TERMS OF REFERENCE
RTCA Special Committee 228
Minimum Performance Standards for Unmanned Aircraft Systems
(Rev 5)

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<td>AUS</td>
<td>Earl Lawrence</td>
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</tbody>
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BACKGROUND:

Unmanned Aircraft Systems (UAS) have the potential to allow civil, public, commercial, and government agencies to increase efficiency, save money, enhance safety, and even save lives. A broad range of applications and services seek to integrate these platforms into non-segregated airspace.

In order to safely and seamlessly integrate these platforms into non-segregated airspace, both a robust Detect and Avoid (DAA) and robust and secure Command and Control (C2) Data Link capability need to be established.

The Federal Aviation Administration (FAA) established the Unmanned Aircraft Systems Integration Office to integrate Unmanned Aircraft Systems (UAS) safely and efficiently into the National Airspace System (NAS).
To achieve this objective, the UAS Integration Office and major UAS Stakeholders are working closely with the UAS community to develop the Minimum Operational Performance Standards (MOPS) for DAA equipment, with emphasis in an initial phase of standards development on civil UAS equipped to operate into Class A airspace under IFR flight rules. The Operational Environment for the MOPS in Phase One is the transitioning of a UAS to and from Class A or special use airspace, traversing Class D and E, and Class G airspace. The Operational Environment for the MOPS in Phase Two is extended UAS operations in Class D, E, and G, airspace, to include Part 91 operations in Class C/B airspace, down to but not including ground operations.

Moreover, the UAS Integration Office is working closely to with the UAS community to develop the MOPS for the C2 Data Link. An initial phase of standards development will provide standards for the C2 Data Link using L-Band Terrestrial and C-Band Terrestrial data links. A second phase of MOPS development will provide standards for the use of SATCOM in multiple bands as a C2 Data Link to support UAS. It will further address networking interoperability standards for both terrestrial and satellite systems as well as low power terrestrial C2 systems.

**DELIVERABLES:**

**PHASE ONE OF MOPS DEVELOPMENT**

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Due Date</th>
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<tbody>
<tr>
<td>DAA MOPS</td>
<td>This deliverable is the final Phase One DAA MOPS based on the results of the V &amp; V activities.</td>
<td>October 2016</td>
<td></td>
</tr>
<tr>
<td>Air-to-Air Radar MOPS</td>
<td>MOPS for an Air-to-Air Radar to support Phase One DAA MOPS</td>
<td>October 2016</td>
<td></td>
</tr>
<tr>
<td>C2 Data Link MOPS (Terrestrial)</td>
<td>This deliverable is the final Phase One C2 Data Link MOPS based on the results of the V &amp; V activities.</td>
<td>July 2016</td>
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### PHASE TWO OF MOPS DEVELOPMENT

