DOE Letter Head
Statement of Airworthiness

Department of Energy
Idaho Operations Office
1955 Fremont Avenue
Idaho Falls, ID 83415

Federal Aviation Administration
Unmanned Aircraft Program Office

SUBJECT: UAS Airworthiness Statement (TD&D-NS-09-012)

Ref: INL UA Certificate of Authorization Application 06/26/2009

Dear Sirs:

The Airworthiness Statement for the Scan Eagle UAS has been reviewed by the Idaho National Laboratory on behalf of the US Dept. of Energy, Idaho Operations Office, National Security Programs and has been determined to be airworthy to operate as specified in the referenced COA application subject to the restrictions included in the application.

Attached is the airworthiness evaluation summary.

Sincerely,

Don S. Michaelson

Don S. Michaelson
Program Manager

Attachment 4: Airworthiness Statement

Reference: FAA AIR-160 UAPO Guidance Document 08-01

The INL certifies that each unmanned aircraft system flown under this COA has been inspected in accordance with a process equivalent to a tailored application of the US Department of Defense Handbook Airworthiness Certification Criteria, MIL-HDBK-516B, dated 26 September 2006, and was determined to be in airworthy condition to conduct safe flight operations at the Idaho National Laboratory flight test area, within the operational and other constraints specified in this COA application.

The airframes are used as sensor platforms for R&D and are designed for limited life expectancy. All airframes, engine, communications links, autopilots, and ground control stations are well tested commercial-off-the-shelf grade. Under prior COAs the INL has flown hundreds of flights using these COTS systems, without injury, with acceptable mishap rates, and with well understood and tolerable failure modes and consequences.

An analysis of the minimum expected reliability, in terms of mean time between failure, and as a function of population density and civil aircraft operations frequency, was performed by Weibel & Hansman [1]. For the INL site, it shows that an MTBF of between one and 100 hours was adequate to meet a target level of safety of 10^{-7} fatalities / flight hr. Table 1 shows INL cumulative MTBF has been about just over three hours.

Therefore the INL has determined that current UAS systems are airworthy for their intended purposes and flight operations are safe and present extremely improbable risk of injury to the public.

General Approach to Demonstrating Airworthiness

The Idaho National Laboratory unmanned aircraft are purchased from commercial suppliers either as complete aircraft/communications systems/ground control systems ready-to-fly, or are purchased as collection of commercial subsystems and assembled for flight. In all cases, overall airworthiness is first established by combining a review of manufacturing design, performance, and flight testing and experience information, with INL UAS staff engineering judgment, coupled with thorough ground testing and preflight checks. All systems are adjudicated for safety using an INL defined independent hazard review (IHR) and job safety analysis (JSA) methodology. All teams members are involved, and each has full authority to stop operations at any time should a perception of safety deficit arise.

As a final step, airworthiness is demonstrated by using a flight testing phase for each new system that is similar in intent and scope to that suggested by the FAA for each manned experimental aircraft, as documented in FAA Advisory Circular 90-89[2]. Each UAS system undergoes a flight test phase to confirm vendor claims, demonstrate the system no hazardous operating characteristics, and the air vehicle is controllable throughout its normal range of speeds and maneuvers.

INL Flight Experience and Failures Roll-up

The INL has been flying UAS under prior COAs since 2003. The following table summarized flight time and failures by aircraft/engine type. Mean time between failure is the average number of flight hours without an failure of any kind. Flight times are cumulative from 2003 to July 2006.

