

TERMS OF REFERENCE
RTCA Special Committee 228
Minimum Performance Standards for Uncrewed Aircraft Systems
 (Rev 17)

ORIGINAL REQUESTORS:

Organization	Person
FAA UAS Integration Office	Jim Williams

SPECIAL COMMITTEE LEADERSHIP:

Position	Name	Affiliation	Telephone	email	Change
Co-Chair	Jim Williams	Aura Network Systems	703 439-9648	jwilliams@auranetworksystems.com>	Affiliation
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Secretary	Greg Moran	The Boeing Company	425-234-5012	greg.moran@boeing.com	Katie Edwards

BACKGROUND:

Uncrewed 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 Uncrewed 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 extended the Operational Environment to 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 as well as continuing to expand the operational environments. 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) Advanced Air Mobility (AAM), 4) Part 135 cargo operations, and 5) operations on the surface.

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 implementations of DO-362A.
 - Update to DO-377A to incorporate new use cases including air taxi, surface operation at public use airports, and low altitude small package delivery.
 - 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 to address several new topics that are of value to the UAS stakeholder community. These topics include new use cases, sensors, and data link topologies.

Two new working groups were initiated in Phase Three is as follows:

- Lost Link (LL) Guidance Working Group was established to create guidance material that will regularize the lost link behavior of UAS operating in controlled airspace.
- Navigation Standards (NS) Working Group was established to develop navigation standards to enable seamless UAS operation in the NAS.

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

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

DO-365B Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) Systems, Issued 03-18-21

DO-365B Supplement Truth Track and Degraded Sensor Track Files Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) Systems, Issued 03-18-21

DO-304A Guidance Material and Considerations for Unmanned Aircraft Systems, Issued 06-17-21

DO-387 Minimum Operational Performance Standards (MOPS) for Electro-Optical/Infrared (EO/IR) Sensors System for Traffic Surveillance, Issued 06-17-21

DO-377A Minimum Aviation System Performance Standards for C2 Link Systems Supporting Operations of Unmanned Aircraft Systems in U.S. Airspace, Issued 09-17-21

DO-366A Minimum Operational Performance Standards (MOPS) for Air-to-Air Radar for Traffic Surveillance, Issued 09-10-20

PHASE THREE

The following documents have been completed in phase three:

DO-365C Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) Systems, Issued 09-15-22

DO-397 Guidance Material: Navigation Gaps for Unmanned Aircraft Systems, Issued 09-15-22

DO-398 Operational Services and Environment Definition (OSED) for Unmanned Aircraft Systems Detect and Avoid Systems (DAA), Issued 09-15-22

DO-387 Change 1 MOPS for Electro-Infrared (EO/IR) Sensor Systems for Traffic Surveillance, Issued 11-01-22

DO-381A MOPS for GBSS for Traffic Surveillance, Issued 12-14-23

DO-400 Guidance Material: Lost C2 Link Procedures for Uncrewed Aircraft Systems, Issued 06-22-23

The following documents are currently under development in phase three:

Product	Description	FRAC Completion Due Date*	Change
C2 Link Systems MASPS (DO-377B)	Address safety risk and performance requirements for air taxi, surface operation at public use airports, and low altitude small package delivery.	October 2023	
C2 Link MOPS for Cellular Networks (DO-YYY)	Create a joint standard with EUROCAE WG-105 for use of Cellular commercial networks for C2 Links used for type certificated UAS.	January 2024	
UHF Band C2 Link System MOPS (DO-XXX)	Create a standard for use of UHF spectrum band for C2 Links used in type certificated UAS.	January 2024	
DAA OSED (DO-398A)	Update DAA OSED to include ACAS Xr use cases and associated material.	January 2024	
DAA Radar MOPS Update (DO-366B)	Update DAA radar requirements for ACAS Xr and Xu, as well as additional clarity improvements	July 2024	New
C2 Link MOPS (Terrestrial) (DO-362B)	Incorporate changes required to harmonize SATCOM compatibility with EUROCAE Standard. Updates required as a result on initial implementation of A revision.	October 2024	
DAA MOPS (DO-365D)	Future revision of the DAA MOPS to add a class of equipment for ACAS Xr.	April 2025	
RTCA Report (RR) for Users of DO-377B for Deriving C2 Link System Requirements	Address the concerns about the definition of availability and continuity raised in DO-377B FRAC and describe methods that can be used by UAS OEM, UAS operators and C2CSPs (Command and Control Link Communication Service Providers) when deriving C2 Link System Quality of Service Requirements from DO-377B	April 2025	New
MASPS for DAA Supporting Taxi Operations (DO-WWW)	This document will capture guidance and requirements for DAA equipment to facilitate operations of UAS on the surface.	July 2025	
MASPS: Navigation for Automatic Taxi (DO-VVV)	Define navigation performance requirements to support automatic taxi operations.	July 2025	

*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 AND COORDINATION:

