



Report ITU-R M.2204
(11/2010)

Characteristics and spectrum considerations for sense and avoid systems use on unmanned aircraft systems

M Series
**Mobile, radiodetermination, amateur
and related satellites services**



Documents
Document Sharing Hub

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Reports

(Also available online at <http://www.itu.int/publ/R-REP/en>)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management

***Note:** This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2011

© ITU 2011

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without written permission of ITU.

REPORT ITU-R M.2204

Characteristics and spectrum considerations for sense and avoid systems use on unmanned aircraft systems

(2010)

TABLE OF CONTENTS

	<i>Page</i>
1 Introduction	1
2 General descriptions and terminology	3
2.1 Terminology	4
2.2 Airspace	4
2.3 Applicability of sense and avoid to overall collision avoidance approach.....	4
2.4 Existing aeronautical radionavigation allocations	5
3 Technical considerations for S&A	5
3.1 Aircraft-based S&A	5
3.2 Other technical issues	11
4 Spectrum considerations for UAS sense and avoid system.....	12
4.1 Aeronautical radionavigation spectrum currently allocated for airborne radars	12
4.2 Aeronautical radionavigation spectrum currently allocated for ground radars ..	13
4.3 Other aeronautical radionavigation spectrum.....	13
5 Conclusions	14
Glossary	15

Objective

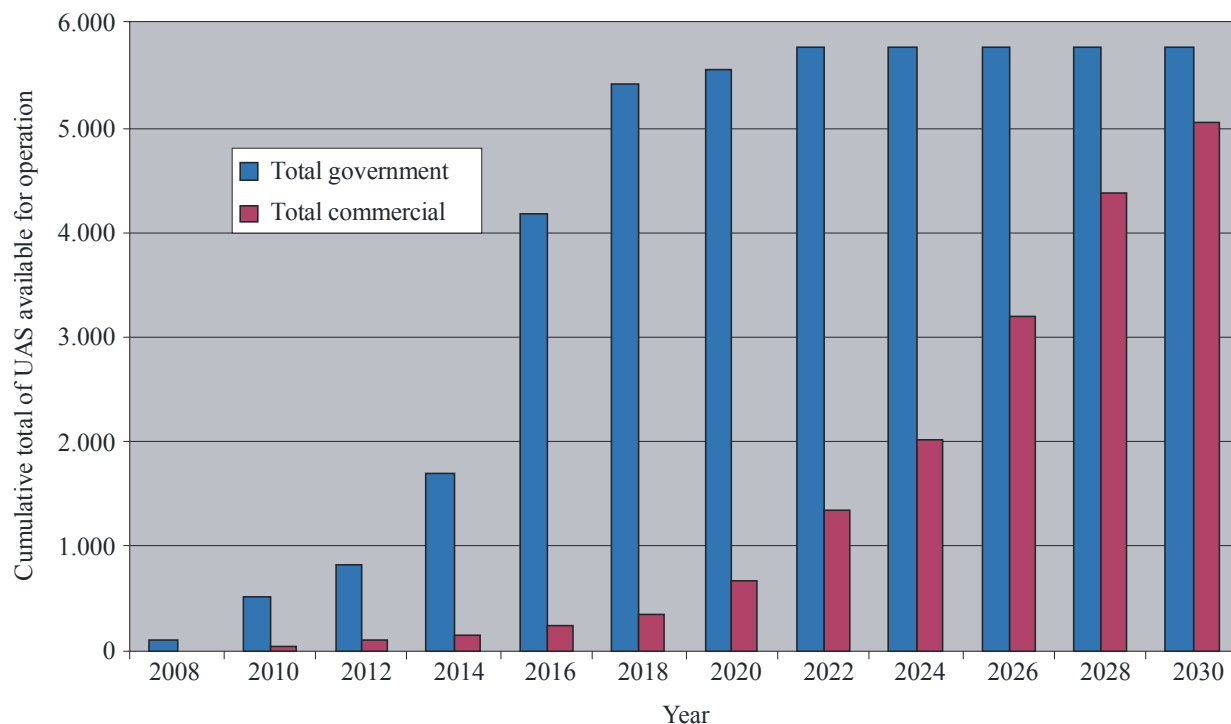
Numerous unmanned aircraft (UA) applications have been demonstrated or are planned that will dramatically increase the numbers of UA worldwide. With integration of UA into non-segregated airspace very close, it is essential that adequate spectrum be found to support UA operations including the spectrum requirements for UA sense and avoid (S&A) systems.

1 Introduction

Though UA have traditionally been used in segregated airspace where separation from other air traffic can be assured, administrations expect broad deployment of UA in non-segregated airspace alongside manned aircraft in the future. Current and future unmanned aircraft system (UAS) operations may include scientific research, search and rescue operations, hurricane and tornado tracking, volcanic activity monitoring and measurement, mapping, forest fire suppression, weather modification (e.g. cloud seeding), surveillance, communications relays, agricultural applications,

environmental monitoring, emergency management, and law enforcement applications. Thus, significant growth is forecast in the UAS sector of aviation and the projected growth is shown in Fig. 1.

FIGURE 1
Cumulative total of UAS available for operation



Report M.2204-01

For an air vehicle to operate in non-segregated airspace there is a requirement to see and avoid other aircraft, properly act and respond to certain weather conditions, and remain well clear of obstacles. Two primary sensor systems are under development to allow a UAS to meet this requirement. The first class comprises sensor(s) or electronic system(s) on the air vehicle and is called aircraft-based sense and avoid (ABS&A). The second class involves sensor(s) or electronic system(s) monitoring the air space from the ground and is referred to as ground-based sense and avoid (GBS&A). It is anticipated that equipage of UA with an ABS&A system or the use of a GBS&A would be dependent on the class¹ of airspace the UA operates.

