SPAARO UAV
Operating Procedures

Virginia Polytechnic Institute & State University
Virginia Center for Autonomous Systems
540-231-8117
cwoolsey@vt.edu

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Virginia Tech UAV Operating Procedures

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Introduction

This document establishes operating procedures and includes a risk analysis and mitigation for safely performing radio control (R/C) and autonomous unmanned aerial vehicle (UAV) flight tests. This document identifies the roles, responsibilities, and procedures for test personnel in pre-test, test, and post-test operations.

Several procedures are discussed in the following section:

- Pre-test Activities (including pre-test notification, briefing, weather & GPS check, and visual inspection),
- Test Activities
- Emergency Procedures.

Pre-test Notifications

The Test Director, Safety Officer, and/or designated representative(s) will coordinate with the appropriate authority to gain access to facilities and surrounding airspace.

Operations at Kentland Farm, VA
The Test Director or Safety Officer will be responsible for coordinating with local air traffic control and with affected university personnel. The POC for Kentland Farm is:

Dwight Paulette, Farm Manager, 540-731-1289, kentland@vt.edu

Pre-test Briefing

The Test Director or Safety Officer shall conduct a pre-test briefing immediately prior to the test reconfirming test objectives, procedures, and emergency procedures. The Pilots and Ground Handlers will ensure that the transmitter and receiver batteries are fully charged . The test Safety Officer will ensure personnel protective equipment are available for all personnel and the fire extinguishers are properly charged. The Safety Officer will also verify critical phases of operations (i.e. verification of preflight checks) and ensure that personnel are properly trained for their given task(s).

Weather & GPS Check

Upon arrival at the test site, the Test Director and test Safety Officer shall verify the weather conditions are within operational limits. Flight testing will only be done during day-time VFR conditions (night-time VFR by exception), with wind limits 15 MPH on sur-

face, 20 MPH measured >10' above ground. Maximum altitude and range boundaries must be followed. Intentional crosswind or downwind landings are discouraged.

In the case of autonomous flight operations, the Test Director and Safety Officer shall also verify that at least six satellites in the GPS constellation are visible and that signal quality is adequate to support autonomous flight.

Test Area Visual Survey

The wind speeds and direction will be observed to be within the test limits. All personnel will be in the designated areas as specified by the Safety Officer and flying layout plan. When the Safety Officer determines test operations may commence, test team members may prepare the vehicle for flight testing.

Procedures

The following procedures (typical example shown below) will be followed for the operation of the UAV (Unmanned Aerial vehicle).

Verify Block	Sequence	Who	Action
100.0 PRE-FLIGHT CHECKLIST			
	100	1	GH	Verify IGN switch is in "OFF" position
	100	2	GH	Charge pneumatic brakes to 110 psi and inspect main gear.
	100	3	GH	Inspect nose gear.
	100	4	GH	Assure batteries, wiring, fuel tank and fuel lines, engine mount, throttle servo, and control surface servos are secured.
	100	5	GH	Check receiver (for engine kill) is secure
	100	6	GH	Assure pitot/static lines are hooked up and not kinked. Verify autopilot pressure lines, antennas, and 40-pin connector are securely in place.
	100	7	GH	Inspect engine (tight on mounts, muffler secure, throttle linkage, starter wiring)
	100	8	GH	Inspect prop for cracks, nicks etc. and secure prop nut
	100	9	GH	Inspect ignition and mission payload batteries – voltage OK and wiring secure
	100	10	GH	Inspect ailerons (horn, hinge, ball link connection wing retention bolts)
	100	11	GH	Inspect flaps (horn, hinge, ball link connection)
	100	12	GH	Inspect horizontal tail
	100	13	GH	Inspect rudder (horns, hinges, and pull-pull tension)
	100	14	GH	Check all flight-critical battery voltages (avionics, back-up receiver, actuators)
	100	15	GH	Assure the wing bolts are securely fastened
	100	16	GH	Assure wing joint tape is in place.
	100	17	GH	Verify external antenna are secure.
200.0 REFUELING PROCEDURES			
	200	1	GH	Verify fuel tank is installed and connected properly
	200	2	GH	Verify all vehicle switches are in "OFF" position.
	200	3	GH	Disconnect spark plug wires and properly ground vehicle.

