Designation: F3002 – 14a

Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems (sUAS)[1]

This standard is issued under the fixed designation F3002; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification is provided as a consensus standard in support of an application to a nation's governing aviation authority (GAA) for a permit to operate a small unmanned aircraft system (sUAS) for commercial or public use purposes.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F2910 Specification for Design, Construction, and Test of a Small Unmanned Aircraft System (sUAS)

F2911 Practice for Production Acceptance of a Small Unmanned Aircraft System (sUAS)

F3003 Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS)

2.2 *EN Standard:*[3]

EN 62262 Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)

2.3 *IEC Standard:*[3]

IEC 60529 Degrees of protection provided by enclosures (IP Code)

3. Terminology

3.1 *Definitions:*

3.1.1 *bit error rate detection, BER, n*—rate at which errors occur in a transmission system; applicable to any system that transmits data over a network of some form in which noise, interference, and phase jitter may cause degradation of the digital signal.

3.1.2 *command and control (C2) link(s), n*—safety-critical radio-frequency (RF) link(s) between the ground control station (GCS) and the unmanned aircraft (UA).

3.1.3 *C2 range, n*—distance between GCS and UA at which positive control of the UA can be maintained.

3.1.4 *downlink, n*—any RF link from UA to GCS.

3.1.5 *flight control system, FCS, n*—composed of system components intended to take GCS commands via a C2 link and control flight control surfaces and propulsion systems.

3.1.5.1 *Discussion*—The FCS may include autopilot functions, lost-link functions, fly-away protection functions, payload functions, and navigation functions. The FCS may be contained in one discrete component or multiple discrete components.

3.1.6 *fly away, n*—unintended flight outside of operational boundaries (altitude/airspeed/lateral) as the result of a failure of the control element or onboard systems, or both.

3.1.7 *fly-away protection system, n*—a system that will return the UA safely to the surface, or keep the UA within the intended operational area, when the C2 link between the pilot and the UA is lost.

3.1.8 *ground control station, GCS, n*—a land- or sea-based control center that provides the facilities for human control of UA.

3.1.9 *licensed band, n*—any frequency or range of frequencies in which transmission requires permission from a governing body (for example, the Federal Communications Commission [FCC]).

3.1.10 *link error, n*—degradation of the digital signal between the GCS and the UA that can be monitored by techniques including BER detection.

3.1.11 *link integrity, n*—acceptable rate of transactions completed with undetected error.

[1] This specification is under the jurisdiction of ASTM Committee F38 on Unmanned Aircraft Systems and is the direct responsibility of Subcommittee F38.01 on Airworthiness.

Current edition approved June 1, 2014. Published July 2014. Originally approved in 2014. Last previous edition approved in 2014 as F3002 – 14. DOI: 10.1520/F3002-14A.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.1.12 *link timeout, n*—time between the actual lost-link event being validated and the system initiating the lost-link procedure.

3.1.13 *lost link, n*—occurrence in which the pilot in command (PIC) has lost the ability to control positively the sUAS because of degradation, loss or interruption of the necessary control or monitoring link(s), or both.

3.1.14 *manufacturer, n*—entity responsible for assembly and integration of components and subsystems to create a safe operating sUAS.

3.1.15 *pilot in command, PIC, n*—the pilot responsible for the operation and safety of the UA during flight time.

3.1.16 *positive control, n*—a condition in which commanded changes in the UA flight path result in the expected maneuver(s) within an expected period of time.

3.1.17 *small unmanned aircraft system, sUAS, n*—composed of the small unmanned aircraft (sUA) and all required on-board subsystems, payload, control station, other required off-board subsystems, any required launch and recovery equipment, and C2 links between the sUA and the control station.

3.1.18 *unmanned aircraft, UA, n*—airborne portion of the sUAS.

3.1.19 *uplink, n*—any RF link from GCS to UA.

