Introduction

The Uglo 7 UA was certified using the procedure outlined in MIL-HDBK-516A as specified in Section 6.3.1 of AFS-400. Certification was performed by the Uglo 7 certification team led by Jack W. Langelaan. Section numbers in the Airworthiness document correspond to section numbers in MIL-HDBK-516A.

Airworthiness

4.   SYSTEMS ENGINEERING

4.1.   Design Criteria

The Uglo 7 UAS is based on radio controlled model airplanes. Uglo 7 will be flown in the same flight envelope as intended for the model airplanes, for which strength, stiffness, aeroelasticity, controls etc. have been verified.

4.2.   Tools and Databases

Since the Uglo 7 is structurally equivalent to existing radio controlled aircraft, standard tools used by Lehigh University Composites Lab are used to assemble and maintain the aircraft.

4.3.   Materials Selection

Materials used in the airframe were structural foams (Divinycell), waterjet cut to size and assembled using structural adhesives. These have been flight tested extensively. Parts such as servos, hinges, control rods, etc. are standard radio control items.

4.4.   Manufacturing, Support and Quality

Manufacturing and support of the Uglo 7 UAS will be done by Lehigh University Composites Lab members. The lab has the knowledge and expertise to meet quality requirements of RC aircraft.

4.5.   Operator's and Maintenance Manuals (technical orders)

Flight logs produced for each flight will have detailed descriptions of damage or failures. Physical inspection will be conducted prior to each flight. Maintenance will be conducted as needed.

4.6.   Configuration Identification

The functional baseline of the Uglo 7 UA is defined in the Piccolo SL documentation as provided by CloudCap Technologies. This documentation is applicable to small RC aircraft such as Uglo.

4.7.   Configuration Status Accounting

The Uglo 7 UA does not employ a CSA system as defined in Section 3 of MIL-HDBK-61.

5.   STRUCTURES

Modifications performed on the baseline airframe were to accommodate the Piccolo SL autopilot module and supporting electronics. These modifications do not affect structural integrity of the baseline airframe.

5.1.   Loads

MTOW of the Uglo 7 UA is 2 kg. Since the aircraft is battery powered load distribution will not change during flight. C.G. location will be checked prior to each flight. For the present aircraft, the maximum coefficient of lift is less than 0.5. The maximum sea level speed VNE is 30 m/s. The wing planform area is 60.91 dm^2. The maximum (limit) load factor is thus 8.6 G, obtained by stalling at VNE.

5.2. Strength

Structural integrity is verified by proof loading to limit loads x 1.5. Control surface movements are verified by tests under static limit loads x 1.5. This was accomplished using distributed weight on the airframe. Repairs will be conducted by Lehigh personnel who have experience in RC and composites construction.

5.3. Materials, Processes, Corrosion Prevention, NDE, and Repair

The composite materials used in the Uglo 7 UA are naturally corrosion resistant. Any repairs will be performed using components that are structurally equivalent or stronger than the originals. Repairs will be conducted by Lehigh personnel who have experience in RC and composites construction.

5.4. Damage Tolerance and Durability (Fatigue)

To mitigate the possibility of failure due to fatigue the Uglo 7 UA will be inspected prior to each flight for fatigue in critical components including wings, fuselage, fin, control surfaces and linkages.

5.5. Flight Operating Limits

A center of gravity range of +20 to -20 mm from the AC marking has been verified safe by flight tests. The UAS is battery operated and no change in CG location during flight is expected.

The flight envelope of the Uglo 7 UA will be kept within normal limits of RC aircraft.

5.6. Functionality

All flight control systems will be inspected and tested prior to each flight to ensure free operation without binding or deflection as required in 5.6.1.

5.7. Structural Dynamics

The aircraft has been verified to be free from flutter, divergence and other aeroelastic instabilities by flight tests. Dive speeds to XXX m/s have been performed.

The Uglo 7 does not have a rotor, thus sections 5.7.9-5.7.11 are ignored.

5.8. Mass Properties Interface

The aircraft will have one configuration and this will be checked prior to flight by weighing the aircraft and testing the CG location as required in 5.8.1. CG limits as prescribed above will be maintained. Weight will be checked using a scale after any change of the aircraft or its systems. CG location will be checked by physically balancing the aircraft prior to each flight. The allowable CG range is marked on the wings as required in 5.8.4. Since the aircraft is electrically powered there is no change in fuel weight over the flight as defined in 5.8.5.

5.9. Stores/armament interface

Uglo 7 has no armaments or stores.

5.10. Structural maintenance manuals (T.O.s)

Flight logs will be used to monitor damage.