	200	4	GH	Confirm GH or TSO is standing by with fire extinguisher.
	200	5	GH	Connect the fill hose from the pump to the fuel inlet .
	200	6	GH	When fueling is complete, stop pumping and reconnect overflow line to the muffler.
	200	7	GH	Disconnect “FILL” hose from vehicle.
	200	8	GH	Stow fuel pump and fuel can.
	200	9	GH	Remove grounding wires

300.0 PRE-FLIGHT POWER UP AND CHECKOUT

	300	1	GH	Verify Pre-flight Check and the Refueling Procedures haves been completed
	300	2	GH	Verify vehicle is in proper CG range – ballast if necessary.
	300	3	P	Verify Autopilot switch (landing gear) is at “MAN”
	300	4	P	Verify throttle at minimum & all trim sliders are at neutral
	300	5	P	Turn ground station and transmitter power “ON” & verify good voltage
	300	6	P	Verify all flight controls functional (aileron, elevator, rudder, throttle & flaps)
	300	7	GH	Turn ignition switch “ON” and verify strobe is flashing
	300	8	P	Turn termination transmitter “ON” and perform range check.
	300	9	P	Turn all other radios on and perform range check
	300	10	P	Perform autopilot ground checks
	300	11	GH	Turn Payload power “ON”
	300	12	GH	Verify payload functionality.
	300	13	GH	Turn Payload power “OFF”
	300	14	P	Turn payload power “OFF”
	300	15	GH	Turn ignition “OFF”
	300	16	GH	Turn transmitter “OFF”

400.0 ENGINE RUN-UP PROCEDURES

	400	1	GH2	Verify fire extinguisher is close to vehicle.
	400	2	P	Perform communications check with GH.
	400	3	P	Verify eye protection is in place.
	400	4	ALL	Inspect area around vehicle for loose debris.
	400	5	GH	Verify vehicle is held securely.
	400	6	P	Turn transmitter, ground station and termination transmitters power “ON”
	400	7	P	Payload power switch “ON”
	400	8	GH	Ignition switch “ON”, verify strobe is flashing
	400	9	P	Cycle throttle several times to confirm proper operation
	400	10	GH	**CLEAR PROP!!!**
	400	11	GH	Start engine using electric starter
	400	12	P	Increase throttle slowly until engine runs smoothly
	400	13	P	Allow engine to warm up
	400	14	P	Increase throttle slowly to max and adjust mixture setting, as required
	400	15	P	Perform engine-on range check of the termination transmitter (JR10X)
	400	16	P	Set Kill/No Kill switch on termination transmitter to “KILL”
	400	17	P	Verify engine shuts down
	400	18	P	Switch Ignition to “OFF”
	400	19	GH	Payload power switch “OFF”
	400	20	GH	Turn transmitter, ground station and termination transmitters power “OFF”

500.0 TAKEOFF PROCEDURES

	500	1	GH	Point vehicle into wind
	500	2	P	Perform communications check with GH
	500	3	P	Verify eye protection is in place for all crew
	500	4	all	Inspect area around vehicle for loose debris
	500	5	GH	Verify vehicle is restrained
	500	6	P	Turn on transmitter and ground station and check voltage
	500	7	P	Cycle throttle several times to confirm proper operation
	500	8	GH	Switch Ignition "ON"
	500	9	GH	Switch Payload "ON"
	500	10	GH	Switch termination transmitter to "NO KILL" , verify strobe is flashing
	500	11	P	Set throttle to approximately 33% power
	500	12	GH	Verify vehicle is held securely
	500	13	GH	**CLEAR PROP!!!**
	500	14	GH	Start engine using electric starter
	500	15	P	Increase throttle slowly until engine runs smoothly
	500	16	P	If there has been a long delay since the previous engine run up, allow engine to warm up
	500	17	P	Reduce throttle to MIN
	500	18	P	Verify all controls operate freely and in the proper direction and the that runway is clear
	500	19	P	Immediately increase throttle to MAX
	500	20	P	Use rudder control stick to steer vehicle while on the ground

600.0 LANDING PROCEDURES

	600	1	P	Make sure the runway is clear and note direction of wind.
	600	2	P	Line vehicle up with runway for an into-the-wind landing, apply flaps, as required.
	600	3	P	Near the ground, flare before landing
	600	4	P	At touchdown, apply brakes.
	600	5	P	When aircraft slows adequately, taxi to a safe location and kill the engine.

