Naval Postgraduate School Field Experimentation (FX)

Range Safety Review Questions For Operating Unmanned Aircraft Systems (UAS)
At Camp Roberts *

V. 1.0, Jun 2015

* *Adapted from the* ***White Sands Missile Range, Range Commanders Council, Range Safety Group Supplement to Doc. 323-99, April 2001.***

B.1. INTRODUCTION TO REVIEW QUESTIONS

Range Safety is tasked to identify potential hazards on the range and ensure safeguards are put in place to reduce risk to an acceptable level, consistent with existing local policy guidance. If the operational risks of a specific program exceed specified levels even after implementation of reasonable safeguards, a waiver decision is required from the local Range Commander.

This is a "living document" intended as a tool for Range Safety to evaluate new and ongoing UAV test programs. The document will help ensure the local range commander is fully advised and informed of all known risks. It also serves as a consistent approach to UAV program range safety reviews.

This appendix is focused on hazards that may result in the following consequences:

- UAV crashes which may result in death or injury, or damage to property.

- Failures that result in a fly-away condition of the UAS, resulting in the UAS leaving its assigned test area, or the Restricted Airspace R2504.

- Mid-air collision between UAV and manned aircraft causing death or injury to pilot, or damage to manned aircraft.

Each section provides questions, based on past experience and lessons learned from other programs, which focus on hazards and safeguards as outlined below:

Section B.2: UAV background information

Section B.3: Potential causes of vehicle loss of control that may result in a crash or flight into non-exclusive airspace.

Section B.4: Common safeguards and emergency procedures to prevent an uncontrolled crash off range or mid-air collision.

Section B.5: The midair collision hazard and system interaction with Air Traffic Control.

Successful completion of this review process will result in confidence that:

- Key system vulnerabilities have been identified
- Safeguards have been verified to exist for these system vulnerabilities
- Safeguards are adequate, and
- Deficiencies or inadequacies of the proposed safeguards have been recognized

B.1.1. Control Measures and Risk Decisions.

Control measures to reduce risks to an acceptable level are identified. Risks that are unacceptable in terms of severity and/or probability need to be controlled. The user must help identify specific strategies, tools, or safeguards to eliminate or reduce the risk to a level acceptable to the range. According to MIL-STD-882, the desired order of precedence for implementing control measures is as follows:

- Design for minimum risk. Eliminate the hazard.
- Incorporate safety devices.
- Provide warning devices.
- Develop procedures and training.

B.1.1.1. Design for Minimum Risk.

The best way to control a hazard is to eliminate it by changing the design or adjusting the test and/or training requirements. If the hazard cannot be eliminated, design changes may reduce the risk to an acceptable level. Some examples of design or requirement changes, which may eliminate or reduce risk include:

- Including a highly reliable engine in the UAV design reduces the risk of loss of propulsion.
- Designing a series of tests with a gradual buildup in risk reduces the chance of sudden unexpected catastrophic failure.
- Confining test flights to an unpopulated area eliminates risk to people on the ground.
- Designing a low-level route that avoids populated areas reduces risk of ground casualties from system
- Establishing policy to avoid icing conditions if the vehicle would be at risk in such conditions reduces the risk of icing induced loss of lift or loss of propulsion.

B.1.1.2. Incorporate Safety Devices.

If the hazard cannot be eliminated through design change, fixed or automatic safety devices should be incorporated. Provisions for periodic functional checks for these safety devices should be instituted. Examples of safety devices include:

- Back-up battery in case of generator failure
- Redundant communications link in case of failure of the primary link
- Software “fly-home” routine in case of lost link
- Independent flight termination systems

B.1.1.3. Provide Warning Devices.

If the risk cannot be reduced adequately through design change or use of safety devices, warning devices that detect the hazardous condition and alert personnel of the hazard can be used. Procedures for functional checks of these warning devices should be incorporated. Examples of warning devices are:

• Engine performance safety data displays at the ground control station (i.e., over temp alert)
• Strobe lights to make the UAV easier to see
• "Low fuel" warning lights
• Warning calls from air traffic control when the vehicle is approaching other traffic or hazard/flight boundaries

B.1.1.4. Develop Procedures and Training.

If it is impractical to eliminate hazards or reduce risk adequately through design changes or safety and warning devices, procedures and training can be used. Safety-critical procedures should be standardized and documented. Tasks and activities that are safety-critical may require certification of personnel proficiency. Examples of safety-related procedures and training include:

• Pre-flight checklists
• Published cautions and warnings
• Emergency procedures
• Specific operating limits
• Established operator qualification procedures
• Requirements for personal protective equipment in specific situations (i.e., hearing protection).

Note: Procedures and training should not be used as the only risk reduction methods for high-risk hazards.

