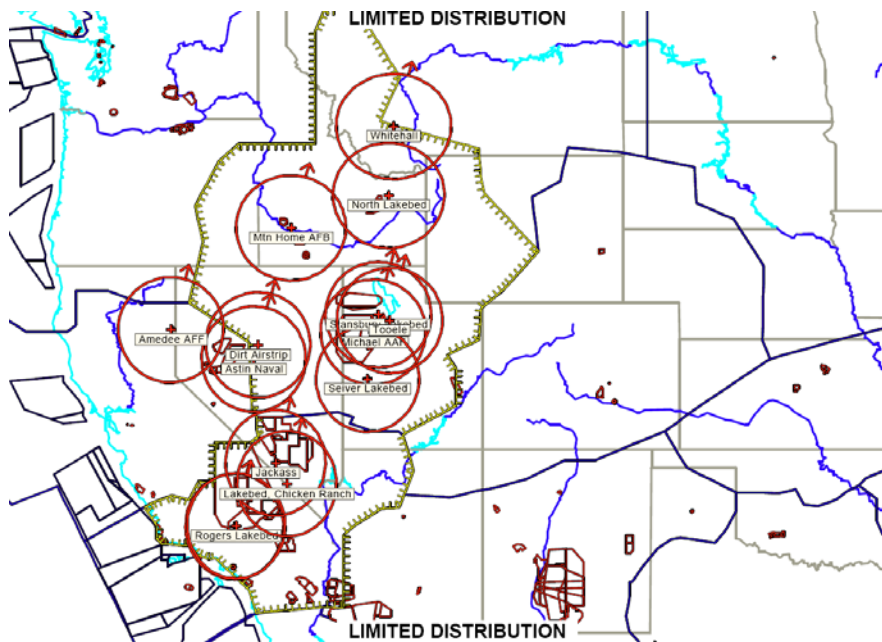


Figure 3 – 2/14/07 Engine Failure nm circles on Zone B Engine Failure ELS

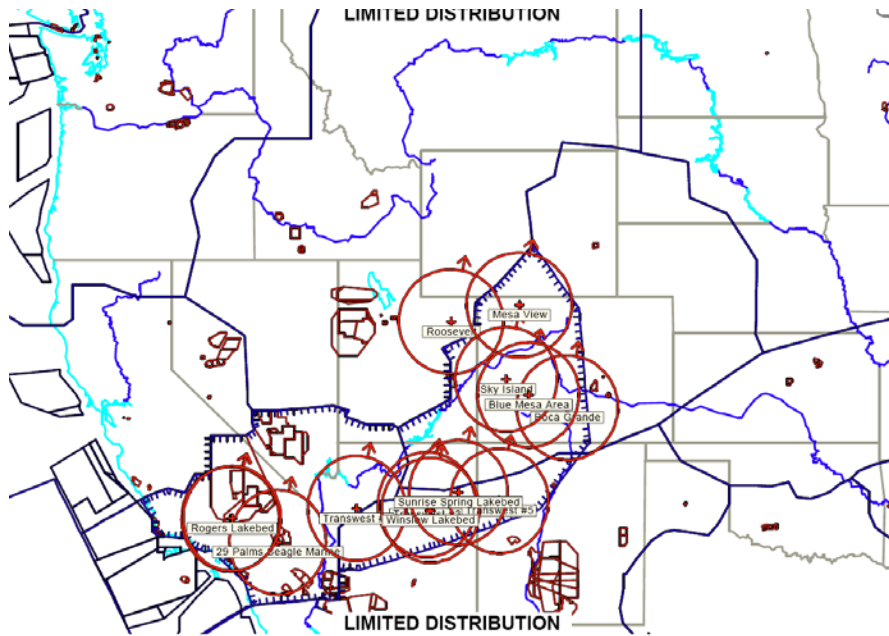


Figure 4 – 2/14/07 Engine Failure nm circles on Zone C Engine Failure ELS

7.3.3. **Emergency Landing Sites – Route A (North)** – A representative list of emergency landing sites follows. Although this list is current as of 2/14/2007, it will be modified and updated as new information is received.

<u>Generator Failure – Emergency Landing Site</u>	<u>State</u>	<u>Status</u>	<u>SEC</u>	<u>Len (ft)</u>	<u>Lat.</u>	<u>Lon.</u>	<u>Remarks</u>	
Fairchild AFB, (KSKA) - Spokane, Wash	Wa	Yellow	Seattle	13899	N 47d 36m 54s	W 117d 39d 20.9s	Need Approval	
Amedee AAF (KAHC) - Herlong, Ca	CA	Yellow	Klamath	7100	N 40d 15m 54s	W 120d 09m 6s	Need approval	RSO – Looks GREAT!! Being extended to 10,000 ft. May not be avail until 8/2007.
Mountain Home AFB (KMUO)	ID	Yellow		13500	N 43d 2m 37.2s	W 115d 52m 21s	Need Approval	
Dugway Proving Gnd, Michael AAF (KDPG)	UT	Yellow	Salt Lake	9000	N 40d 12m	W 112d 56m 12s	Need Approval, Need to ensure proper personnel clear zone. 13,000 ft rwy closed	
Edwards AFB, (KEDW), Edwards, Ca	CA	Green	Los An	15013	N 34d 54m 19.8s	W 117d 53d 1.2s		
<u>Engine Failure – Emergency Landing Site</u>	<u>State</u>	<u>Status</u>	<u>SEC</u>	<u>Len (ft)</u>	<u>Lat.</u>	<u>Lon.</u>	<u>Remarks</u>	
Manzanar	CA	Green	San F	4800	N 36d 43m 48s	W 118d 09m		