700.0 POST LANDING PROCEDURES

	700	1	GH	**CAUTION: Engine will be HOT**! **Do not touch!**
	700	2	GH	Turn ignition and payload switches to the "OFF" Position
	700	3	GH	Transmitter, ground station, and termination transmitter switch to "OFF"
	700	4	GH	Inspect for and note any apparent damage to vehicle/payload systems.
	700	5	GH	Remove remaining fuel from airplane.

Emergency Procedures

In the event of personnel injury (i.e. laceration due to spinning propeller);
Test Director Calls "Stop Engine" and the pilot kills the engine.
Seek medical attention. **911 as appropriate.**

If UAV loses primary (900MHz) link in autonomous flight mode;
Autopilot automatically directs aircraft toward base station.

When UAV is within range for manual piloting, if reliable 900 MHz communication has not been re-established, pilot switches to 72MHz manual control link and lands the aircraft (in a remote location if necessary).
Testing is halted until reliable 900MHz link is re-established.

If UAV engine fails;

Pilot switches UAV autopilot mode to “Return to Base Station.”
Pilot attempts to re-start engine in flight using electric starter.
If engine fails to start, when UAV is within range for manual piloting, pilot takes manual control and lands the aircraft (in a remote location if necessary)
Testing halted until reliable engine performance is re-established.

If fire starts;

Closest person (pilot, ground handler or test director) shouts “FIRE” and attempts to extinguish the fire using chemical fire extinguisher or sand, as appropriate.
Remaining test personnel move away 75 feet from vehicle.
Safety Officer radios or calls fire department. **911, as appropriate.**

Post-Test Activities

UAV will be disassembled.
Ground station will be disassembled.
All equipment and test hardware will be transported back to the hanger.
Inspect the test area for debris and be sure to gather all test equipment.

Recommended Staging of Ground Operations

A. Introduction:
The Academy of Model Aeronautics has determined that most modelers and model clubs are careful in their selection of flying sites, site layout, and operational practices.
The suggested specification detailed below has been developed to promote improved field management and provide added margins of safety for the ever-increasing numbers of fliers and spectators. Most clubs should be able, with reasonable effort, to comply with this suggested layout for general field arrangement and conditions for sport flying.
The suggested specifications are not intended as mandatory requirements, and compliance with these suggestions does not, of course, guarantee that no accident will occur. The AMA recommends that individual clubs design their flying sites based not only on the suggested specifications below, but also upon the individual characteristics of the flying site and the type of RC activity which is anticipated. AMA should be contacted if there are any questions concerning site specifications and site layouts.
The AMA Safety Code remains the governing factor. All members and clubs must conduct their field operation in accordance with the Code.

Taxi Area: No landings or takeoffs from this area.
—Provides additional open space between pilots and aircraft during time when most out of control accidents happen.
—Allows taxi room in front of other pilots with less likely chance of other frequencies “swamping” taxiing aircraft.
Barrier: Designed to stop taxiing models from veering into pilot’s and/or spectator’s positions (plastic or chainlink fencing, hay bales, shrubbery, etc.).
Pilot Line: Set back from runway edge to keep pilots away from aircraft.