B.1.1.5. Hazard Controls.

Control measures used in the hazard analysis are incorporated into range users test plan or procedure document. The range user must show that identified control measures are incorporated, understood, and documented. If required, test procedures and monitoring of the control measures must be certified and in place. If the control measures are not implemented, or the implementation is not effective or sufficient, the hazard is still present. If hazards still exist after all control measures are in place, the first step is to re-evaluate the hazard and control measures and verify that nothing was missed and no other solutions are available. Once this process has been established, documentation of all hazards, their respective control measures, and any remaining risks and recommendations must be presented to the appropriate level of authority for a waiver. The deciding authority will consider the benefits versus the risks to decide whether a waiver will be granted.

B.1.1.6. Supervision.

Follow-up evaluations of the control measures are planned in order to ensure effectiveness. Adjustments will be made before continuing with the test or operation. Independent review and approval of the documentation, hazard analysis, hazard controls, and test procedures and monitoring must take place prior to the test or operation. This monitoring of safety limits must take place on a continuing basis for each test and/or operation.

B.1.1.7. Alternatives If the Risk Management Criteria Are Not Met.

If normal risk management criteria are not met, the following alternatives may be exercised.

- Range may re-evaluate the hazard analysis incorporating changes such as flight parameters, flight path, and new information from the user.
- Range may impose restriction to planned flight to control identified risk.
- Range may require additional control measures or safeguards to control identified risk.
- User can request a waiver from the Range Commander.
- User may not get permission to fly on this range.

NOTE:

Other than in the UAS Background Information section (B.2.), please avoid describing programmable capabilities of the system without defining how that capability will be implemented. Any "if, can, may, or programmed to" statement should be followed with a description of how that function will be programmed.

For example, DO NOT state "The Sputnik MK2 autopilot is capable of flying to any programmed waypoint in case of lost link, where it can hold for a programmed amount of time after which it can be programmed to auto-land at a predetermined location if desired."
Without adding something like this-

"For Camp Roberts operations, the Sputnik MK2 autopilot will be programmed to fly to the lost link point assigned by the Air Boss where it will hold for 10 minutes in an attempt to regain local control. After 10 minutes it will fly to Lost link zone (or other assigned area) and attempt an auto land."

When the review is completed, the safety analyst will have enough information to clearly tell the project what deficiencies they must fix, to document for the Range Commander the areas of risk, and to recognize the key range safety issues to monitor during the test.

B.2 UAV BACKGROUND INFORMATION

Background information about the UAV system is required to understand the system well enough to make a defensible risk assessment. This background information is used as a starting point for identifying potential system hazards and reviewing existing system safeguards. Items listed below are basic guidelines with potential reference sources that are helpful in satisfying the requirement for understanding the system.

B.2.1. Vehicle Description.

- [ ] ***** Submit a photo of the UAV(s) via e-mail along with this document to the NPS JIFX air planner.*****

Veh. Manufacturer	DJI
Veh. Name(s)	Matrice 100
Veh. Model #(s)	n/a
Owner/Operator:	Naval Postgraduate School, SE Dept., John Smith
Airframe Value ($):	$3,000
Veh. Dates(s) of Operation	Marth 20-24, 2018
Classification: *(POR, NPOR, EXP)*	Experimental
Type: *(FW, RW, or Quad-Hexa-Octo-rotor etc.)*	Quadcopter
Max Gross Weight (lbs):	5
Wing/rotor Span (in.)	9
Length (in.)	24
Fuel /Battery Type/Quantity	*(See HAZMAT Section B.2.7)*
Method for Launch: *(hand-launch, bungee, wheel-launch, VTOL, etc)*	VTOL
Method for Recovery: *(deep-stall, runway, VTOL, net, wire, etc)*	VTOL
Method of control: *(autonomous, semi-auto, RC-only, etc)*	RC only
Payload Capacity (Cube / lbs):	4" cube / 1 lbs.

B.2.2. Vehicle Performance.

Max wind for takeoff *(avg. / gust-above avg)*	24 kn
Max cross-wind *(avg. / gust-above avg)*	24 kn
Max Altitude (ft)	1,000 ft AGL
Max Range (from operator/GCS)	2 km
Speed: Cruise / Max (kts)	32 kn
Max Endurance (hrs.)	20 minutes
Operation at night: *(yes/no)*	no
Operation in rain: *(yes/no)*	no
Air Vehicle Construction (molded composite, wood, etc.)	plastic / carbon fiber

B.2.3. Vehicle Payload(s).

Item: *(EO, IR, SIGINT, etc)*	**Details:** *(resolution, FOV, range, etc.)*	**Preferred Altitude**	**~Value ($)**
camera	12 mp gimbaled camera	0 - 5,000 ft	$300

B.2.4. Vehicle Radio Frequency Requirements.