Aircraft	Engine	# Flights	Total Flight Hours	# Engine Failures	# Auto Pilot/GPS Failures[1]	# TO mishaps	# Landing mishaps[2]	Lost Comms[3]	Battery Failure[4]	MTBF (hrs)
Xtra Easy 2[5]	OS 46	77	44.84	5	2	6	4	3	0	2.24
Mad max	OS 46	12	6.06	0	0	0	2	0	0	3.03
RnR APV3[6]	Fuji 86cc, OS 46	40	45.91	1	0	0	1	0	0	23.0
Manta 5[7]		18	12.51	1	0	6	3	0	0	1.14
Arcturus T15[8]	Honda GX31/GX50	42	54.54	0	6	0	4	1	5	3.41
Rascal		3	2.12	1	0	0	0	0	0	2.12
ALL	**ALL**	**192**	**165.98**	**8**	**8**	**12**	**14**	**4**	**5**	**3.25**

Table 1: INL flight log roll up 2003-2006

Takeoff and landing mishaps occur during pilot training and testing of various techniques and procedures, and are expected and acceptable. No airframe structural or flight control systems failures have occurred in flight (excepting the occasional hard landing), and the control surfaces and handling of the airframes have proven adequate in all flight regimes.

In-flight failures have occurred in engines (due to such causes as fuel line constrictions), spurious loss of command/control links, and to battery failure. In all cases where these failures occurred, the UA pilot was able to manually “dead stick” the UA to a controlled landing. Only one instance was seen where the command and control link failed for more than a few seconds, and in that case the UA, flying GPS based waypoint navigation, autonomously returned to its lost-communications waypoint and orbited until the flight crew was able to reestablish the control link.

1 More common during periods of poor satellite coverage - constellation coverage forecast is part of preflight planning. Several GPS dropouts found to be caused by on-board wireless 802.11x LAN.
2 Majority of landing mishaps counted were readily repairable such as propeller or servo replacement
3 Does not include momentary communications fade outs due to antenna masking during maneuvering
4 Most battery failures occurred during maximum duration flight tests, and thus were expected
5 Xtra Easy 2 is a recreational airframe used as a disposable initial trainer
6 Also sold by Lockheed Martin as the APV-3
7 The Manta 5 aircraft has been grounded due to high takeoff failure rate and poor flying qualities
8 Selected by Marine Corps to supply off-the-shelf concept demonstrator for a Tier II unmanned air vehicle (Aerospace Daily and Defense Report, October 26, 2006)

Additional flight data from 2007 for the T15 is summarized in Table 2 as reported to the FAA UA Manager per requirements of the special provisions of the existing INL COA.

Aircraft	Engine	# Flights	Total Flight Hours	# Engine Failures	# Auto Pilot/GPS Failures	# TO mishaps	# Landing mishaps	Lost Comms	Battery Failure	MTBF (hrs)
Arcturus T15	Honda GX50	28	40.1	0 preflight ignition switch replaced	0	1 – launcher shock absorber replaced	1 – propeller replaced	2 – ground station modem replaced	1 on-ground recharge failure	13.3

Table 2: INL T15 / 16 flight data for 2007

Note: MTBF (Mean time between failure) for this data is measuring the time between reportable incidences (i.e. communications interference) rather than equipment failure or loss of equipment. It is very rare for the INL to experience failures resulting in equipment loss with the current T15 flight configuration.

It is also notable that only one occasion was logged where the UA was evacuated from its current flight area upon the sighting of a small manned aircraft nearby (2 miles) and higher (about 1000 ft).

So with analogy to the Experimental Aircraft Certification process used for many manned aircraft, where airworthiness is demonstrated during a 25 to 40 hour flight test period, these UA have flown the equivalent and much more.

Tailoring of MIL-HDBK-516B

Tailoring of the MIL standard certification criteria in accordance with Section 1.2.1, “Tailoring to create the certification baseline” of MIL-HDBK-516B takes into account the trivial to minor consequences of system failure. INL UAVs are limited in weight, size, and performance characteristics, and fly over an isolated and access controlled surface test range, with continuous line-of-sight, and only in good visual conditions.

Each criterion in the handbook is identified as to its applicability or non-applicability, “considering system or product complexity, type, data, and intended use.” The rationale for addressing applicable criteria is documented, and applicable criteria are supplemented with specific measured parameters.