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Due Date</th>
<th>Change</th>
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<tbody>
<tr>
<td>White Paper (see page 8 for a more detailed description of White Paper) for Phase Two DAA MOPS</td>
<td>This white paper defines the assumptions, envisioned approach, bounds of the approach, the core requirements for, and the approach to defining further requirements for UAS DAA Equipment to support UAS integration into the NAS.</td>
<td>July 2017</td>
<td></td>
</tr>
<tr>
<td>Ground-based Non-Cooperative Radar MOPS</td>
<td>MOPS for a ground-based non-cooperative radar to support the Phase Two DAA MOPS.</td>
<td>September 2019</td>
<td></td>
</tr>
<tr>
<td>DAA MOPS, DO-365, Rev A</td>
<td>Revision to the DAA MOPS that incorporates at least the Ground-based Non-Cooperative Radar MOPS including architectural considerations and operational concepts.</td>
<td>September 2019</td>
<td></td>
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<tr>
<td>Airborne EO/IR Sensor MOPS</td>
<td>MOPS for an alternative sensor to detect and track non-cooperative aircraft in support of the Phase Two DAA MOPS.</td>
<td>September 2020</td>
<td></td>
</tr>
<tr>
<td>Air-to-Air Radar MOPS, DO-366, Rev A</td>
<td>Revision to Airborne Radar MOPS (DO-366, Rev A) in support of the Phase Two DAA MOPS.</td>
<td>September 2020</td>
<td></td>
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<tr>
<td>DAA MOPS, DO-365, Rev B</td>
<td>Revision to the DAA MOPS that incorporates at least DO-366, Rev A including architectural considerations and operational concepts, as well as ACAS XU (SC-147).</td>
<td>September 2020</td>
<td></td>
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<tr>
<td>White Paper for Phase Two C2</td>
<td>This white paper defines the assumptions, envisioned approach, bounds of the approach, the core requirements, and the approach to defining further requirements for UAS C2 Systems to address SATCOM link and network applications for multiple access network systems for both SATCOM and terrestrial communication architectures.</td>
<td>July 2017</td>
<td></td>
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<tr>
<td>C2 Link Systems MASP</td>
<td>This MASP will provide system performance requirements for end-to-end C2 link systems. This material is specifically intended for delivery to ICAO to support their development of Standards and Recommended Practices (SARP) in preparation for World Radio Conference 2019. This will provide full analysis for (at a minimum) two Use Cases supporting industry near-term demand.</td>
<td>December 2018</td>
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<tr>
<td>C2 Link System MOPS (SATCOM)</td>
<td>This MOPS will provide system performance requirements for Ka technology based SATCOM based C2. This document is anticipated to lead to TSO for new functions of existing SATCOM terminals.</td>
<td>March 2019</td>
<td></td>
</tr>
<tr>
<td>C2 Link Systems MASP Rev A</td>
<td>This MASP will provide system performance requirements for end-to-end C2 link systems. Specifically, it will provide full analysis for all remaining Use Cases not provided in the initial release.</td>
<td>December 2019</td>
<td></td>
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<tr>
<td>C2 Link System MOPS (SATCOM) Rev A</td>
<td>This MOPS will provide system performance requirements for Ka / Ku technology based SATCOM based C2. The Ku material will be new and Ka will be updated (if required) from initial release.</td>
<td>March 2020</td>
<td></td>
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<tr>
<td>C2 Data Link MOPS (Terrestrial) Rev A</td>
<td>This revision to the C2 Data Link MOPS (Terrestrial) will address: 1) any required updates resulting from ongoing TACAN / DME compatibility testing, 2) any required updates to harmonized shared use of C band between terrestrial and SATCOM systems, 3) any required updates to augment the original point-to-point MOPS description to include multiple access techniques and 4) any other updates to clarify or correct shortcomings identified while the document is open for changes.</td>
<td>June 2020</td>
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**SCOPE:**

**Detect and Avoid MOPS – Phase One**

- The scope of DAA Working Group activities during Phase One of standards development will be to specify and validate UAS DAA Equipment performance requirements for civil UAS participating in the Operational Environment described above and performing the missions described above. In order to meet the schedules this Terms of Reference specifies, appropriate and continued focusing of DAA Working Group activities will be required.
- The Phase One DAA MOPS will be developed assuming that the requirements for UAS DAA operation while the UAS is in Class A airspace will be specified outside of the MOPS (e.g. through rulemaking) and is not part of this TOR.
- In developing the Phase One DAA MOPS, the DAA Working Group may consider, only if necessary to establish a satisfactory safety case for UAS operation, an allocation of DAA requirements between the UAS and the ground subsystem associated with the UAS.