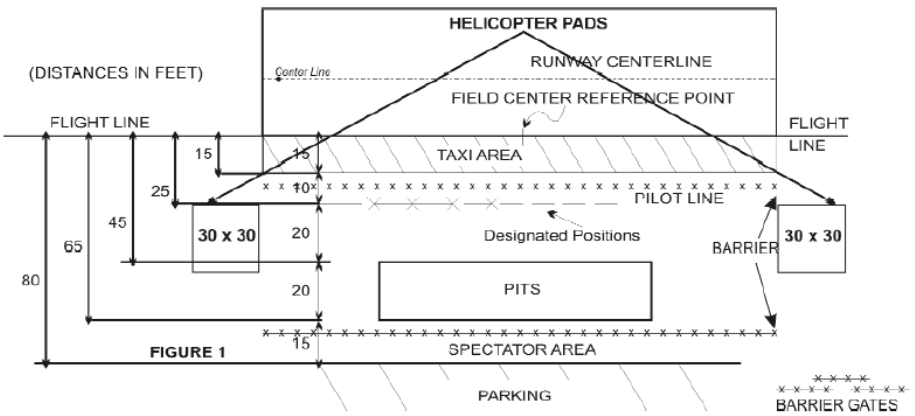

FIGURE 1

1.0 RISK ASSESSMENT AND MITIGATION

Detailed safety actions, training, and procedures are required to prevent injuries to test personnel. Due to the nature of this effort, specific detailed test procedures may change based on recent test experience, for specific measurement objectives, or to remedy urgent hazardous situations. Should modification of these specific safety plans be required, the Test Director (TD), with Safety Officer (SO) concurrence, has the authority to assess the test environment and implement modified test procedures in the field. All such modifications shall then be evaluated and this Risk Assessement plan may be revised to incorporate lessons learned. Thus, this risk assessment will anticipate hazards & mitigate their consequences and embody experience gained during tests. The TD and/or SO will evaluate the residual risk once the risk assessment has been completed to determine if the test can proceed.

2.0 SCOPE

These procedures apply to R/C and autonomous flight test operations of the SPAARO UAV carried out by Virginia Tech personnel at Kentland Airfield. Operations shall meet guidelines specified by current authorizations.

3.0 DEFINITIONS

3.1 Test Coordinator/Director (TD): The Test Director is primary supervisor for all tests. The TD must take any action not restricted by test rules to safeguard equipment & personnel. The TD has the responsibility to ensure that hazards have been appropriately mitigates and that operations are conducting safely. The TD has the authority to cancel any flight activity due to safety concerns.

3.2 Pilot (P): The Pilot manages the controls of a single UAV when operating in manual mode. The P must be proficient and may not be compelled to operate a vehicle in a manner which s/he believes is unsafe. Pilots are designated by the Test Director and/or the Safety Officer.

3.3 Ground Crew/Handler (GH): The Ground Crew/Handlers include individuals who support the experiment other than as UAV Pilots. Activities of GH's include telemetry data logging and processing, UAV preparation and maintenance, documentation, and logistics.

3.4 Safety Officer (SO): The Safety Officer advises the TD of any observed hazardous situations and suggests corrective actions.

4.0 SAFETY

4.1 Propeller Hazard – The propeller is driven by an IC engine. The potential impact zone for debris from propeller structural failure extends throughout the plane of the rotation disc and, to a lesser extent, forward and aft of the rotation disc.

4.1.1 Starting area will be cleared of personnel not associated with starting the UAV engine. The area will be clear of debris for 2 feet forward and to the sides and 5 feet aft the UAV prior to engine start.

4.1.2 Personnel in proximity to the engine during startup shall wear eye protection.

4.1.3 All test personnel/observers shall stay clear of a spinning propeller and shall at all times avoid standing in the plane of the propeller.

4.1.4 At the end of a flight, the Pilot will kill the engine after taxi back to a safe location. The Ground Handlers will verify the Ignition and receiver power switch is in the "OFF" position prior to handling or moving the UAV.

4.2 Personnel & Equipment Impact Potential - Aircraft loss of control represents an impact risk to test team and observers.

4.3.1 The AMA recommended flying site specifications will be used, as appropriate (subject to modification as approved by the Test Safety Officer)

4.3.2 Cars, trailers, tables etc should be positioned to serve as protective fencing, as appropriate.

5.0 UAV FLIGHT TESTING RULES

5.1 Personnel Protection

5.1.1 All ground test personnel not participating in the engine starting, launch or training for launch activities will remain in designated areas. TSOs are expected to observe this rule.

