

**TERMS OF REFERENCE**  
**RTCA Special Committee 228**  
**Minimum Performance Standards for Unmanned Aircraft Systems**  
 (Rev 10)

**ORIGINAL REQUESTORS:**

Organization	Person
FAA UAS Integration Office	Jim Williams

**SPECIAL COMMITTEE LEADERSHIP:**

Position	Name	Affiliation	Telephone	email	Change
Co-Chair	John R. Moore	Collins Aerospace	319-295-5987	john.r.moore@collins.com	John Moore
Co-Chair	Brandon Suarez	General Atomics	858-524-8316	brandon.suarez@ga-asi.com	
Government Authorized Representative	Steve Van Trees	FAA/AIR-6B2	202-267-8546	stephen.vantrees@faa.gov	
Secretary	Christina Westover	Boeing Commercial Airplanes	425-422-1643	christina.m.westover@boeing.com	

**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.

- Phase One of standards development focused 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, E, and G airspace.
- Phase Two extends the Operational Environment is 1) extended UAS operations in Class D, E, and G, airspace, 2) take-off and landing operations in Class C, D, E, and G airspace, and 3) transit through Class B airspace. Ground operations remain out of scope.
- Phase Three will expand the supported operations of DAA equipment to address use cases that are applicable to smaller UAS as well as more specialized UAS. This includes use cases for 1) High Altitude Pseudo-Satellite launch and recovery operations, 2) smaller UAS platforms with more limited performance and operations closer to terrain/obstacles, 3) VTOL operations including Advanced Air Mobility (AAM), and 4) Part 135 cargo operations.

Moreover, the UAS Integration Office is working closely with the UAS community to develop the performance standards for the C2 Data Link.

- Phase One of standards development provided standards for the C2 Data Link using L-Band Terrestrial and C-Band Terrestrial data links.
- Phase Two provides 1) material regarding appropriate content for service level agreements between UAS operators and satellite operators, 2) UAS design and operational considerations for use of SATCOM, and 3) a unified methodology and example of a link budget to support applicants through certification and/or operational approval.
- Phase Three will include:
  - Updates to DO-362A. The document will 1) be harmonized with C-Band satcom usage internationally if required, 2) adjust requirements in response to lessons learned from initial implantations of DO-362A.
  - Update to DO-377A to incorporate new use cases including E above A airspace and any new requirements on the C2 link to support the new work on DAA standards
  - Consider new licensed bands that are made available for use for C2 Links. This includes but is not limited to Cellular Networks. This work will require a new MOPS modeled on the approach taken by SC-222 for SATCOM systems.

During Phase Two RTCA transitioned from being a Federal Advisory Committee to that of a Standards Development Organization. As such the FAA will no longer provide the primary direct tasking for this group as in the past. However, SC-228 will continue to coordinate closely with the FAA's UAS Integration office as they continue as a key stakeholder with a unique relationship to this work.

For Phase Three SC-228 will continue natural extensions to the DAA and C2 body of work as initiated by UAS Integration Office, as described above. Additionally, as DAA and C2 standards are reaching better maturity, SC-228 will expand our scope address several new topics that are of value to the UAS stakeholder community. These topics include new use cases, sensors, and data link topologies.

New work to be initiated in Phase Three is as follows:

- Lost Link (LL) Guidance Working Group established to create guidance material that will regularize the lost link behavior of UAS operating in controlled airspace. This tasking addresses Recommendation Two from the Unmanned Aircraft System (UAS) Controlled Airspace Aviation Rulemaking Committee (ARC) dated 30 May 2019.
- Navigation Standards (NS) Working Group established to enable GNSS-based UAS operations to meet navigation requirements for all phases of flight without the use of legacy ground-based navigation aids, including precision approach capability with auto-takeoff and autoland features. This tasking addresses Recommendation Five from the Unmanned Aircraft System (UAS) Controlled Airspace Aviation Rulemaking Committee (ARC) dated 30 May 2019.