MIL-HDBK-516B Inapplicable Sections

Section	Topic	Reason for inapplicability
4.2	Tools and databases	No tools needed in requirements allocation
5.2	Structural Dynamics	Airspeed much too low for vibration/flutter
5.4	Damage Tolerance	Aircraft are designed for minimum life thus damage tolerance is not a requirement
5.5	Mass Properties	Proper c. g. location is measured before each flight
5.6	Flight Release	Included in each pre-flight check
6.2	Vehicle control functions	Does not apply – Only for manned aircraft
7.1	Propulsion safety management	Does not apply – Propulsion not safety critical
7.2	Gas turbine engine applications	Does not apply – No gas turbines used
8	Air Vehicle Systems	Does not apply – trivially simple/RC grade COTS subsystems
9	Crew systems	Does not apply – unmanned operation
12	Electrical System	Does not apply – trivially simple DC battery power
13	Electromagnetic Environment Effects	Does not apply – trivially low emissions and auto crash response to interference with avionics
14	Safety Program	Does not apply – No system is safety critical
17	Armaments/stores	Does not apply – none used
18	Passenger Safety	Does not apply – Unmanned aircraft

Table 3: Inapplicable Sections of MIL-HDBK-516B

MIL-HDBK-516B Applicable Sections

The following sections of the Handbook are judged applicable, and were satisfactorily established by the above airworthiness process.

4.1	Design Criteria	Addressed in COTS selection process
4.3	Materials Selection	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience
4.4	Manufacturing and quality	Addressed in COTS selection process, COTS acceptance examinations, ground tests, and preflight inspection
4.5	Operator’s and maintenance manuals	Addressed in COTS selection process, review of manufacturers data sheets & manuals, INL independent hazard reviews and job safety analyses
4.6	Configuration identification	Addressed in INL COTS equipment configuration management and maintenance records
4.7	Configuration status accounting	Addressed in INL COTS equipment configuration management and maintenance records
5.1	Loads	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience

5.3	Strength	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience
6.1	Stability and control, failure modes	Addressed in ground tests & flight test experience
6.3	Aerodynamics and performance	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience
7.3	Alternate propulsion systems	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience
10.1	Failure modes	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience
10.2	Operation	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience
11.1	Avionics architecture	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience
11.2	Avionics subsystems	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience
11.3	Avionics air vehicle installation	Addressed in in-house assembly, maintenance, and flight test experience
15.1	Air vehicle processing architecture	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience
15.2	Functional design integration of processing elements	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience
15.3	Subsystem/processing element	Addressed in COTS selection process and review of manufacturers data sheets and flight test experience
16.1	Maintenance manuals/checklists	Addressed in COTS selection process, in-house assembly & maintenance, independent hazard review and flight test experience
16.2	Inspection requirements	Addressed in COTS selection process, in-house assembly & maintenance, independent hazard review and flight test experience

Typical Airworthiness Flight Test Plan

As evidence of our airworthiness determination process, below is a core procedure used on new airframes, modifications to existing airframes, and inclusion of new payloads which may change UA flight characteristics.

The main features include:

- Extensive ground based simulations and tests will be performed prior to each flight test;
- The series of flight tests will provide gradual build up and verification of capabilities and fault-tolerance;
- Flight test plans for the later-phase tests/demonstrations will be further refined based on the results and lessons learned from the earlier-phase tests; and
- Excellent flight test facilities supported by proven flight test and safety procedure and experienced personnel.

Demonstrations of the UAV will be conducted at altitudes varying between 500 to 1000 feet above ground level in varying field conditions.

Flight tests will follow the same iterative spiral development of performing basic operations, building upon lessons learned, confirming test plan objectives via hardware-in-the-loop (HIL) simulations, and repeating as necessary to prove flight test readiness. Following is a general description of the proposed spiral flight test plans that successively build upon increased core capabilities.