Link: *(C2, payload, FTS,..)*	**Brand:** *(Microhard, Freewave,...)*	**Frequency:** *(high-low)*	**Type:** *(DSS, WiFi, etc)*	**Power:** *(dBm/Watts)*
C2		2.40 - 2.48 GHz	DSS	20dBm
Video		5.73 - 5.83 GHz	DSS	13dBm

B.2.5. Vehicle Safety History and Reliability Data

A flight clearance is typically required for flight operations in the R2504 airspace. For DOD owned systems, a DOD issued flight clearance (Safety of Flight (SOF) or Interim Flight Clearance (IFC)) is required. For non-DOD systems, a flight clearance issued by the aircraft manufacturer, or other competent authority is required.

B.2.5.1 Does the UAS currently have a one of the following: a flight clearance, an FAA issued Certificate of Waiver, Certificate of Authorization (COA), airworthiness, or experimental certificate? Yes ☐ No ☒ If yes to any of the above, state type and the issuing entity. Please also provide a copy.

B.2.5.2. Vehicle history: How many flights (# of sorties, flight hours) has the UAS completed to date?

None, just bought it

B.2.5.3. Is the UAS currently in use with the uniformed services? Yes ☐ No ■
If so, provide details.

B.2.5.4. What is the heritage of the UAS (i.e. is it an evolution of another UAS system)?

Commercial off-the-shelf quadcopter system developed primarily for hobbyist videography and photography.

B.2.5 .5. Mishap history: How many crashes and failures have occurred? What has been the corrective action to ensure the failures do not occur again?

n/a

B.2.6 <u>Minimum Crew Requirements & Operator Qualifications.</u>

B.2.6.1. Minimum Crew. List all personnel involved in the mission and state their functions. Use legend below for position title. Minimum crew consists of a PIC, VO, and FSO. Depending on UAS uniqueness and complexity, more personnel may be required.

Name (Last, First)	**Position (s)*** (list all that apply, add new if needed)
Smith, John	UAC, AVO, MPO
Smith, John	VO, FSO

<u>Crew position legend:</u>
- UAC: The Unmanned Aircraft Commander (UAC) shall be responsible for the safe, orderly flight as related to the physical control of one or more UASs . The UAC may direct the actions of an AVO. The positional authority of the UAC is analogous to that of an "Aircraft Commander" of a manned aircraft. As with manned aircraft, a single individual may act as both UAC and perform other UAS Crewmember (UASC) duties.

- AVO: The air vehicle operator (AVO) is in direct control of the unmanned vehicle. The AVO shall be designated as the Pilot in Command (PIC) and is responsible for the operation and employment of the unmanned vehicle. The AVO/PIC shall not perform concurrent duties as both pilot and observer.

- MPO: The Mission Payload Officer (MPO) is responsible for the employment and tactics for any and all payloads onboard the unmanned vehicle. These payloads include, but are not limited to, EO and IR cameras, communications, and collection devices.

- VO: The Visual Observer is a trained person who assists the unmanned aircraft pilot in the duties associated with collision avoidance. This includes, but is not limited to, avoidance of other traffic, clouds, obstructions and terrain. An observer is required for all UAS operations at Camp Roberts. Additionally, the VO shall be the primary radio communication interface between the UAC/PIC/AVO and the NPS Air Boss and range safety officer (RSO).

- FSO. The Flight Safety Officer (FSO) is designated by each participating unit. The FSO is responsible for the safe conduct of the entire UAS operation (preflight/flight/ Recovery /post-fight). The FSO is knowledgeable of all aircraft systems, functions, and safety of flight procedures and monitors the entire operation for safety hazards to personnel and the aircraft. The FSO cannot assume any other crew position.

- Other. If none of the above, please list the appropriate position/title

B.2.6.2. Operator Qualifications and Training

B.2.6.2.1. What is the basis of the qualification of the vehicle operators? How much experience do they have? How recently have they flown this / each type vehicle? Answer in the table below.

Name (Last, First)	Hours (UAS / RC / GCS)	Current in model?
Smith, John	10 hours	similar

B.2.6.2.2. State the training experience of each of the listed UAS operators below. If required, differentiate between crew position and specific platform as required.

Smith John operates DJI Matrix 100 drone for his thesis research and is current in flying the said drone. He clocked approximately 4 flights per week on the Matrix 100. Smith John has flown (as a hobbyist) various quadcopters and is proficient in manned remote controlling.

B.2.6.2.3. Are any of the personnel licensed pilots or former military pilots? If so, what is their flight experience (A/C type, hrs, etc.)