5.11. Rotary Wing air vehicles

The Uglo 7 is not a rotary wing vehicle.

6.   FLIGHT TECHNOLOGY

6.1.   Stability and Control

Stability and control have been verified through flight tests. In particular:

- flight at and near stall (10 m/s IAS) at all CG locations

- flight at VNE (30 m/s IAS) at all CG locations

- control surface mis-trim on takeoff

- prevent or stop over-rotation in takeoff

- safe control and landing with engine stopped

- sufficient trim capability for all flight speeds from Vstall to VNE

- safe handling in turbulence, including mechanical turbulence near tree lines

The Piccolo SL autopilot module ensures stable flight characteristics when coupled with a stable aircraft such as the Uglo 7.

6.2.   Vehicle control functions (VCF)

The physical components of the VCF (i.e. the servos, control links, control surfaces, and electrical connections) are commercially available radio-control components. They are safe and provide the required level of control to fly the Uglo 7 UA. Thus there are two means of control: (1) autonomous flight via the Piccolo SL; (2) manual flight through the Piccolo SL. Pre-flight checklists for the Uglo 7 UA are used to minimize the risk of failure as per 6.2.2.36. The emergency procedures, as outline in [A-1], are appropriate and address the full range of possible emergencies as required in 6.2.55.

The power source for the motor and servos is separate from the power source for the Piccolo SL autopilot module. Ground tests have shown that the motor/servo battery is sufficient for 20 minutes operation and the autopilot battery is sufficient for 60 minutes operation.

There are no redundancies on this power system, but this is an acceptable risk for a UA of this size. Note that the loss of the VCF power system is the only single point of failure for the VCF. This will result in uncontrolled descent of the UA, however, due to the small size of the Uglo 7 UA (less than 2 kg) and unpowered aircraft stability this failure will result in minimal risk to persons or property, other than the Uglo 7 UA itself. The VCF software is provided commercially by CloudCap for the Piccolo SL autopilot. This software is extensively tested and is safe in all normal flight conditions. For emergency situations, the procedures used are outlined in [A-1].

6.3.   Aerodynamics

6.3.1.   Flight Vehicle

The Uglo 7 UA uses electric propulsion, so the weight of the fuel (battery) is constant throughout the flight and will be positioned such that the center of gravity is in the prescribed location. The Uglo 7 UA is hand launched so take-off field length is governed by the distance required to clear obstacles (e.g. trees). For landing, a 300ft. field is required for all possible atmospheric conditions. The Piccolo SL autopilot will have the ability to terminate the flight over the entire envelope using either autoland or aerodynamic termination. The procedures for this are described in greater detail in [A-1]. It was verified through flight tests that the Uglo 7 UA will have sufficient power throughout the range of possible weight and flight conditions.

6.3.2. Installed Propulsion Capability

The Uglo 7 UA employs the BP A2826-4 electric brushless motor for propulsion. All requirements in this section pertaining to fuel flow, inlet, and icing do not apply to an electric motor. The engine control system is a BP 60A Brushless Electronic Speed Controller. It was verified by flight tests along with static ground tests that this controller can handle the full range of throttle inputs.

6.3.3. Flight Limits

The flight limits for the Uglo 7 UA are within what is typically flown by RC pilots.

7. PROPULSION

7.1. Performance

The Uglo 7 UA employs the BP A2826-4 brushless electrical motor. The performance of this motor is sufficient for an aircraft of this size, and there is no performance degradation due to icing.

7.2. Operability

A positive stability margin exists over all critical flight conditions for the Uglo 7 UA.

7.3. Engine Structures

The Uglo 7 UA employs a small electrical motor, therefore most of the discussion in this section does not apply. The structure of the BP A2826-4 is not anticipated to have any issues. The motor will however be checked and tested on the ground prior to each flight, which is a sufficient maintenance schedule for this type of motor.

7.4. Engine control and accessory systems

The motor on the Uglo 7 UA is controlled through the BP 60A Brushless Electronic Speed Controller by the Piccolo SL autopilot system. This speed controller is sufficient for control over all possible flight regimes. Failure in the flight control system will result in a loss of propulsion. However, this is a normal occurrence for RC size aircraft, and the Uglo 7 UA pilots will be trained in landing the aircraft without motor power. Therefore a failure in the motor control system will not affect safe operation of the Uglo 7 UA as required in 7.4.5.

7.5. Engine monitoring system

The Uglo 7 UA will not be equipped with any engine monitoring systems. These are deemed unnecessary for such a small UA with an electrical motor.

7.6. Engine bearing and lubrication system

The BP A2826-4 is a small, commercial RC motor, and as such it is not necessary to monitor the bearing and lubrication system.