All test flights will be performed at the Idaho National Laboratory UAV Research Park located about 45 miles west of Idaho Falls, Idaho and within the Department of Energy's 889 square mile site **Error! Reference source not found.**.

All flights will be conducted within visual observation (as required by the INL FAA COA). The autopilot ground control station will always remain active to provide additional risk mitigation.

The Principal Investigator (PI) will conduct pre-job briefings with the work group prior to the onset of testing activities. Risk and complexity of the testing activities will dictate the level and formality of the pre-job briefing. The briefing will address safety concerns, test limitations, site-specific housekeeping, and other test parameters deemed necessary by the PI. The PI is the point of contact for establishing and maintaining the schedule of range activities. All UAV activities will be conducted in accordance with the INL Management Control Procedure-1118 "Aviation and Notification Approvals" procedure and Independent Hazard Review 1096-05-NBA-NHL. This will require the UAV PI to notify the INL Range Director of scheduled activities by Tuesday of the prior week in order to have activities reported at the Plan-of-the-Week meetings. Additionally, the CFA Security official will be notified to coordinate activities with site security.

Base UAV Safety Check and Flight Worthiness Verification

Objective:

- Verify UAV flight worthiness with surrogate payload
- Verify flight communications
- Verify loss of communications and navigation fail-safes

Equipment:

- UAV & ground support equipment (safety pilot, fuel, starter, etc.)
- Ground control station & networked laptop to CDS team
- Surrogate payload (equal to weight and balance of camera payloads) with video down link
- Video Receiver with antennas and video monitors

Test 0-1

Perform Ground Preflight checks:

- Verify proper UAV operation (gyros, telemetry, CG check, etc.)
- Test UAV and video communications,
- Test interlocks including loss of communications and navigation,
- Test flight termination interlocks (various engine-kills)

Test 0-2

Verify UAV autonomous capabilities

- Perform pilot-in-the-loop controlled take-off
- Verify UAV telemetry received via ground control station
- Verify UAV flight stability under pilot-in-the-loop control
- Determine all conditions "go" for autonomous operations
- Transition UAV to autonomous control in "No-Comms" flight path

Note:

All tests from this point forward are conducted under line-of-sight operations of the UAV safety pilot. If at any time UAV operations are deemed unstable or unsafe, the safety pilot will resume pilot-in-the-loop control via the native ground control station and either stabilize the UAV or abort operations and land the UAV. The control architecture of the Cloud Cap Technology avionics always gives precedence to the pilot-in-the-loop control signals and all other command and control is overridden by the safety pilot.

Test 0-3

Verify UAV operations and video reception at areas of interest

- Transition UAV to flight paths at locations of interest
- Verify autonomous operations such as flight path modification, altitude and speed control, video reception, etc. at locations of interest
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Test 0-4

Return UAV to Base and land

- Exercise Return-to-Base (RTB) of UAV via ground station
- Initiate pilot-in-the-loop UAV landing

Incorporate lessons learned and repeat Test 0 as necessary until functionality achieved for all target UAVs.

In addition to the above test flight sequence, we use the following procedure for new, modified, or repaired aircraft in support of assessing airworthiness.

FIRST FLIGHT PREFLIGHT CHECKOUT TEST
FOR NEW AND
MODIFIED/REPAIRED AIRCRAFT

CONTROL SYSTEM:

( ) Determine ground range with transmitter antenna collapsed or ground station antenna removed and check range with all servos plugged in. If a reduction in range or erratic operation is noted - LONG servo wire lengths or a noisy servo maybe the culprit. Do not fly until this is corrected.