**Detect and Avoid MOPS – Phase Two**

The focus of Phase Two activities for Detect and Avoid will be to develop performance standards for a broad range of civil UAS capable of operations Beyond Visual Line of Sight (BVLOS). These operations, at a minimum will take place in Class D, E and G, for the entire duration of a flight (i.e., extended operations) and will include Part 91 operations in Class C/B airspace. Three development efforts are envisioned for Phase Two and will be enumerated in the White Paper; MOPS for a ground-based sensor, MOPS for an airborne sensor, and an update to the DAA MOPS (Rev A and Rev B) to incorporate new technology and operational concepts. Below is additional guidance for consideration in developing the White Paper for DAA Phase Two:

- Geographically limited operations and operations within a terminal environment should be considered to include; Class D airspace, towered airfields within Class E airspace, non-towered airfields within Class E airspace, non-towered airfields within Class G airspace, Part 91 operations in Class C/B airspace, and off-airfield launch and recovery sites within Class G airspace. It is expected that this will lead to the development of MOPS for a ground-based non-cooperative radar.
- Technologies to enable UAS with less available Size, Weight, and Power (SWaP) should be considered. It is expected that this will lead to the development of a MOPS for a non-cooperative sensor.
- A collision avoidance capability that operates in the absence of a C2 Datalink will be included as part of a class of DAA equipment to support an airborne DAA architecture in order to remove the DAA dependency on the C2 Datalink.
• The White Paper should elaborate potential Visual Operations that could be enabled with a Phase Two DAA Capability. It is assumed that all UAS-DAA operations will be conducted under Instrument Flight Rules (IFR) to be flown on published procedures (i.e. SIDS, STARS and approaches). Approaches shall be limited to precision IFR straight in procedures (i.e. ILS, GLS). Visual approaches including “charted visual approach procedures”, arrivals and departures are not within scope of this TOR.

• Operations in other classes of airspace may be considered in the White Paper where the specific operations and the enabling DAA capability can be detailed.

• Very Low Level (VLL) operations, which includes operations exclusively below 500 ft AGL in any Class of Airspace (D, E, or G), are not within the scope of Phase Two DAA MOPS.

• Ground operations by UAS are not in scope of Phase Two DAA MOPS.

• In order to meet the schedules this Terms of Reference specifies, appropriate and continued focusing of DAA Working Group activities will be required.

SC-228 will work in close collaboration with SC-147 in the design, development and standardization of the Airborne Collision Avoidance System for UAS (ACAS XU). ACAS XU is considered a key enabler to achieving the full scope of the Phase Two DAA capabilities and to the full integration of all types of UAS into the NAS. An Inter-Special Committee Requirements Agreement (ISRA) will be established to facilitate the interoperability of Phase Two DAA equipment with ACAS XU.

The focus of the C2 data link will be to provide the command and control function as part of safe operations within the NAS. During a period of transition to the FAA’s digital voice switch network, a secondary capability will be included on the C2 Data Link for ATC voice communications relay. It is expected that this voice communications relay function will no longer be included in the C2 Data Link once the digital voice switch network is fielded in the NAS.

International Telecommunications Union (ITU) has identified multiple spectrum bands as candidates for use for this C2 Data Link. These include:

• L-Band Terrestrial
• C-Band Terrestrial
• SATCOM in multiple bands

For safe UAS flights in the NAS, there is the need to define, establish performance characteristics, and validate and verify the developed data link standards. Such efforts will confirm the need for such an allocation of the spectrum.

As the Phase One C2 Data Link MOPS will not contain requirements for SATCOM, UAS operations using the Phase One deliverables of SC-228 will involve having any use of satellite Data Link in those operations covered through bilateral agreements between the operator and the FAA.
In developing the Phase One C2 Data Link MOPS, the C2 Data Link Working Group should discuss in detail in its White Paper deliverable which Data Link protocol levels will be defined in the MOPS. It is not anticipated that application-level message formats will be specified (as opposed to how message payloads are framed).