7.7. Engine installations compatibility

The engine of the Uglo 7 UA is mounted on the forward firewall. This is common for installation of electric motors on RC aircraft and it has been shown safe by flight tests over all flight regimes.

7.8. Failure modes

The only failure mode for the Uglo 7 UA propulsion system is loss of electrical power. This is a standard failure mode in RC aircraft, and the procedures are outlined in [A-1].

7.9. *Flight manual/procedures and limitations*

The Uglo 7 UA does not have a flight manual, but the pilots are experienced RC flyers who are aware of the propulsion limitations.

7.10. *Engine externals*

The wiring to the engine on the Uglo 7 UA is attached using bullet and Dean's connectors, which are standard connectors for RC aircraft. The engine on the Uglo 7 UA has no other externals.

7.11. *Engine computer resources*

The engine on the Uglo 7 UA does not utilize any computer resources.

7.12. *Propellers and associated subsystem components*

The propeller was selected after flight testing various propellers. The propeller as well as the attachment hardware are standard RC model aircraft items.

7.13. *Rotors and associated subsystem components*

The Uglo 7 UA is not equipped with a rotor.

8. *AIR VEHICLE SUBSYSTEMS*

Note, sections 8.1-8.3, 8.7, 8.10-8.12 of MIL-HDBK-516A are not applicable to the Uglo 7 UA because it does not utilize any hydraulic or pneumatic systems, there is no onboard EMS, there is no fuel system (propulsion is electrical), there will be no aerial re-fueling, and it is not a rotary wing aircraft.

8.1.

N/A

8.2.

N/A

8.3.

N/A

8.4. *Fire and hazard protection:*

The Uglo 7 UA is not equipped with any on-board fire monitoring or prevention systems. However, as per 8.4.19 the ground crew operating the Uglo 7 UA will be equipped with a fire extinguisher in the event of a post-crash or other ground fire.

8.5. *Landing gear and deceleration systems:*

The Uglo 7 is landed on its belly. This is common among RC aircraft. Hence sections 8.5.1 and 8.5.2 do not apply. Further, belly landing means that sections 8.5.3 through 8.5.11 do not apply.

Ground handling (section 8.5.12) is performed by ground crew carrying the UAV.

8.6. *Auxiliary/emergency power system(s) (APS/EPS)*

The Uglo 7 UA is not equipped with any APS or EPS systems.

8.7.

N/A

8.8. Propulsion Installations

The engine/air vehicle physical interface was verified to be safe through static ground tests at full throttle as required in 8.8.1. The current throttle setting is the only information required for the ground crew, and is available through the ground control station. The Uglo 7 UA will not be flown in rain or extreme temperatures, and the BP A2826-4 will be able to handle all operating weather conditions.

8.9. Mechanisms

The Uglo 7 does not have any mechanisms as outlined in section 8.9.

8.10.

N/A

8.11.

N/A

8.12.

N/A

9. CREW SYSTEMS

The Uglo 7 is unmanned, therefore there are no on-board crew systems. The ground control station consists of a laptop computer running CloudCap Technologies' proprietary ground station software.

10. DIAGNOSTIC SYSTEMS

10.1. Failure modes

All critical failure modes and the methods of detecting them are outlined in the emergency procedures document [A-1].

10.2. Operation

The diagnostics systems on the Uglo 7 UA are solely available through the Piccolo SL autopilot. These systems are specific to the operation of the autopilot. Diagnostics of other systems will either be done on the ground through physical inspection, or in the air using the pilot's knowledge of the behavior of RC aircraft. This diagnostic system will not induce failures in the Uglo 7 UA as required in 10.2.3.

11. AVIONICS

11.1. Avionics Architecture

The Uglo 7 UA employs the CloudCap Piccolo SL avionics system, a commercially available autopilot module. The number and types of sensors on the Piccolo SL are sufficient for safety-of-flight (SOF) as stated in 11.1.1. SOF can be maintained for failures in the autopilot or sensors by switching to manual mode and allowing the pilot to fly the Uglo 7 UA as an RC aircraft. Other Piccolo failures are discussed in the emergency procedures [A-1].

11.2. Avionics Subsystems

All necessary flight information is provided to the ground crew through the Piccolo Ground Control Station as required in 11.2.1. See [A-3] for the procedures used in the event of lost link. These procedures are sufficient to minimize the risk to persons and property.

11.3. Avionics air vehicle installation

The Piccolo SL autopilot is installed as outlined in the CloudCap installation manual, which is adequate for safety of flight.