( ) Start the engine(s) and recheck the range with the engine(s) operating over the complete speed range. If any reduction of range is noted, the problem maybe engine ignition noise. This problem is historically cured through use of a completely shielded ignition system, including magneto coils, all associated wiring and switches, plus a resistor type spark plug. Resorting to complete shielding of all flight control equipment, including receiver, servos, battery packs, and associated wiring is sometimes required. Do not fly until you are confident of proper operation with the engine(s) operating. ANY reduction in range means a loss in signal/noise ratio and a chance of control loss in flight.

( ) Check servo operating for erratic performance, especially with the engine(s) operating. Be sure they operate smoothly throughout the entire control range. Apply hand load to surfaces while being moved by transmitter action to check for non-flexing of control cables/rods.

( ) Check the output of the control transmitter, preferably with an independent field-strength meter. Perform this check before each flight. Transmitter battery life MUST have been previously established by a discharge test, prior to first flight.

( ) If installed, check the function of the fail-safe system by turning off the transmitter and observing the results.

VEHICLE:

Thoroughly inspect the aircraft and components for assembly and for structural integrity.

( ) Inspect the wing and tail assembly for signs of structural failure.

( ) Examine all control surface hinging for design integrity.

( ) Examine servo mounting and retention screws or bolts.

( ) Examine all push rods and keepers.

( ) Be SURE there is no looseness or slop in the control components.

( ) Check the mounting provision for tightness and security of all components that are removable for transporting to and from the flying site.

( ) For modified aircraft, inspect fuselage for signs of potential failure or damage during previous flights or transporting.

( ) Check servo installation and be sure the servo arm retention screws are tight.

( ) Inspect receiver/servo wiring for integrity and see that all plugs connecting the components are taped or in some way protected from vibrating apart. Include battery pack plugs.

( ) Check to see that receiver antenna(s) are routed away from servos and directly away from the receiver area. (Vertical orientation of antenna is preferred for best performance)

( ) Check for NO STRAIN on antenna/receiver connection.

( ) Examine landing gear mounting and function. (Retract/steering)

( ) Examine fuel tank(s) installation for adequate support, isolation from vibration and ZERO leakage. Special care must be given to gasoline systems in view of the increased fire hazards involved.

ENGINE RUN-UPS:
( ) Exercise extreme caution when starting and operating engines. A starter is preferred to avoid hazards to the hands or body.

Securely restrain the vehicle. Do not allow ANYONE to be positioned in the plane of rotation of the propeller(s).

The use of safety glasses and other PPE is required per IHR 1124-05-CFA. Avoid loose clothing, transmitter straps, etc. that might engage the propeller.

( ) Always have a FIRE EXTINGUISHER and shovel available when operating gasoline engines.

( ) Start the engine(s) and check for proper idle.

( ) Be sure that the engine(s) operates at desired top end R.P.M. and does not sag with prolonged running, from inadequate cooling.

FIRST FLIGHT:
The vehicle shall be flown AWAY from people at anytime (other than landing and take-off). It must occupy airspace that will permit safe impact on loss of control. This infers function of the fail-safe system to a limited dispersion impact. Flight maneuvers shall not exceed the design limits of the vehicle. Flight velocity shall not exceed 115 knots. (132 MPH)

A "Flight Log" for each vehicle is required. The flight must be recorded in the log. Date, time, place, conditions, purpose and any other significant data should be included in each entry.

( ) First flights shall be relatively short in duration and be devoted to checking out the "trim" of the aircraft. This should include slow flight and stall characteristics to assist the pilot with first landings. Control limits, roll rates, climb rates and glide rates should also be included.

References

[1] Roland Weibel and R. John Hansman, "Safety Considerations for Operation of Unmanned Aerial Vehicles in the National Airspace System," MIT International Center for Air transportation, Report ICAT-2005-1, March 2005; p 71, Figure 22. "Tactical UAV Reliability Required to Meet a Target Level of Safety of 10^{-7} fatalities / hr."

[2] US DOT FAA Advisory Circular 90-89A, 5/24/95, "Amateur Built Aircraft and Ultralight Flight Testing Handbook, AFS-340