Smith John - Private pilot (SEL), 600 hours

B.2.6.3. Operator Currency

Per FAA Interim Operational Approval Guidance 08-01 (Mar 2008), the PIC shall demonstrate three takeoffs (launch) and landings (recovery) in the specific UAS in the previous 90 days. For night operations, the PIC must demonstrate three takeoffs (launch) and landings (recovery) in the specific UAS at night to a full stop in the previous 90 days. Note, various organizations may have more stringent currency requirements than the FAA. This questionnaire only sets the minimum standard for participation.

B.2.6.3.1. Will all of the UAC/AVO/PICs listed above be current for flight during daylight operations during the JIFX/NPS event? Yes ■ No ☐

B.2.6.3.2. Will all of the UAC/AVO/PICs listed above be current for flight during nighttime operations during the NPS JIFX event?
Yes ☐ No ■ **or N/A** ☐

B.2.6.4. CERTIFICATION. For non-uniformed military UAS operators, we require an official signature(s) by the appropriate approval authority(s) (i.e. Program Manager, Principle Investigator, Research/Company Team Leader, etc.) verifying that:

(1) The UAS model(s) has/have been previously flown in the current configuration

(2) The operators listed above are qualified and current to fly the UAS as configured

(3) The UAS will be operated in a safe manner during the event, abiding by all policies, guidance, & restrictions issued by the Camp Roberts Garrison Commander, the NPS Field Experimentation Director & staff, and the Air Boss.

Smith, John		Professor	05/23/2017
Printed Name (Last, First, Mi.)	***Signature***	***Title***	***Date (mm/dd/yyyy)***

B.2.7. **Hazardous Materials.**

B.2.7.1. List any hazardous materials onboard (flammable, toxic, energy storage, ordnance) below:

Item: *(fuel, battery, fuel-cell, etc)*	**Chemistry:** *(gasoline, heavy-fuel, lithium-Ion, etc)*	**Quantity:** *(volume, voltage, capacity, weight, etc)*
Battery	Lithium Polymer	4.7 Ah

B.2.7.2. Can a crash start a fire? Yes ☒ No ☐ Explain:

Damage to a LiPo battery can cause a fire.

B.3. CAUSES OF "LOSS OF CONTROL"

Vehicle loss of control can easily result in a mishap. If we can identify any potential causes of "loss of control" that may have been overlooked, safeguards can be applied, or test conditions can be restricted to reduce risk to an acceptable level. The following questions focus on system vulnerabilities previously experienced, some of which have resulted in mishaps.

B.3.1 **Loss of Command Links.**

B.3.1.1. Fully describe the command and control links, including equipment used, frequency, bandwidth, modulation, power output.

Transmitter specs: 5.725 - 5.825 GHz and 2.400-2.483 GHz radios, power max 9W (5km range).

B.3.1.2. What happens when command link is lost?

The aircraft immediately returns to the home location and lands.

B.3.1.3. Will UAV climb to a specific altitude? Yes ☐ No ☒

B.3.1.4. Will UAV orbit? Yes ☐ No ☒ How long?

B.3.1.5. Can the UAV land itself? Yes ☒ No ☐ If "yes" explain how the landing will be accomplished.

The Inspire can automatically return and land at the home location. Landing is accomplished via VTOL.

B. 3.1.6. What is the timing and sequence of events? Is there a time limit?

In less than 5 seconds the vehicle will enter lost link mode, and immediately return to home and land.

B. 3.1.7. How does vehicle respond if link is never re-established?

See previous section.

B.3.1.8. How does the vehicle recognize that loss of command link has occurred?

Onboard software/hardware automatically detects loss of signal from the ground station equipment.

B.3.1.9. How does the UAS operator in the ground control station recognize loss of command link has occurred?

Visual and audible notification of lost link.

B.3.1.10. Are there any identified Single Point or Common Mode failures in the Command and Control Links? If so, how are these mitigated?

No

B.3.1.11. What is the processing time (i.e. lag time) of the Command and Control links?

< 0.1 s

B.3.2. **<u>Backup Communications Links.</u>**

B.3.2.1. Is there a backup command transmitter and receiver? Yes ☐ No ☒
Is the backup link on the same frequency as the primary? Yes ☐ No ☐ Explain.

B.3.2.2. Does the backup transmitter have the same or more "effective radiated power"

B.3.3 **<u>Link Analysis.</u>**

B.3.3.1. Has RF link analysis been performed to verify both primary and backup transmitters can communicate with the vehicle at the furthest point in its planned operation? Yes ☒ No ☐

B.3.3.2. Does link analysis address all RF links below?