3.2 *Acronyms:*

3.2.1 *BER*—Bit Error Rate

3.2.2 *C2*—Command and Control

3.2.3 *FCC*—Federal Communications Commission

3.2.4 *FCS*—Flight Control Station

3.2.5 *GAA*—Governing Aviation Authority

3.2.6 *GCS*—Ground Control Station

3.2.7 *GPS*—Global Positioning System

3.2.8 *HMI*—Human/Machine Interface

3.2.9 *PIC*—Pilot in Command

3.2.10 *RF*—Radio Frequency

3.2.11 *RFI*—Radio Frequency Interference

3.2.12 *RX*—Receiver

3.2.13 *sUA*—Small Unmanned Aircraft

3.2.14 *sUAS*—Small Unmanned Aircraft System

3.2.15 *TX*—Transmitter

3.2.16 *UA*—Unmanned Aircraft

4. Applicability

4.1 This standard is written for all sUAS that are permitted to operate over a defined area and in airspace authorized by a nation's GAA. It is assumed that one or more visual observers will provide for the sense and avoid requirement to avoid collisions with other aircraft and that the maximum range and altitude at which the sUAS can be flown will be specified by the nation's GAA. Unless otherwise specified by a nation's GAA, this standard applies only to UA that have a maximum gross takeoff weight of 25 kg (55 lb) or less.

5. Functional Architecture

5.1 A high-level functional block diagram of the C2 system is presented in Fig. 1.

6. General Requirements

6.1 The following are general C2 requirements involving the system components listed below:

6.1.1 All C2 system and UA components shall minimize RFI so as not to degrade C2 link performance below acceptable levels.

6.1.2 All C2 system and UA components shall minimize RFI so as not to corrupt data transmitted or received over the C2 link.

6.1.3 All C2 system electronic components shall be protected from impacts that may occur during normal operation (an impact rating of EN 62262 IK06 is recommended).

6.1.4 All C2 system electronic components shall be protected from environmental conditions that may occur during normal operation.

6.1.5 All C2 electronic devices shall be labeled with power requirements.

6.1.6 The C2 system's antenna, associated RF connections and System Acceptance Test Report shall be furnished as part of the C2 system.

6.1.7 Signal and power connectors for C2 electronic devices shall provide self-locking or positive locking connectors to ensure continuity of power and signal transmission during normal operation.

6.1.8 The C2 system shall provide for mounting to a fixed surface using rigid or semi-rigid fasteners. (Non-rigid fasteners, such as strings, rubber bands, and glue, are not permitted for this purpose.)

7. C2 System Spectrum Requirements

7.1 Small UAS operations using unlicensed bands shall be conducted in accordance with applicable regulations.

7.2 Small UAS operations using a licensed band shall obtain approval to use that band from the appropriate governing agency.

8. C2 Link

8.1 *Functional Requirements*—The C2 link shall provide C2 link status to the UA FCS to allow the UA FCS to initiate lost-link logic when C2 link connectivity is lost.

8.2 *Performance Requirements:*

8.2.1 The rate of C2 link transactions completed with undetected error shall not exceed 0.001 %.

8.2.2 The C2 link shall be capable of transmitting the minimum set of data required by the GAA.

8.2.3 The C2 link shall be capable of receiving the minimum set of data required by the GAA.

8.2.4 The C2 link shall transmit all data that are safety critical as established by the manufacturer.

8.2.5 A loss of connectivity for longer than a maximum duration to be established by the country's GAA shall trigger a lost-link condition.