## **DELIVERABLES:**

### **PHASE ONE**

Phase One is complete. The following documents were the products of this phase:

WP-1 Detect and Avoid (DAA) White Paper, Issued 03-18-14

WP-2 Command and Control (C2) Data Link White Paper, Issued 03-18-14

DO-362 Command and Control (C2) Data Link Minimum Operational Performance Standards (MOPS) (Terrestrial), Issued 09-22-16

DO-365 Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) Systems, Issued 05-31-17

DO-366 Minimum Operational Performance Standards (MOPS) for Air-to-Air Radar for Traffic Surveillance, Issued 05-31-17

**PHASE TWO**

Phase two is currently in progress. The following documents have already been released as of the date of this TOR:

WP-3 Detect and Avoid (DAA) White Paper Phase 2, Issued 09-21-17

WP-4 Command and Control (C2) Data Link White Paper Phase 2, Issued 09-21-17

DO-377 Minimum Aviation System Performance Standards for C2 Link Systems Supporting Operations of Unmanned Aircraft Systems in U.S. Airspace, Issued 03-21-19

DO-365A Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) Systems, Issued 03-26-20

DO-381 Minimum Operational Performance Standards (MOPS) for Ground Based Surveillance Systems (GBSS) for Traffic Surveillance, Issued 03-26-20

<b>Product</b>	<b>Description</b>	<b>FRAC Completion Due Date*</b>	<b>Change</b>
<b>Air-to-Air Radar MOPS (DO-366A)</b>	Revision to Airborne Radar MOPS (DO-366, Rev A) in support of the Phase Two DAA MOPS.	<b>July 2020</b>	
<b>DAA MOPS (DO-365B)</b>	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).	<b>October 2020</b>	
<b>C2 Data Link MOPS (Terrestrial) (DO-362A)</b>	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.	<b>July 2021</b>	<b>July 2020</b>

<b>Airborne EO/IR Sensor MOPS</b>	MOPS for an alternative sensor to detect and track non-cooperative aircraft in support of the Phase Two DAA MOPS.	<b>January 2021</b>	
<b>C2 Link Systems MASPS Rev A (DO-377A)</b>	This MASPS will provide system performance requirements for end-to-end C2 link systems. Specifically, it will provide full analysis for all remaining scenarios not provided in the initial release. This document will also provide system performance requirements for Ku and Ka band SATCOM based C2 Link Systems. It will contain material on service level agreements as well as methodology and example(s) for link budget analysis	<b>April 2021</b>	<b>October 2020</b>

**PHASE THREE**

Product	Description	FRAC Completion Due Date*	Change
<b>Guidance Material &amp; Considerations for UAS (DO-304A)</b>	This guidance material summarizes the operational use case / scenarios to be used by all the working groups in conducting Phase Three.	<b>April 2021</b>	
<b>GBSS MOPS (DO-381A)</b>	Revision to include a class of reduced performance consistent with en route DWC requirements.	<b>April 2021</b>	
<b>GM for Lost C2 Link UAS Behavior</b>	Guidance material that will regularize the lost link behavior of UAS operating in controlled airspace.	<b>April 2022</b>	
<b>GM for UAS Navigation Systems</b>	Create standard equivalent level of safety guidance material for Part 91 operations under IFR.	<b>April 2022</b>	
<b>C2 Link MOPS (Terrestrial) (DO-362B)</b>	Incorporate changes required to harmonize SATCOM compatibility with EUROCAE Standard. Updates required as a result on initial implementation of A revision.	<b>July 2022</b>	
<b>DAA MOPS (DO-365C)</b>	Future revision of the DAA MOPS to accommodate new functionality from completed SPR and/or OSED material.	<b>October 2022</b>	
<b>C2 Link MOPS for LTE Networks</b>	Create standard for use of LTE commercial networks for C2 Links used for type certificated UAS.	<b>January 2023</b>	

<p><b>C2 Link Systems MASPS (DO-377B)</b></p>	<p>Incorporate needed revisions from DAA system changes/additions. Address safety risk requirements for operations in Class E above A airspace and operations on the surface at public use airports.</p>	<p><b>April 2023</b></p>	
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\*Note: Final Review and Comment (FRAC) Completion Due Date refers to the date that the committee plenary approves the document after completing the FRAC Process. SCs should submit the final document at least 45 days before the Program Management Committee (PMC) meeting where it will be considered for approval.