B.3.3.2.1. Uplinks from primary and backup ground stations.
Yes ■ No ☐

B.3.3.2.2. Secondary uplinks from each ground station.
Yes ☐ No ☐

B.3.3.2.3. Downlinks to primary and backup ground stations.
Yes ■ No ☐

B.3.3.2.4. Flight Termination Link (if equipped).
Yes ■ No ☐

B.3.3.2.5. Is there at least 12 dB of signal excess in FTS link?
Yes ■ No ☐

B.3.3.3. What is the maximum range for each link?

> 1 km

B.3.3.4. How do you determine if the primary and backup transmitters are radiating specified output power?

The DJI pilot application provides signal strength to the pilot.

B.3.3.5. How do you determine if the vehicle primary and backup command and control receivers (and FTS receivers, if equipped) are operating at specified sensitivity?

The DJI pilot application provides signal strength to the pilot.

B.3.3.6. Are there any nulls in the command transmitter antenna pattern?
Yes ☐ No ▣ If "yes", describe.

B.3.3.7. Are there areas of RF masking due to location of antennas on the UAS relative to their position and to ground station antennas? Yes ☐ No ☒ If "yes" explain.

B.3.3.8. What is the link susceptibility to multipath?

Unlikely

B.3.3.9. What is the system response if multipath is experienced?

Weak signal indicated.

B.3.3.10. Does link analysis consider RF horizon?

n/a

B.3.4. <u>Radio Frequency Interference (RFI).</u>

B.3.4.1. What is the effect of RFI on the command and control system?

Potential loss of link.

B.3.4.2. Is the backup command link sufficiently protected from spurious command signals? Yes ☐ No ☒

B.3.5. <u>Loss of Vehicle Position Information.</u>

B.3.5.1. Fully describe the navigation system of the UAS, including backup navigation sources if applicable.

GPS and inertial navigation/stabilization.

B.3.5.2. What are the sources of vehicle navigation position information to the UAS operator?

The DJI pilot app provides artificial horizon, compass, GPS location (on map), and variometer for the pilot (connected directly to the pilot transmitter/controller).

B.3.5.3. Are there redundant navigation sources so the UAS operator can tell if there is a discrepancy?

No

B.3.5.4. How will the UAS respond in a denial of GPS environment?

Navigation is controlled manually by the pilot, without GPS the aircraft may deviate slightly during hover operations, but will not further degrade flight performance.

B.3.5.5. What happens if GPS is not recovered?

See above

B.3.5.6. What happens if the GPS stops reporting (locks up) or keeps reporting the same position information?

See above

B.3.5.7. Does your navigation system take into account GPS Dilution of Precision (DOP) in using GPS data for navigation?

Navigation is controlled solely by the pilot (manual navigation).

B.3.5.8. If the UAS operator loses primary position information, is control also lost? Yes ☐ No ☒ If "yes", what can the Operator do to regain control?

Solely manual flight operation.

B.3.5.9. Does the UAS operator have access to any external sources of position information that could serve as a backup (radar, IFF, binoculars)? Yes ☒ No ☐ Explain.

Visual line of sight will always be maintained.

B.3.5.10. How does the vehicle autopilot respond to loss of primary internal navigation source?

Manual flight operations only.

B.3.5.11. Is there a backup? Yes ☐ No ☒

B.3.5.12. What are the indications in the ground station to the UAS operator?

The DJI pilot app provides artificial horizon, compass, GPS location (on map), and variometer for the pilot (connected directly to the pilot transmitter/controller).

B.3.6. <u>Loss of Flight Reference Data.</u>

B.3.6.1. Fully describe the inertial flight data system of the UAS, including backup sources if applicable.

GPS, inertial measurement unit, pressure altimeter, and low-altitude ultrasonic sensor (for ground detection).

B.3.6.2. What are the on-board sources of position, attitude, heading, altitude, and airspeed information to the UAS operator and/or autopilot?

GPS, inertial measurement unit, pressure altimeter, and low-altitude ultrasonic sensor (for ground detection).

B.3.6.3. How does the vehicle autopilot respond to loss of primary attitude source?

Immediately attempt to land the aircraft

B.3.6.4. Is there a backup? Yes ☐ No ☒

B.3.6.5. What are the indications to the UAS operator?

Obvious from visual contact.

B.3.6.6. Is there a DR (dead reckoning) mode if GPS or inertial navigation is unavailable or degraded? Yes ☐ No ☒

B.3.7. <u>Unresponsive Flight Controls.</u>

B.3.7.1. What will happen if a servo or flight control sticks or becomes unresponsive? How does the autopilot respond? Is there a backup? How quickly will the UAS operator recognize this?

UAV will return to home and land.

B.3.7.2. What happens if the throttle is stuck?

Vehicle is battery controlled and has no throttle.

B.3.7.3. How will the UAS operator recognize this condition and is there a recovery procedure?

Visual and audible notifications from the pilot application.