Complete C2 systems engineering tasks:

- Develop system architectures / performance allocations to C2 architectures, with particular focus on how differing DAA allocations may impact required C2 performance. What are the differing performance levels for different DAA architectures? Specification of the performance levels to support the DAA Architecture of the Phase One DAA MOPS will be the top priority here.
- Evaluate / determine point-to-point and network C2 architectures that must be supported.
- Evaluate potential for sharing waveform structure between L band and C band solutions to reduce certification.
- Evaluate potential / value of simultaneous operation of L band and C band to improve system performance.
- Evaluate potential / value of physical integration of L band and C band into a common radio for SWAP advantage. Or do we have L band alone, and joint L band / C band variant? Small UAS may need L band alone, larger UAS will need both and might want a single LRU.

Determine preferred MOPS structure

- Determine if a single MOPS (with L band and C band unique characteristics in appendices) is preferable to the approach of two separate MOPS
- Determine the preferred approach for ground radio requirements – Included in airborne MOPS, a separate ground MOPS, or 2 ground MOPS (L band and C band), or in a form other than MOPS.

Complete MOPS

- Determine / document the frequency allocation scheme that is adequate to support anticipated system capacity and performance.
- Determine / document physical layer waveform requirements
- Determine / document network waveform requirements.
- Determine / document upper level services that need to be co-located in the C2 LRU.
- Determine / document external interfaces.
- Write performance verification.
C2 Data Link — Phase Two Activities

Phase Two activities are focused on extensions to point-to-point architectures addressed in Phase One to address Beyond-Radio-Line-of-Sight (BRLOS) applications and architectures. The primary focus as envisaged in the original Terms of Reference (TOR) is on Satellite Communication (SATCOM) architectures. This will include multiple bands of application, to include selected Ku and Ka sub-bands, and possibly C band allocations. Additionally, standards for network architectures and performance (SatCom and terrestrial based) may be developed. Finally, updates / refinements to C2 MOPS (Terrestrial) are anticipated to implement changes consistent with requirements from other standards developed during this phase.

Additionally, there is a need to address emerging requirements driven by changes in the UAS market needs and how they impact required C2 performance and implementation limitations. Specifically work done in Phase 1 (and foundational work by RTCA Special Committee 203) focused on larger aircraft, with operational sizing, anticipated size/weight/power (SWAP). There is a need to support smaller UAS, operating BRLOS, which have significant SWAP limitations and are anticipated to be deployed in larger numbers than considered previously.

C2 Data Link White Paper

The Phase Two C2 Data Link White Paper will address the following topics:

1. **Assumptions and boundary conditions in developing performance standards for Satellite Communications (SATCOM) C2 systems.** At World Radiocommunication Conference 2015 there were a number of fielded SATCOM systems in Ku and Ka bands identified as potential candidates for UAS SATCOM based C2. The White Paper would address performance considerations upon which to build a safe and efficient C2 system. Additionally, the Special Committee will assess progress toward fielding a proposed C Band UAS C2 constellation to determine if there is sufficient maturity within project timeline to include C Band in the standard. If so, this task would consider coordination strategies between Phase 1 and Phase 2 C2 MOPS (Terrestrial), as they share the same spectrum allocation with SATCOM in C Band.

2. **Assumptions and boundary conditions in developing performance standards for UAS C2 multiple access networks.** This task should span both potential communications architectures, SATCOM and terrestrial based. There are multiple potential use cases to be considered, to include: 1) multiple aircraft communicating through a common ground or satellite transmitter, and 2) single aircraft sequentially transiting through a series towers in a closed network through a series of tower handoffs.

3. **Concept of operations and operating environment description for smaller UAS operating at lower altitudes.** In recent years there has been rapid development of interest in commercial UAS operations with smaller UAS operating at lower altitudes than envisaged when the original SC-228 TOR was developed. This results in the need to
assess several key assumptions from earlier work of SC-228 and SC-203, to include: 1) greater aircraft densities per unit of area, 2) lower available power from the aircraft for radio transmission, and 3) potential to significantly reduce frequency planning radii due to lower altitudes of planned operations.