**SCOPE:**

Detect and Avoid MOPS – Phase One – Completed July 2016

- 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 take-off and landing operations in Class C, D, E, and G airspace, as well as transit through Class B airspace. Three development efforts are envisioned for Phase Two are 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 used 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, take-off and landing operations in Class C, D, E, and G airspace, transit through Class 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 elaborated 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 were 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.

### Detect and Avoid MOPS – Phase Three

Phase Three activities are focused on developing DAA capabilities that address more specialized UAS operations that require more tailored performance or constrained guidance. These operations are expected to take place in all classes of airspace with the exception of surface operations and Class E above A which remain out of scope. These operations are expected to address the following use cases but will be prioritized according to community needs and support.

- Smaller UAS operations that occur at slower speeds and closer to terrain and obstacles. The expectation is that the guidance may need to be constrained by airspace restrictions and terrain and obstacle concerns.
- High Altitude Pseudo-Satellite launch and recovery operations. This functionality will be limited to the transition to/from Class E above A. It is expected that there will be a separate layer of separation automation employed in Class E above A that will be developed outside of the scope of SC-228.
- VTOL operations including the AAM use case. These aircraft are capable of different maneuvers and make approaches to different environments than addressed by the Phase 2

activity. It is expected that guidance may need to be tailored for the approach and departure phase of these vehicles.

- Part 135 cargo operations. It is expected that the existing functionality will support this use case, however, detailed operations were not investigated during Phase 2 OSED development. Phase 3 OSED development will further develop the concept and capture any changes needed.

DO-365B will be revised to incorporate any modifications necessary to accommodate minor changes to Phase I and II functionalities in support of these new use cases. Major functions (e.g. ACAS sXu) will be captured in new documents.

DO-381 will be revised to add a class of performance to support en-route DWC operations that is less stringent than the performance needed in the terminal environment.

#### C2 Datalink – Phase One – Completed July 2016

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 does 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 discussed in detail in its White Paper deliverable which Data Link protocol levels will be defined in the MOPS. Application-level message formats will be specified (as opposed to how message payloads are framed).



### 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 — Phase Three Activities

Phase Three activities are focused on creating a standard for use of LTE commercial networks for C2 Links used for type certificated UAS as part of a new standalone MOPS. This MOPS would be modeled on the SC-228 SATOM documents that consider the installed base of an existing communications system and address the safety requirements for its use as a C2 Link System. Additional frequency bands proposed for use could be added to the new MOPS structure if support from avionics companies and the network provider obtain approval from the PMC to increase the scope beyond generic LTE/5G services.

#### Updates to DO-362A

- Incorporate changes required to harmonize SATCOM compatibility with EUROCAE Standard.
- Add additional C-band waveforms as presented by proponents who bring resources to validate those proposed waveforms.
- Updates required as a result on initial implementation of A revision.

#### Updates to DO-377A

- Incorporate needed revisions from DAA system changes/additions.
- Address safety risk requirements for operations in Class E above A airspace and operations on the surface at public use airports.
- If additional scope is added by the Ad Hoc team (e.g. C2 Link Systems supporting AAM or small package delivery) the deadline would be assessed and adjusted if necessary, with consent of the PMC.

#### New C2 Scope

- Create standard for use of LTE commercial networks for C2 Links used for type certificated UAS.