B.3.8. Loss of Propulsion.

B.3.8.1. What happens to the vehicle when propulsion stops? Will the UAS immediately depart controlled flight or can it glide for some distance?

Vehicle free-falls.

B.3.8.2. Will sufficient velocity and electrical power remain for "controlled ditch" or "dead stick landing"? Yes ☐ No ☒ Explain.

Aircraft will simply fall with no auto-gyration capabilities at this time.

B.3.8.3. Can the engine be restarted, turned off or turned on in flight? Yes ☒ No ☐ Explain.

Unlikely due to rapid descent rate.

B.3.8.4. Is the propulsion system affected by environmental conditions (temperature, icing, dust, etc.)? Yes ☒ No ☐

B.3.8.5. Are the limits and failure modes confirmed by test data? Yes ☒ No ☐

B.3.8.6. What are the limits?

Inspire manual specifies the limitations as: altitude 4,500m, 22 m/s max speed, ascent speed limit 5 m/s, wind speed 10 m/s, and temperature range of -10 to 40C.

B.3.8.7. Are limits considered in the test plan? Yes ☒ No ☐

B.3.8.8. How is fuel volume/utilization (or battery charge) monitored during flight?

Battery level indicated on GCS.

B.3.9. Loss of Electrical Power.

B.3.9.1. What happens when primary electrical power is lost?

Vehicle free-falls.

B.3.9.2. Battery Bus Power.

B.3.9.2.1. Is there a separate battery bus? Yes ☐ No ☒

B.3.9.2.2. What does the battery bus power?

B.3.9.2.3. Does automatic system load shedding occur if power is reduced? Yes ☐ No ☒ Explain.

B.3.9.2.4. Are there "essential busses" for reduced power operations?

no

B.3.9.2.5. Are all flight essential systems on an essential bus? Yes ☐ No ■

B.3.9.2.6. Is there a battery power available time limit associated with loss of electrical power? Yes ☒ No ☐ How long?

Estimated flight time remaining is displayed directly on the pilot application. When battery is sufficiently low, the aircraft automatically returns to home and lands.

B.3.9.2.7. If equipped with a backup battery, how is it checked prior to takeoff?

n/a

B.3.9.2.8. Safety backup system battery lifetime is a critical issue. How do you know how much emergency battery power is left?

n/a

B.3.9.2.9. Is battery usage data available on telemetry? Yes ☒ No ☐

B.3.9.2.10. Is a battery use log kept? Yes ☐ No ☒ Where?

B.3.9.2.11. What if the UAV is too far from base to get back before power runs out?

Vehicle free-falls (or lands).

B.3.10. <u>Ground Control Station.</u>

B.3.10.1. What is the source of electrical power for the ground control station?

LiPo battery

Is there an uninterruptible backup power source? Yes ☐ No ☒

B.3.10.2. What happens if electrical power is lost?

The transmitter turns off and immediately enters lost link mode.

B.3.10.3. Do backup command transmitter and emergency systems have adequate protection from loss of electrical power? Yes ☐ No ☒ Explain.

n/a

B.3.10.4. If power to the ground station is lost, does it affect how flight information is calculated? Yes No Do all flight parameters get reset to zero? Yes ☐ No ☒

Parameters are restablished if GCS regains power.

B.4. REVIEW OF COMMON SAFEGUARDS

Many UAV designs take similar approaches ("return home" modes, FTS, parachutes, etc.) to safeguards in order to reduce the risk associated with loss of control. Some of these approaches have not always been adequate. This section asks questions related to the adequacy of those approaches to loss of control safeguards, based on previous experience with several UAV designs.

B.4.1 <u>Degraded Modes of Flight.</u>

B.4.1.1. What subsystems will fail and cause the UAV not to be able to continue flying?

Motors, propellers, and most other flight systems.

B.4.1.2. Loss of which subsystems will cause the flight to be aborted (i.e., precautionary return to base)?

Lost link with GCS

B.4.2. <u>Return Home Modes (*Not Lost Link*).</u>

Some UAS will self-detect an in-flight failure/discrepancy and automatically abort the mission and return.

B.4.2.1. Does this vehicle have an automatic "return home" feature (sometimes also called "reversion mode" or "Preprogrammed Emergency Mission")? Yes ☒ No ☐ If yes, explain.

Aircraft automatically returns to home and lands during lost link scenarios.

B.4.2.2. What conditions will cause the vehicle to go into "return home" mode?

Lost link

B.4.2.3. What does the vehicle do once it arrives at the "return home" point?

Slowly descends and lands.

B.4.2.4. Will it climb to a specific altitude? Yes ☒ No ☐

B.4.2.5. Will it Orbit? Yes ☐ No ☒ How Long?