8.2.6 The C2 link shall prevent unauthorized ground control stations from pairing with or controlling the UA.

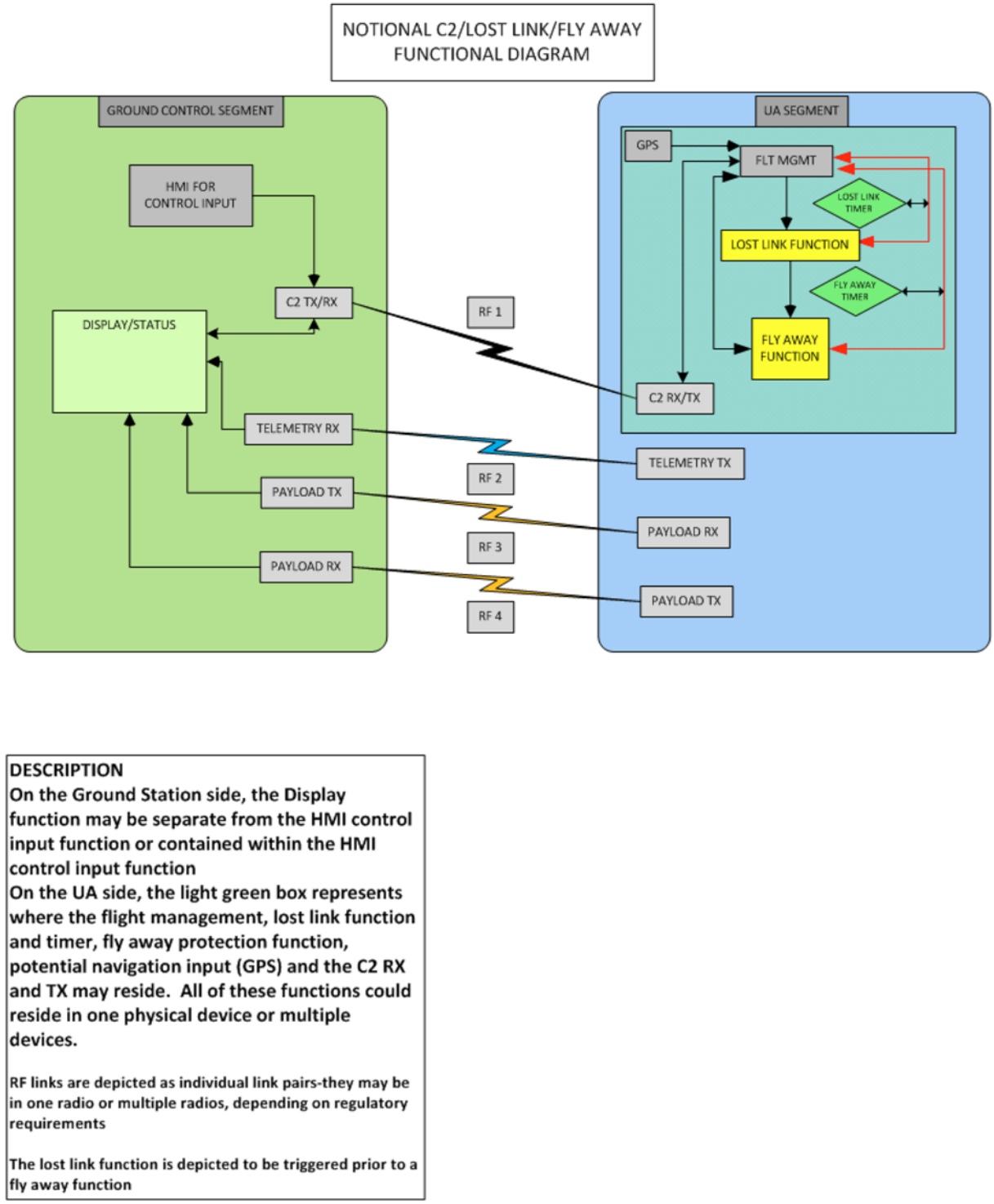

FIG. 1 High-Level Functional Block Diagram of the C2 System

8.2.7 The C2 link shall be rated by the manufacturer with maximum range.

8.2.8 C2 radios shall be labeled with operating frequency and channel information.

8.3 *Testing Requirements*—If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, the C2 link data integrity shall be monitored while C2 system elements are emitting RF and the GCS transmitter is operating at maximum transmission power.

9. GCS

9.1 *Operational Requirements:*

9.1.1 There shall be a means for verifying before flight that the fly-away protection system is capable of functioning properly during flight.

9.2 *Functional Requirements:*

9.2.1 If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, the GCS shall be capable of providing position and altitude data to the PIC.

9.2.2 If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, the GCS shall provide the capability to monitor the C2 uplink bit error rate.

9.2.3 If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, the GCS shall provide the capability to monitor the C2 downlink bit error rate.

9.2.4 If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, the GCS shall provide the capability to monitor link status.

9.2.5 If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, the GCS shall provide an alert to the PIC when a lost-link condition is entered.

9.2.6 If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, the GCS shall provide an alert to the PIC if the uplink or downlink message error rate exceeds 0.001.

9.2.7 If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, the GCS shall provide an alert to the PIC when an incompatibility is detected between the GCS and the systems with which it communicates.