### Lost Link Standards

This will begin by standing up a new working group for this new scope after completion of initial plenary level guidance material work. This group will have a stronger operational focus than our other groups. Key stakeholders include, but not limited to:

- Air Traffic Organization (ATO) Procedures
- National Air Traffic Controllers Association (NATCA)
- Current UAS Operator (Department of Homeland Security, CPB, or Air Guard)
- Flight Standards representative assigned to FAA UAS Integration Office support
- Air Line Pilots Association (ALPA)
- Current UAS OEMs
- European Union Aviation Safety Agency (EASA)
- EUROCONTROL

### Guidance Material for Lost Link Behavior of UAS

- Create guidance material that will regularize the lost link behavior of UAS operating in controlled airspace. This tasking addresses Recommendation Two from the Unmanned Aircraft System (UAS) Controlled Airspace Aviation Rulemaking Committee (ARC) dated 30 May 2019. This activity will have a more directed operational focus than many RTCA technical standards. Strong involvement from FAA Air Traffic Organization, air traffic controllers, non-UAS airspace users and related activities will be the key to timely progress.

### Navigation Standards for UAS

This will begin by standing up a new working group for this new scope after completion of initial plenary level guidance material work. This work will have a more technical focus than lost link activity, but there are some key stakeholders beyond the navigation technical community include, but are not limited to:

- FAA Flight Standards or Air Traffic Organization representatives responsible for Part 91 navigation regulation.
- FAA Aircraft Certification
- European Union Aviation Safety Agency (EASA)
- EUROCONTROL

### Guidance Material for UAS Navigation Systems

- Navigation Standards Working Group established to enable GNSS-based UAS operations to meet navigation requirements for all phases of flight without the use of legacy ground-based navigation aids, including precision approach capability with auto-takeoff and autoland features. This tasking addresses Recommendation Five from the Unmanned Aircraft System (UAS) Controlled Airspace Aviation Rulemaking Committee (ARC) dated 30 May 2019. This will include creation of a standard approach to evaluate equivalent level of safety for Part 91 operations under Instrument Flight Rules (IFR) for all phases of

flight. This activity will also identify and recommend changes to existing RTCA MASPS and MOPS that address navigation system standards that are not consistent with the UAS Navigation Guidance Material, which may address specific technical areas: e.g., Anti-Jam, Anti-Spoof, Inertial coupling

### Operational Use Case / Scenario Baseline Ad Hoc

To initiate the Phase Three activities SC-228 will stand up an ad hoc working group of stakeholders with a focus on the operational framework for setting the foundation for the two new working groups. Some key characteristics of this group:

- Will be chaired by the SC-228 Plenary Co-Chairs.
- Will include representatives from FAA Air Traffic Organization, air traffic controllers, airspace user community, and related operational organizations.
- Will include some members across the current standing working groups to seed the initial Phase Three activity.

### Guidance Material & Considerations for UAS

- Create a normalized set of use cases for use across the Special Committee in Phase Three. These are expected to include (but are not limited to): 1) High Altitude Pseudo-Satellite (HAPS) UAS, 2) Linear Infrastructure Survey / Low Altitude, 3) UAS Cargo Operations Under Part 135 and 4) Advanced Air Mobility / Vertical Takeoff and Landing (VTOL) UAS.
- This document will be a major update of DO-304 Guidance Material to reflect the current state of UAS operations. The focus of this revision will be use cases / scenarios, with less emphasis on the functional decomposition and related work in the original document.

## **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 equipment as soon 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 ICAORPAS Panel, among other bodies, to facilitate harmonization.

## **SPECIFIC GUIDANCE:**

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

- SC-228 recommendations and standards will be based on the premise that UAS will safely and seamlessly integrate into the NAS.
- The Working Group products will be developed using the RTCA MOPS Development Guidelines and considering as appropriate the methodology described in the RTCA MASPS/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 and Three 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, SC-159, SC-186, and SC-227
  - EUROCAE WG 75 and WG-105
  - ICAO RPAS Panel
  - ASTM F-38
  - ISO TC-20
  - NATO Flight in Non-Segregated Airspace (FINAS) Working Group

#### **TERMINATION:**

When the scope of this Terms of Reference is complete, the committee will recommend to the PMC that the committee Sunset, go into Active Monitoring Mode, or spend a period of time in Hiatus. Any change/extension of the committee's work program requires prior PMC approval.