Alkali lakebed (on sectional) Next to Carson Sink (Nat'l Wildlife Refuge)	NV		San F		N 39d 37m 6s	W 118d 38m 36s	Inside Restricted Area near Fallon Target Area Baker	
Ash Airport	WA	Yellow	Seattle	3000	N 46d 14m 24s	W 118d 49m 48s	RSO – Poor Google image, not on Falcon View	
Carson Sink (Nat'l Wildlife Refuge)	NV	Green	San F		N 39° 41m 54s	W 118° 41m 24s	Some water	
Coaldale lakebed	CA	Green	San F		N 38° 04m 24s	W 117° 57m 48s	Rough surface	
EAFB/Rogers lakebed	CA	Green	LA		N 34° 55m 24s	W 117° 49m 30s		
Grand Canyon Rim	AZ	Yellow	Las Vegas	3400	N 36d 23m 12s	W 112d 07m 54s	Turf	RSO – Poor Google image.
Gunderson lakebed	NV		Las Vegas		N 37° 42m 12s	W 115° 45m 36s		
Mesquite lakebed	CA		LA		N 35° 43m 6s	W 115° 35m		
Middle Alkali lakebed	CA	Green	Klamath		N 41° 27m 54s	W 120° 06m 6s	Some parts dry	
Palen lakebed	CA	Green	LA		N 33° 47m 18s	W 115° 12m 48s		
Silver lakebed	OR		Klamath		N 43° 05m 36s	W 120° 52m 42s		
Summer Lake	OR		Klamath		N 42d 50m	W 120d 42m 3s		
Toppenish Fields	WA		Seattle		N 46° 14m 30s	W 120° 32m 24s		
Removed from list								
Name	State	Status	SEC	Len (ft)	Lat.	Lon.	Remarks/Reason	Reason
Big Island	ID			2600	N 46d 42m 12s	W 115d 58m 42s	Turf, Below min length	
China Lake, NAWC	CA			10,000 , 9000, 7700	N 35d 41m 6s	W 117d 41m 30s	Need approval	Proj Mgr – Do not consider
Devils Garden/ Alturas	CA	Red	Klamath	6250	N 41d 15m	W 120d 40m 12s		RSO – Appears

								used
Fallon, NAS	NV			11 k 7,000	N 39d 25m	W 118d 42m	Need approval, 14,000 ft rwy closed	Proj Mgr - Do not consider
Jackass Naval (abandoned)	WA		Seattle	2400	N 46d 25m 12s	W 119d 04m 48s	Turf, Below min length	
Lowry	WA			2500	N 44d 55m 48s	W 117d 46m 48s	Dirt, Below min length	
Nason Creek	WA			2100	N 47d 46m 12s	W 120d 47m 24s	Turf, Below min length	
Target Area Baker 17, Frenchman	NV			6000	N 39d 14m 24s	W 118d 14m 24s	Within Fallon NAS Restricted Area 4804A, Need approval by Fallon NAS, unexpended ordnance on rwy	DFRC - Dummy bombs on runway
Vagabond	WA		Seattle	2000	N 46d 40m 12s	W 120d 27m 36s	Below min length	
Willow Creek	CA			2500	N 40d 57m	W 123d 37m 12s	Below min length	RSO - Populated, GA - short, narrow valley
Wonder Valley	CA			2465	N 36d 48m	W 119d 18m 18s	Below min length	RSO - population

7.3.4. **Emergency Landing Sites – Route B (Northeast)** - A representative list of emergency landing sites follows. Although this list is current as of 2/14/2007, it will be modified and updated as new information is received.

Generator Failure - Emergency Landing Site	State	Status	SEC	Len (ft)	Lat.	Lon.	Remarks	
Mountain Home AFB (KMUO)	ID	Yellow		13500	N 43d 2m 37.2s	W 115d 52m 21s	Need Approval	
Fairchild AFB, (KSKA) - Spokane, Wash	Wa	Yellow	Seattle	13899	N 47d 36m 54s	W 117d 39d 20.9s	Need Approval	