9.2.8 If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, the GCS shall provide a lost-link condition status to the PIC.

9.2.9 A backup power supply capable of lasting long enough for a safe UA recovery shall be provided.

9.2.10 If warning lights are used, red shall signify a warning, yellow shall signify caution, and green shall signify satisfactory status.

9.2.11 If warning lights are used, a unique audible alarm tone consistent with the warning lights shall sound for a maximum of two seconds.

9.2.12 If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, displays of flight-critical information, including fuel level, battery status, and conformance with restrictions on airspeed, altitude, and lateral distance from the GCS, shall be made readily available to the PIC.

9.2.13 The GCS shall provide the capability of performing a reduced-range test to test link capability in situ.

9.3 *Interoperability Requirements:*

9.3.1 The GCS shall verify that it is configured to control the intended UA before flight.

9.4 *Design Requirements:*

9.4.1 If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, the GCS shall provide a visible indication of link status.

9.4.2 The GCS shall provide a manual or automatic means of interfacing a C2 link reduced-range attenuator between the C2 RF source and the link antenna.

9.4.3 The GCS shall provide a capability to test and measure the maximum RF output of the C2 link to and from the UA at a specified line-of-sight distance.

9.4.4 The GCS shall provide the operator an interface for interpreting the results of the C2 link reduced-range test.

9.4.5 The GCS shall prevent the PIC from launching the UA while the C2 link reduced-range attenuator is in use.

9.5 *Testing:*

9.5.1 The GCS transmitter maximum range value shall be tested.

9.5.2 The GCS receiver maximum range value shall be tested.

10. Unmanned Aircraft

10.1 *Operational Requirements:*

10.1.1 The responses to a lost-link condition shall include a combination of one or more of the following actions:

10.1.1.1 Landing the UA after the expiration of the C2 link timeout counter,

10.1.1.2 Returning the UA to the UA launch/takeoff location or some other previously designated location within the operation area,

10.1.1.3 Termination of the flight in a predictable manner after confirmation of lost link and the expiration of the C2 link timeout counter, or

10.1.1.4 Loitering within the operational area for a specified period of time before initiating one of the above three techniques.

10.2 *Functional Requirements:*

10.2.1 If a C2 downlink is required by the manufacturer for safety-of-flight or operational requirements, or both, the UA shall transmit position and altitude data to the PIC.

10.2.2 The UA shall record any occurrence of a lost-link condition.

10.2.3 The UA shall execute lost-link logic upon occurrence of a lost-link condition.

10.3 *Performance Requirements:*

10.3.1 The UA shall be capable of remaining in a contained area if one has been specified by the PIC.

10.4 *Interoperability Requirements:*

10.4.1 A C2 lost link shall not cause UA system failures.

10.4.2 The lost-link function shall be capable of executing after the C2 uplink capability fails.

10.4.3 The lost-link function shall be capable of executing after the C2 downlink capability (if one is required by the manufacturer for safety-of-flight or operational requirements, or both) fails.

10.5 *Design Requirements:*

10.5.1 The UA transmitter shall be labeled with operating frequency and channel information.

10.5.2 The UA receiver shall be labeled with operating frequency and channel information.

10.5.3 The UA antenna(s) shall be mounted such that the performance and functionality of the antenna are met regardless of UA attitude or orientation relative to the GCS.

10.6 *Testing:*

10.6.1 The UA transmitter maximum range value shall be tested.

10.6.2 The UA receiver maximum range value shall be tested.

11. Fly-Away Functionality

11.1 *Functional Requirements*—Any failure of fly-away functionality shall be recorded.

11.2 *Performance Requirements:*

11.2.1 The fly-away function shall be capable of executing after the C2 uplink capability fails.

11.2.2 The fly-away function shall be capable of executing after the C2 downlink capability (if one is required by the manufacturer for safety-of-flight or operational requirements, or both) fails.

12. Design Documentation and Change Requirements

12.1 Refer to Specification F2910, Practice F2911, and Specification F3003 for specific requirements on the following topics:

12.1.1 Quality assurance procedures,

12.1.2 Configuration control and documentation of changes, and

12.1.3 Verification and validation.

13. Keywords

13.1 permit; small unmanned aircraft system; sUAS