B.4.2.6. Can it land itself? Yes ☒ No ☐ If "yes" explain how the landing will be accomplished.

Slow VTOL

B.4.2.7. What is the timing and sequence of events?

In return to home mode the aircraft will land immediately at the home location.

B.4.3. <u>Selection of Lost Link "Return Home" (i.e. EMERGENCY Locations.</u>

B.4.3.1. Emergency Way Points.

B.4.3.1.1. Can the "emergency" point be any location, or just the takeoff point?

Can be updated in-flight, but default is the takeoff location.

B.4.3.1.2. How many "emergency" locations can the UAS have?

1

B.4.3.1.3. Is the "emergency" point pre-programmed, or can it be updated in flight? Yes ☒ No ☐

B.4.3.1.4. Is the UAS required to fly direct to the "emergency" location or can it fly a programmed route (intermediate waypoint(s)) to its assigned location? Are altitude limits defined? What happens if the altitude limits are exceeded?

The aircraft flies directly to the home location, no waypoints can be programmed.

B.4.3.1.5. How are the "emergency" positions entered? What safeguards prevent erroneous position input?

The home location must be clicked on the pilot app, with an additional confirmation screen which severely decreases the risk of accidental home location updates.

B.4.4 <u>GPS Vs Dead Reckoning (DR) Navigation Source and "Return Home" Mode.</u>

B.4.4.1. How does "return home" mode navigate (dead reckoning, inertial nav, radio beacon homing, GPS)?

GPS

B.4.4.2. Is the reversionary mode tied to GPS? What happens if GPS is not being received or GPS jamming tests are being conducted?

The aircraft will immediately land at the current location.

B.4.4.3. Is there a DR (dead reckoning) "return home" mode if GPS or inertial driven navigation is unavailable or degraded?

No

B.4.5. <u>Failure to Regain Control.</u>

B.4.5.1 What happens if the UAV operator fails to regain control of the vehicle once it arrives at the "return home" point and climbs to altitude? Is there a time limit? Does a “Fail Safe” event occur? Does it try to land?

Aircraft automatically lands.

B.4.6. <u>Ditching/Dead Stick Landings.</u>

B.4.6.1. What situations would cause the UAV operator to perform a forced landing?

Low battery power, air boss instructions, safety issues, or weather events.

B.4.7. <u>Pre-planned Ditching Locations.</u>

B.4.7.1. Do pre-planned ditching or forced landing locations exist? Can these locations be reached from any point in the planned route of flight?

Yes. Operator will only operate in areas where emergency landings can be safely performed.

B.4.7.2. What is the criteria for the selection of those locations?

Clear of obstacles, structures, wildlife, and personnel.

B.4.7.3. How do you know if these locations will be clear of people? Will the locations be in a controlled area or under surveillance?

Yes, both

B.4.8. FLIGHT TERMINATION SYSTEM (FTS)

A major concern for Range Safety is containment of the UAS within its assigned range test area. Range Safety must ensure that the UAS system does not enter into a 'fly-away' condition. This section should describe those features of the UAS, which will prevent a fly-away condition.

B.4.8.1. FTS FUNCTION.

An FTS (aka, *Dead Man's Switch, Kill Switch, or Failsafe timer*) is typically circuitry that is incorporated into the UAS that will cause the UAS to stop flying, typically by stopping propulsion. The FTS functionality can be programmed to occur automatically, based upon a hardware failure, such as loss of heartbeat or software failure. In some cases it can also be controlled from the ground. The Cloud Cap/Piccolo Tech. / FTS engine interface board is one example of this technology.

B.4.8.1.1. Has a Dead Man's switch, kill switch or some other failsafe mode been incorporated into the UAS design? Yes ☐ No ☒ Is it a standalone/independent system? Yes ☐ No ☐

B.4.8.1.2. Describe how this function has been incorporated into the UAS design.

Vehicle is light enough that impact force is sufficiently small.

B.4.8.1.3. When the function is activated, describe what happens to the UAS. What is the timing and sequence of events?

n/a

B.4.8.2. Prevention of Fly-Away Conditions

B.4.8.2.1. Describe any systems installed in the UAS designed to prevent a fly-away condition.

none

B.4.8.2.2. What failures could cause a fly-away condition and how are these mitigated?

Operator's error (operating in manual mode only).

B.4.8.3. Independent/Standalone FTS Function.

B.4.8.3.1. Does the FTS operate on an independent battery circuit?
Yes ☐ No ■

B.4.8.3.2. Does the FTS activate if the battery fails (i.e., fails "safe")?
Yes ☐ No ▣ If "no" to any question, explain.

Aircraft free-falls

B.4.8.3.3. If there is a separate FTS Transmitter? Yes ☐ No ☒ If "yes", where is it and what type?