As shown in Fig. 1, the number of commercial and government UAS is rapidly expanding. UAS densities vs. altitude and size are shown in Tables 1 and 2. The goal of airspace access for appropriately equipped UA systems is to achieve a level of safety equal to that of an aircraft with a pilot in the cockpit. If UAS operate in non-segregated civil airspace, they must be integrated safely and adhere to current operational rules that provide an acceptable level of safety similar to that of a conventional manned aircraft. Thus it is envisioned that UA will require an S&A system

¹ The world's navigable airspace is divided into three-dimensional segments, each of which is assigned to a specific class. Most nations adhere to the classification specified by the International Civil Aviation Organization (ICAO) in which classes are fundamentally defined in terms of flight rules and interactions between aircraft and Air Traffic Control (ATC). Individual States may also designate Special Use Airspace, which places further rules on air navigation for reasons of national security or safety.

that can maintain simultaneous tracks of nearby aircraft, terrain, weather, and obstacles to replace current functionality and actions performed by the pilot on manned aircraft.

TABLE 1

UAS densities vs. altitude based on Fig. 1 projections

UA density	UA/10 000 km ²
At surface	(3 UA at an airport) 2.395
0-FL50 (1 500 m)	4.017
FL50-FL195 (1 500-6 000 m)	1.560
> FL 195 (> 6 000 m)	0.644
Total density	8.616

TABLE 2

UAS densities vs. size based on Fig. 1 projections

UA categories	Per 10 000 km ²	Per spot-beam*	In regional-coverage beam**
Large	0.440	21	341
Medium	1.950	93	1.515
Small	8.031	385	0
Total	10.421	501	1.856

* 480 000 km²

** 7 800 000 km²

Since the S&A systems will be used to ensure the safety of life and property, a radiofrequency (RF) based S&A system is one of these technologies. These RF systems will need to be designated a safety service and operate in an aeronautical radionavigation service (ARNS) allocation.

2 General descriptions and terminology

Unmanned aircraft are powered, aircraft that do not carry a human pilot, use aerodynamic forces to provide vehicle lift, and may fly semi-autonomously or autonomously, or be piloted remotely. The current state-of-the-art in UAS design and operation is leading to the rapid development of UAS applications to fill many diverse requirements. UAS applications that have been demonstrated or planned come from such areas as agriculture, communications relays, aerial photography, mapping, emergency management, scientific research, environmental management, and law enforcement. The safe operation of UAS outside segregated airspace requires addressing the same issues as manned aircraft, namely integration into the air traffic control (ATC) system. Because the pilot is no longer aboard, a method of replacing the pilot's "see and avoid" responsibilities as well as procedures, are required. While existing onboard systems may be adapted or incorporated to accommodate the S&A requirements for cooperative targets, it is likely that new technologies as well as additional systems will be required for detecting and acting on non-cooperative targets.

2.1 Terminology

Unmanned aircraft (UA): Designates all types of aircraft remotely controlled.

Unmanned aircraft control station (UACS): Facilities from which a UA is controlled remotely.

Control and non-payload communications (CNPC): The radio links, used to exchange information between the UA and UACS, that ensure safe, reliable, and effective UA flight operation. The functions of CNPC can be related to different types of information such as: telecommand messages, non-payload telemetry data, support for navigation aids, air traffic control voice relay, air traffic services data relay, target track data, airborne weather radar downlink data, non-payload video downlink data.

Sense and avoid (S&A): S&A corresponds to the piloting principle “see and avoid” used in all air space volumes where the pilot is responsible for ensuring separation from nearby aircraft, terrain and obstacles.

Unmanned aircraft systems (UAS): Consists of the following subsystems:

- UA subsystem (i.e. the aircraft itself).
- UACS subsystem.
- CNPC subsystem.
- ATC communications subsystem (not necessarily relayed through the UA).
- S&A subsystem.
- Payload subsystem (e.g. Video camera ...).

Intruder: An aircraft (manned or unmanned) that enters the S&A surveillance volume and tracked by the S&A system.

2.2 Airspace

To date, operations have been limited to segregated airspaces designated as “R” (Restricted), “D” (Dangerous) or “P” (Prohibited). For the purposes of this report, the airspace may be grouped into three categories, namely:

- ATC Separation Assurance – Air traffic control is responsible for safe separation of all aircraft. This comprises Classes A, B, and, if the UAS is operated in accordance with Instrument Flight Rules (IFR), Class C airspace.
- Limited or no ATC Separation Assurance– Air traffic control is not responsible for safe separation of all airspace users. This comprises Classes D, E, F and G airspace.
- Segregated – A defined volume of airspace is reserved for exclusive use of a particular UAS. In such airspace there would be no air traffic control service and therefore ATC is not responsible for separation but there are one or more aircraft, under the control of the same operator, in this airspace at a given time.

2.3 Applicability of sense and avoid to overall collision avoidance approach

An important point to consider in the design of a sense and avoid system is how it fits into the total systems approach to collision avoidance. As shown in Fig. 2, the approach to collision avoidance uses a layered approach. Current technologies that may accommodate these layers include ATC procedures, ground and surface ATC surveillance systems, automatic dependant surveillance-broadcast (ADS-B), airborne collision avoidance system (ACAS) also called traffic collision avoidance system (TCAS), and S&A. ACAS (or TCAS) for use on an UA is still being developed and requires modification to the ACAS algorithms not only for the UA, but also on existing manned aircraft prior to implementation. ADS-B is a newer situational awareness system that is currently