Detect and Avoid MOPS – Phase One – Completed July 2016

- The scope of the DAA Working Group activities during Phase One of standards development was 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.
- The Phase One DAA MOPS was developed assuming that the requirements for UAS DAA operation while the UAS is in Class A airspace would be specified outside of the MOPS (e.g., through rulemaking) and was excluded from the TOR.
- In developing the Phase One DAA MOPS, the DAA Working Group was given latitude to 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 was 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 take place in Class D, E and G, for the entire duration of a flight (i.e., extended operations) and 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 were envisioned for Phase Two as 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) and ATAR MOPS (Rev A) 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. This led to the development of MOPS for a ground-based non-cooperative sensor system, RTCA DO-381.
- Technologies to enable UAS with less available Size, Weight, and Power (SWaP) should be considered. This led to the development of a MOPS for a non-cooperative EO/IR sensor, RTCA DO-387.
- 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. This resulted in an Appendix to RTCA DO-365 of guidance material for automating collision avoidance maneuvers.
- 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 were detailed
- Very Low Level (VLL) operations, which includes operations exclusively below 500 ft AGL in any Class of Airspace (D, E, or G), were not within the scope of Phase Two DAA MOPS
- Ground operations by UAS were not in scope of Phase Two DAA MOPS.

SC-228 worked 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.

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 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.
- 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 was 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-365C will be revised to Rev D to add a class of equipment for ACAS Xr.

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

DO-366A will be revised to Rev B to include new radar requirements for ACAS Xr and to introduce material related to how a manufacturer can reduce the required radar performance for more capable aircraft. This will also align with the new scope in DO-398A and the new requirements in DO-365D that support ACAS Xr.

Change 1 to DO-387 addressed the following changes: Appendix F in DO-387 describes a sample tracker for an EO/IR sensor system. Additional analysis conducted since the initial publication of DO-387 has revealed areas of potential improvement of this tracker.

Stand-Alone DAA OSED (DO-398) involved splitting out Appendix A of DO-365B into a stand-alone document as part of revision to DO-365C. This change was being driven by the size of DO-365B and will help make new revisions of DO-365 more manageable. DO-398 will be revised to Rev A to include ACAS Xr use cases and associated material.

SC-228 will continue to work in close collaboration with SC-147 in the design, development, and standardization of the Airborne Collision Avoidance System X (ACAS X) variants that are relevant to remotely piloted aircraft (ACAS Xu and sXu). During Phase 3 this collaboration will center around ACAS Xr in support of the AAM use case.

Additionally, new concepts will be pursued to address object detection, alerting, and guidance on and near the surface environment. The initial scope will be to draft a new MASPS to capture the use cases, functions, and performance analysis supporting DAA functionality on and near the surface environment.

A White Paper was completed to address the need for surveillance (A2G, G2A, A2A) and coordination between collision avoidance systems for new airborne entrants and third-party service providers. Spectrum should be considered in the context of available frequency resources and ongoing coordination with the FAA.

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 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 includes 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) were enabled. Finally, updates / refinements to C2 MOPS (Terrestrial) were completed to implement changes consistent with requirements from other standards developed during this phase.

Additionally, the working group addressed 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). DO-377 was revised 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 cellular 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 SATCOM 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 cellular services. This document will be developed jointly with EUROCAE WG-105 to enable a common standard for avionics using standardized cellular services offered worldwide.

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.
- Development of this revision is dependent on FCC action subsequent to their notice of proposed rulemaking for the 5030-5091 MHz band and may be delayed if no FCC action is taken.

Updates to DO-377A

- Address safety and performance requirements for air taxi, surface operations at public use airports, and low altitude small package delivery.
- If additional scope is added by the Ad Hoc team (e.g., C2 Link Systems supporting AAM) the deadline would be assessed and adjusted if necessary, with consent of the PMC.

New C2 Scope

- Create a joint standard with EUROCAE WG-105 for use of Cellular commercial networks for C2 Links used for type certificated UAS.
- Create standard for use of the UHF spectrum band used for C2 Links used in type certificated UAS

RTCA Report for Users of DO-377B for Deriving C2 Link System Requirements

- Address the concerns about the definition of availability and continuity (performance parameters) within DO-377B that were raised during DO-377B FRAC
- Describe methods that can be used by UAS OEM, UAS operators and C2CSPs when deriving C2 Link System Quality of Service Requirements from DO-377B

Lost Link Standards – Completed April 2023

This began by standing up a new working group for this new scope after completion of initial plenary level guidance material work. This group had 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 (DO-400)

- 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

The navigation standards working group was started in Phase 3. 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

Since being created, the navigation standards working group has completed the following deliverable:

Guidance Material for UAS Navigation Systems

- Guidance Material: Navigation Gaps for UAS (DO-397) was completed and published in September of 2022.

The navigation standards working group is currently tasked with the following deliverable:

DO-VVV: Minimum Aviation Systems Performance Standards (MASPS): Navigation for Automatic Taxi

- The WGs initial document, DO-397, identified a lack of navigation standards to support automatic taxi operations. This document is being developed to fill the identified gap.
- The scope of this document is to define navigation system performance requirements to support automatic taxi operations (traditionally crewed or remotely piloted).

Note: Similar to DO-236(): RNP for Area Navigation, certain requirements defined in this document may go beyond what is typically regarded as a navigation requirement.

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 (Delivered June 2021)

- 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.