B.4.8.3.4. Does its coverage equal or exceed the command transmitter coverage? Yes ☐ No ☐

B.4.8.3.5. Does the coverage exceed or meet or the maximum range the UAS will fly? Yes ☐ No ☐ If "no", explain.

B.4.8.4. FTS Transmitter.

B.4.8.4.1. Where is the FTS transmitter located?

n/a

B.4.8.4.2. Does FTS coverage equal or exceed the command transmitter coverage? Yes ☐ No ☐

B.4.8.4.3. Does the coverage meet or exceed the maximum range the UAV will fly? Yes ☐ No ☐

B.4.8.5. Flight Termination Criteria.

B.4.8.5.1. What are the criteria for command activation of the FTS?

n/a

B.4.8.5.1. Do the criteria include the following? Yes ☐ No ☐

- Loss of all tracking data
- After all other remedial actions have been taken, a vehicle that cannot be contained within the operating area or range
- If during loss of link mode, a vehicle that does not fly to a predetermined "return home" point

B.4.8.6. <u>FTS Testing and Certification.</u>

B.4.8.6.1. Who certifies the FTS as "flight ready," and what processes are involved in issuing the certification?

n/a

B.4.8.6.2. Is the flight termination system independent of other vehicle systems? Does it have its own antenna, receiver, signal processing capability, and power supply?

n/a

B.4.8.7. <u>Fail Safe Mode</u>

B.4.8.7.1. Is there a "fail safe" mode that comes into play if a FTS command is not received? Yes ☐ No ■

B.4.8.7.2. What conditions cause it to activate?

B.4.8.7.3. What happens (engine shut off, flight controls to "turn" or "tumble")?

B.4.8.7.4. What causes self-activation of the flight termination system? Electrical power loss? Loss of flight critical function? Loss of FTS signal?

B.4.8.7.5. Is there a specified time delay between what triggers fail safe mode and actions taken to cause the vehicle to stop flying?

B.4.9. <u>Parachute.</u>

B.4.9.1. If the UAS has a parachute system, at what altitude will the chute deploy and what is the impact and drift rate?

No parachute

B.4.9.2. What is the rate of descent at max weight?

B.4.9.3. Are there altitude, airspeed, or attitude limits on deploying the parachute? Yes ☐ No ☐ If “yes”, explain.

n/a

B.4.9.4. Does the engine have to shut off prior to the deployment of the parachute? Yes ☐ No ☐

B.4.9.5. Can the propeller cut the parachute shroud line? Yes ☐ No ☐

B.4.9.6. What happens if the engine fails to shut down?

B.5 QUESTIONS ABOUT “MIDAIR COLLISION” HAZARDS

B.5.1. Airspace.

B.5.1.1. Will test procedures require exclusive airspace? Yes ☐ No ☐ If not, how will risk to other aircraft be minimized?

All flight ops will be coordinate with the airboss to prevent collisions. Additionally, flights will be coordinated with internally collaborative UAS flight ops.

B.5.1.2. If shared, is UAV airspace use compatible or incompatible with any type aircraft or type mission?

Compatible with other aircraft under direction of air boss.

B.5.1.3. What are the weather minimums for this type vehicle? Can the UAS fly in clouds or IFR conditions?

< 10 m/s wind and within -10 to 40C. LOS operations only.

B.6. MISCELLANIOUS

B.6.1. Ground Safety.

B.6.1.1. For systems that *do* utilize wheels for takeoff and/or landings, what runway length is required for UAV takeoff roll? What distance is required for landing and landing roll out?

n/a

B.6.1.2. For systems that *do not* utilize wheeled takeoff and/or landings, what is the ground safety radius required for launch and recovery operations?

25 ft

B.6.2. Tracking Systems.

B.6.2.1. Do you have a tracking system? Yes ☒ No ☐

B.6.2.2. What kind do you have?

Onboard GPS with communication with GCS.

B.6.2.3. Can it be shared? Yes ☐ No ☒

B.6.2.4. Is your UAS capable of disseminating MITRE's Cursor On Target (CoT), Google's Keyhole Markup Language (KML)? Other? Yes ☐ No ■ Explain.

B.6.2.5. Are the restricted airspace (RAS) and restricted operation zones (ROZ) displayed on your GCS Map? (Both the RAS and ROZ MUST be displayable on GCS heads up display) Yes ☐ No ■

B.6.2.6. Has a 500' buffer been added to the RAS boundaries on your GCS map? Yes ☐ No ☐

B.6.2.7. Do you have a forward looking camera on board? Camera must be on board for non- line of sight. Yes ☒ No ☐

B.6.2.8. Line of Sight. All non-proven UAS must be flown within visual line of sight until NPS personnel give safety approval to fly non line of sight.