Dugway Proving Gnd, Michael AAF (KDPG)	UT	Yellow	Salt Lake	9000	N 40d 12m	W 112d 56m 12s	Need Approval, Need to ensure proper personnel clear zone. 13,000 ft rwy closed	
Edwards AFB, (KEDW), Edwards, Ca	CA	Green	Los An	15013	N 34d 54m 19.8s	W 117d 53d 1.2s		
Engine Failure – Emergency Landing Site	State	Status	SEC	Len (ft)	Lat.	Lon.	Remarks	
Austin Naval (abandoned)	NV	Green	Las Vegas	6000	N 39d 28m 12s	W 117d 12m		
Dirt Airstrip North of Austin Naval	NV	Green	Las Vegas		N 39d 51m 18s	W 117d 2m 54s		
EAFB/Rogers lakebed	CA	Green	LA		N 34° 55m 24s	W117° 49m 30s		
Jackass	NV	Green	Las Vegas	6000	N 36d 38m 24s	W 116d 25m 12s		
Lakebed West of Chicken Ranch, Nv	Ca	Green	Las Vegas		N 36d 4m	W 116d 1m 12s		
Seiver lakebed	UT	Green	Las Vegas		N 38° 55m 24s	W 113° 08m 30s		
Stansbury lakebed	UT	Green	Salt Lake		N 40° 40m 36s	W 112° 45m 24s		
North lakebed	ID	Green	Salt Lake		N 43° 55m 30s	W 112° 23m 24s		
Whitehall	MT	Green	Great Falls	5900 x 3600	N 45d 48m 36s	W 112d 12m 36s	RSO – vacant field, no clear runways	

Removed from list								
Name	State	Status	SEC	Len (ft)	Lat.	Lon.	Remarks/Reason	Reason
Chicken Ranch	NV			3200	N 36d 4m 12s	W 115d 57m		RSO - has population
China Lake, NAWC	CA			10,000, 9000, 7700	N 35d 41m 6s	W 117d 41m 30s	Need approval	
Desert lakebed	NV				N 36° 31m 24s	W 114° 56m 36s		RSO - Road through middle
Evanston (original)	WY			5000	N 41d 21m	W 111d 0m	Wire fence across runway	RSO - Population, roads. Wire fence
Fallen, NAS	NV			11,000, 7,000	N 39d 25m	W 118d 42m	Need approval, They are busy. 14,000 ft rwy closed	
Kenworthy	ID	Red			N 42d 57m 32s	W 116d 2m 7s		Can't find from the air
Mountain Home (a field)	ID	Red			N 43° 08m 42s	W 115° 53m 12s	RSQ - Some population nearby, can't find it	
Saylor Creek Target	ID			8200	N 42d 45m	W 115d 34m 48s	Dirt, Need approval by Mountain Home AFB, Aircraft on runway, unexpended ordnance on rwy	DFRC - Dummy bomb casings on rwy
Wendover	UT			9900	N 40d 43m 12s	W 114d 00m		RSQ - Population, FAA - FBO

7.3.5. **Emergency Landing Sites - Route C (East)** - A representative list of emergency landing sites follows. Although this list is current as of 2/14/2007, it will be modified and updated as new information is received.

<u>Generator Failure - Emergency Landing Site</u>	<u>State</u>	<u>Status</u>	<u>SEC</u>	<u>Len (ft)</u>	<u>Lat.</u>	<u>Lon.</u>	<u>Remarks</u>	
Amedee AAF (KAHC, Herlong, Ca)	CA	Yellow	Klamath	7100	N 40d 15m 54s	W 120d 09m 6s	Need approval	RSO – Looks GREAT!! Being extended to 10,000 ft. May not be avail until 8/2007.
Edwards AFB, (KEDW), Edwards, Ca	CA	Green	Los An	15013	N 34d 54m 19.8s	W 117d 53d 1.2s		
<u>Engine Failure – Emergency Landing Site</u>	<u>State</u>	<u>Status</u>	<u>SEC</u>	<u>Len (ft)</u>	<u>Lat.</u>	<u>Lon.</u>	<u>Remarks</u>	
29 Palms - Seagle Marine	CA			6700 dirt, 2000	N 34d16.2m	W 116d11.4m	UAV Field, Within 29 Palms Restricted Area 2501S, need approval	
Transwest #3	AZ			5000	N 35d18.0m	W 110d51.0m		
Transwest #4	AZ			4800	N35d12.0m	W 113d21.6m		
Transwest #5	NM			7000	N 35d24.0m	W 108d15.0m		
Tooele	UT			4000	N 40d31.2m	W 112d21.0m		
Roosevelt	UT			3600	N 40d19.2m	W 109d58.8m		
Boca Grande	CO			7000	N 37d57.6m	W 105d48.8m		
Sky Island	CO			3000	N 38.44.4m	W 108d00.0m		
Mesa View	CO			3000	N 40.46.6m	W 107d32.1m		

Bullseye 05, EAFB/Rogers lakebed	CA	8/30			34° 55.4' N	117° 49.5' W		
Bullseye 27, Winslow lakebed	AZ				35° 08.7' N	110° 43.1' W		
Bullseye 26, Sunrise Spring lakebed	AZ				35° 38.2' N	109° 43.0' W		
Bullseye 28, Blue Mesa area	CO				38° 18.6' N	107° 12.6' W		