12. ELECTRICAL SYSTEM

12.1. Electric power generation system

The Uglo 7 UA does not have a power generation system. Instead, separate batteries are employed for propulsion and avionics. Through ground tests and calculations it was found that the propulsion battery has a lifetime of 20 minutes and the avionics battery will last for 1 hour. This ensures sufficient power throughout a flight. All batteries will be fully charged and checked prior to flights. The Piccolo SL autopilot will monitor the power of both batteries throughout the flight and report this to the ground controller.

12.2. Electrical Wiring, including power distribution

The electrical wiring used throughout the Uglo 7 UA is appropriate to handle the required load, specifically the wiring used for the propulsion motor, and the control servos as required in 12.2.1 and 12.2.2. Power distribution on the Uglo 7 is done through XXX that uses Deans connectors which have been used for several years by the RC community. All circuitry on the Uglo 7 UA is properly isolated.

13. ELECTROMAGNETIC ENVIRONMENTAL EFFECTS

The E3 qualification of the Uglo 7 UAS is not guaranteed, however risks are mitigated in several ways. Prior to every flight, range tests are done on the 900MHz Piccolo SL control link to ensure that E3 effects are not degrading performance. Finally, received signal strength indication (RSSI) is available to the ground controller such that degradation in performance can be monitored during the flight. In the event of lost communication due to E3 effects the procedures outline in [A-2] will be followed.

14. SYSTEM SAFETY

14.1. System Safety Program

The system safety program of the Uglo 7 UA involves logs [A-4] to track all flight times, in-flight damage and repairs, inspections results, and modifications. Inspections will be done before and after every flight of the UA by the Uglo 7 UA team. The checklists for these inspections can be found in [A-5].

14.2. Safety Design Requirements

The Uglo 7 UA system was designed to maximize safety. Most possible failures are outlined in [A-1], [A-3], and [A-2] along with the procedures of how to respond to them.

14.3. Software Safety Program

The software used in the Uglo 7 UA is provided by CloudCap for the Piccolo SL autopilot. The Uglo 7 UA team will ensure this software is up to date. Also, new versions will be tested in the

Uglo 7 Hardware in the Loop simulator [A-6] prior to being implemented in the aircraft for flight. The software will not be modified by the Uglo 7 UA team.

15. COMPUTER RESOURCES

15.1. Air vehicle processing architecture

Given the closed nature of the autopilot there is no way for us to determine whether the proper levels of redundancy exist. However, given the autopilot system has been previously certified, we assume that proper redundancy does exist and proof has been documented by the Cloud Cap corporation.

The autopilot interfaces have been designed according to the aircraft integration guidelines provided by Cloud Cap.

The SOF software has been designed entirely by Cloud Cap Technologies. The SOF hardware created for the Uglo 7 consists of the interface between the battery and servo systems of the aircraft and the Autopilot. Measures appropriate for an aircraft of the Uglo 7 class have been followed for these hardware interfaces. This consists of both ensuring all connections are crimped rather than soldered, and that all interfaces have been effectively protected against the vibration environment encountered in flight.

For documentation regarding contingencies for PLOC refer to A-1.

Separate and independent power sources are provided for the propulsion system and servos and the autopilot module. This has been done to ensure control of the aircraft despite loss of propulsion power. The autopilot does not have a redundant battery system, but has been tested to ensure an appropriate margin of safety given specified operational durations.

Beyond redundant operations designed into the autopilot, all other systems are not redundant and any single failure will result in termination of flight.

Piccolo SL firmware is currently at Revision 2.1.2 and will only be upgraded in the event of a CloudCap recommended safety critical upgrade. If an upgrade is done, hardware in the loop tests will be performed to ensure safety of the system.

15.2. Functional design integration of processing elements

Parameters passed among SOF elements have been defined by Cloud Cap Technologies.

The aircraft will revert to fully autonomous mode in the event of certain failures (refer to A-1) and are therefore sufficient to preclude loss of flight due to certain failures.

Integration of all safety-critical elements is done according to procedures defined by Cloud Cap Technologies.

15.3. Subsystem/processing element

All elements in this section are defined by Cloud Cap Technologies.

16. MAINTENANCE

The Uglo 7 UA employs checklists and log files in lieu of maintenance manuals. See appendix [A-4] and [A-5] for a template of these.

17. ARMAMENT/STORES INTEGRATION

N/A

18. PASSENGER SAFETY

N/A

19. OTHER CONSIDERATIONS

The Uglo 7 carries no armaments, therefore this section does not apply.

The Uglo 7 is unmanned, therefore this section does not apply.

As per 19.1.2 the payload does not interfere with the avionics or communication link.