ENVISIONED USE OF DELIVERABLES

While SC-228 deliverables can be used by the UAS industry, the primary intent of these deliverables is for FAA (and potentially other civil aviation authorities) use in integrating UAS safely and efficiently into the NAS (or other civil airspace), with operational deployment of UAS with certified DAA and C2 Data Link equipment as soon after Phase One MOPS completion as is practical. It is the FAA’s intent to invoke the MOPS through Technical Standard Orders (TSOs) and Advisory material. The work efforts leading to these products are being informally coordinated with EUROCAE and the ICAO UAS Study Group, among other bodies, to facilitate harmonization.

SPECIFIC GUIDANCE:

The following provides specific guidance that should guide all work within SC-228:

- DAA and C2 Data Link recommendations and standards will be based on the premise that UAS will safely and seamlessly integrate into the NAS.
- The white papers provide initial insight into the work being performed to establish performance standards for integrating UAS into the NAS. Contents of the white papers should include the following:
  - Background
  - Scope of this RTCA Activity
  - What is addressed in this MOPS
  - What is not addressed in this MOPS
  - What are the assumptions of this MOPS
  - Establish a set of core operational requirements that can be referenced
  - What is the approach to developing the MOPS
  - What is the Safety Methodology that will validate the MOPS
  - What are further RTCA activities (if any) expected to occur after approval of this MOPS
  - MOPS development schedule
  - Resource requirements
  - Issues
  - List of dissenting opinions on white paper contents (if any)
- SC-228 will be provided UAS stakeholder guidance on an ongoing basis by an RTCA SC-228 Steering Committee. The Steering Committee will meet on a regular basis to review DAA and C2 MOPS progress and focus and to ensure, along with SC-228, that stakeholder priorities are being addressed. SC-228 should in particular consult frequently
with the Steering Committee while preparing the White Paper deliverables enumerated above.

- A work plan for SC-228, which will be coordinated with the SC-228 Steering Committee, will be established to ensure that requirements and performance needs are documented and coordinated between the C2 Data Link Working Group and the DAA Working Group (SC-228 might find the ISRA format helpful).
- The Working Group products will be developed using the RTCA MOPS Development Guidelines and considering as appropriate the methodology described in the RTCA MASP5/SPR development guidelines and the accelerated standards development methodology used by RTCA SC-186. The committee will conduct studies and analyses of current and planned capabilities of the NAS to evaluate and present various alternatives for use in development of future products.
- Without distracting from the Phase Two guidance above or delaying the schedule, SC-228 will coordinate with other RTCA special committees and stakeholder groups tasked with the development of enabling systems and technologies such as:
  - RTCA SC-147 and SC-186
  - EUROCAE WG 73 and WG 75
  - ICAO RPAS Panel
  - ASTM F-38
  - ISO TC-20
  - NATO Flight in Non-Segregated Airspace (FINAS) Working Group

SC-228 should review, in developing its deliverables, the following documents:

1) RTCA DO-320 - *Operational Services and Environmental Definition (OSED) for Unmanned Aircraft Systems*
2) FAA Concept of Operations for UAS
3) FAA UAS Road Map
4) DoD Concept of Operations for UAS – when available
5) UAS ARC Road Map
6) UAS ARC Recommendations for Small UAS
7) SC-203 DO-XXX – expected in June 2013
8) Change recommendations for FAR 91.113 -- when available
9) NextGen Unmanned Aircraft Systems Research, Development and Demonstration Roadmap (UAS RD&D Roadmap) Version 1.0. (JPDO)
10) UAS-related ICAO documents
11) UAS-related NATO documents
12) Small UAS documents from ASTM
13) UAS-related SAE documents

**TERMINATION:**

Special Committee 228 will terminate its activity when the Program Management Committee (PMC) approves the committee’s final document. Any change/extension of the committee’s work program requires prior PMC approval.