5.1.2 The Ground Handler shall wear eye protection (goggles or safety glasses). Due to the low noise level of these specific 4-stroke engines, the use of hearing protection is not required.

5.1.3 The wind speed seen by the R/C pilot will not exceed 15 mph as measured by a hand held windspeed gauge or 20 mph as measured by an anemometer mounted approximately 10 feet above the

ground. Flight operations are prohibited if gust magnitudes exceed 5 mph within a 30 second period.

5.1.4 The test team shall have ready access to a fire extinguisher and a first aid kit whenever flight operations are conducted.

5.1.5 The TSO will carry an operable cellular phone and/or range control radio during all flight operations. The TSO is responsible for verifying that these communication devices are fully charged and operational.

5.2 Test Commit Criteria

Flight test operations will be postponed or cease immediately for an evaluation/debugging period (to last at least 15 minutes) if:

5.2.1 Wind conditions exceed the following, determined either by a hand held wind gauge or a fixed anemometer:

5.2.1.1 Total wind speed greater that 15 mph as measured at 6 feet above the ground or 20 mph as measured 10 feet above the ground.

5.2.1.2 Wind in excess of 10 mph perpendicular to the planned landing or take-off direction.

5.2.1.3 Wind gusts in excess of 5 mph.

5.2.2 Inclement weather is imminent (precipitation or lightning observed within 10 miles)

5.2.3 Either the primary or secondary control transceiver fails to establish link during the pre-flight range check or during flight.

6.0 EMERGENCY PROCEDURES

6.1 Emergency contact information is given below:

All personnel shall remain vigilant to the safe conduct of operations. The contact information for emergency services and fire department shall be determined prior to flight operations.

Be prepared to provide critical information:

Caller's Name: _____

Location: _____

Building Name: _____

Building No: _____

Nature of the Emergency: _____

Name & Number of Victims: _____

Emergency Contacts and Phone Numbers:

_____

_____

_____

6.2 Personnel approaches a spinning propeller:

6.2.1 TD Calls “STOP ENGINE”.

6.2.2 P drops throttle control on the transmitter and trim slider to engine kill switch or activates the kill switch or other remote kill device.

6.2.3 All personnel help in securing medical attention, if necessary (see emergency contact information above).

6.3 UAV loses primary (900MHz) link in autonomous mode:

6.3.1 P calls “LOSS of LINK”

6.3.2 TD notifies all Team Members and Observers of situation.

6.3.3 Autopilot automatically directs aircraft toward base station.

6.3.4 If 900 MHz link is not re-established once UAV is within range for manual piloting, backup pilot takes control via secondary 72MHz manual control link.

6.3.5 P lands the UAV (in a remote location if necessary)

6.3.6 GH and TD safes UAV and engine.

6.3.7 GH and TD inspect for damage to UAV.

6.3.8 Testing is halted until UAV airworthiness and reliable 900MHz link are re-established.

6.4 UAV engine fails:

6.4.1 P calls “LOSS of ENGINE” or “DEADSTICK”

6.4.2 TD notifies all Team Members and Observers of situation.

6.4.3 P attempts to re-start engine in flight using electric starter.

6.4.4 If engine re-start fails, P switches UAV autopilot mode to “Return to Base Station.”

6.4.5 Once UAV is within range for manual piloting, P takes manual control and lands the aircraft (in a remote location if necessary)

6.4.6 GH and TD safes UAV and engine.

6.4.7 GH and TD inspect for damage to UAV.

6.4.8 Testing halted until UAV airworthiness and reliable engine performance are re-established.

6.5 UAV or component catches on fire

6.5.1 Person who first notices the fire calls “FIRE”.

6.5.2 All test personnel move 75 feet from UAV.

6.5.3 SO evaluates use of fire extinguisher and assigns closest person to the extinquisher (P, GH or TD) to extinguish the fire. (If the fire is from a lithium chemistry battery, sand will be used to extinguish the fire.)

6.5.4 If fire is uncontained, SO radios or calls fire department (see emergency contact information above) on cellular phone. SO is responsible to ensure that the fire department is inserted as a quick-dial number during all flight activities.