Radio Division, TEC

Communication aspects of Unmanned Aircraft System (UAS)

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1. Introduction

The unmanned aerial vehicle (UAV) or the unmanned aircraft system (UAS) sector is facing a massive expansion, from all points of view. The UAV is also interchangeably called drone, however the standard terminology is UAS. The number of drones put in operation is exploding, with several millions devices produced annually in the recent past years. The range of devices is expanding from micro-drones weighing a dozen of grams to large machines of the size of a passenger aircraft. Once reserved to specific military operations, drones are now used or planed for use for an increasingly wide number of civil applications. Considering the pace of development, the numbers involved and the apparently unlimited possibilities offered by drones technology, there is no doubt that unmanned aerial devices will fundamentally change the face of the air transportation industry. The figure below shows the projected usage of UAS in the government/defense applications and civil/commercial applications.

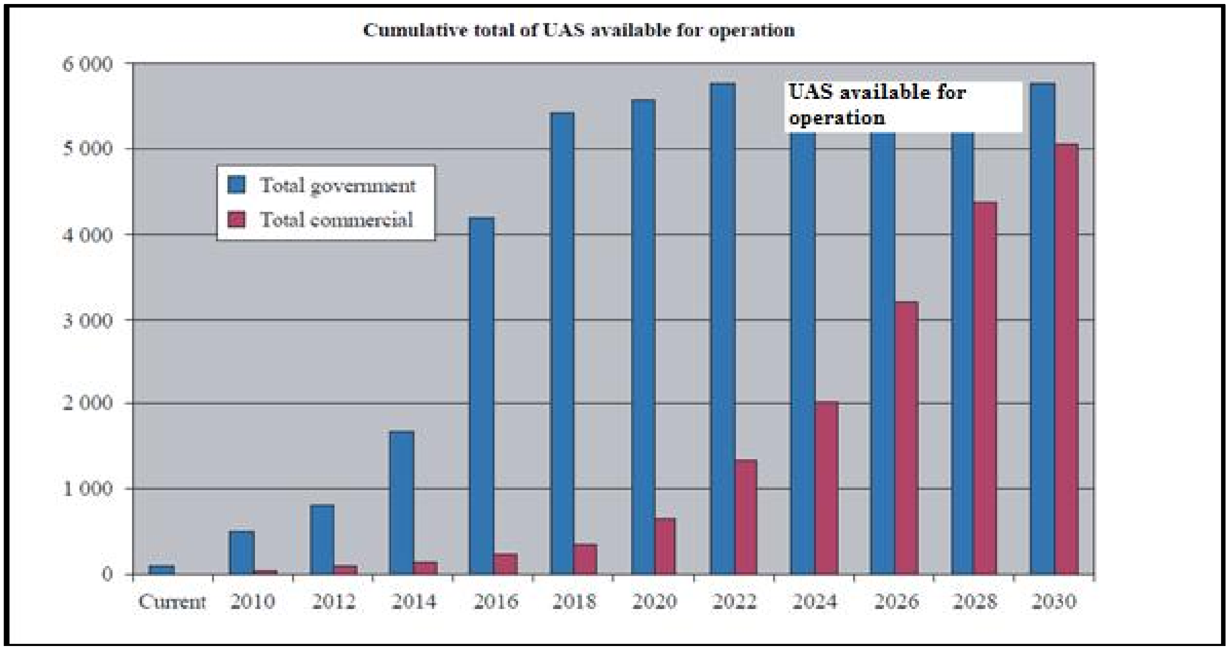

Figure 1 Government and civil usage of UAS **Source: ITU-R M.2171**

The regulatory landscape with respect to UAS is still in its nascent stage with formal regulations in place in USA. Other countries are still in the process of drafting the regulations for the adoption of UAS in the civil application landscape. The major concern lies in the safe operation of the UAS and in accordance with the prevalent laws of air-space. The efficient inclusion and integration of UAS in the existing civil aviation framework is what is being aimed for, and there is no denying the fact that communication system of a UAS plays a crucial role in achieving this.

The purpose of this paper is to outline the telecommunication related aspects of a UAS and try to explore the regulatory framework for the pervasive yet safe adoption of UAS in the civil aviation sector.

2. Definition of UAS

The International Civil Aviation Organization(ICAO) in its Circular 328 defines UAS as;

"An aircraft and its associated elements which are operated with no pilot on board."

3. Classification of UAS

3.1. ICAO Classification

The ICAO classifies UAS, broadly in two categories:

- **Remotely-piloted aircraft system:** A set of configurable elements consisting of a remotely-piloted aircraft, its associated remote pilot station(s), the required command and control links and any other system elements as may be required, at any point during flight operation.

- **Autonomous aircraft:** An unmanned aircraft that does not allow pilot intervention in the management of the flight.

3.2. Classification based on weight

Civil UA are classified in accordance with weight of UA as indicated below:

- Micro : Less than two kg.
- Mini : Greater than two kg and less than 20 kg.
- Small : Greater than 20 kg and less than 150 kg.
- Large : Greater than 150 kg.

3.3. Classification from spectrum perspective

ITU classifies UAS in the following three categories based on the spectrum perspective. By spectrum perspective, it is meant to categorize on the amount of spectrum required for the operation of the particular category of UAS. The quantum of spectrum in this case is highly dependent on the range, altitude and cruise speed of the UAS. The following table depicts the classification as per ITU Report M.2171:

UA categories from a spectrum perspective

UA Category	Weight (kg)	Maxime altitude (m)	Cruise speed (km/h)	Endurance (hours)	Maximum range (km)
Small	< 25	< 300	< 111	< 5	Visual LoS < 3
Medium	25-2 000	300-5 500	111-185	5-30	RF LoS 150-250
Large	> 2 000	> 5 500	> 185	> 30	Beyond RF LoS

The UAS can also be classified based on its functionality and deployment scenario like Target and decoy – providing ground and aerial gunnery a target that simulates an enemy aircraft or missile, Reconnaissance – providing battlefield intelligence, Combat – providing attack capability for high-risk missions, Logistics – delivering cargo, Research and development – improve UAV technologies, Civil and commercial UAVs – agriculture, aerial photography, data collection, to name a few.

4. UAS Application scenarios

The figures below depict the major application scenarios of UAS. These include civil applications like high voltage power line monitoring, environmental monitoring, high accuracy terrain mapping etc.

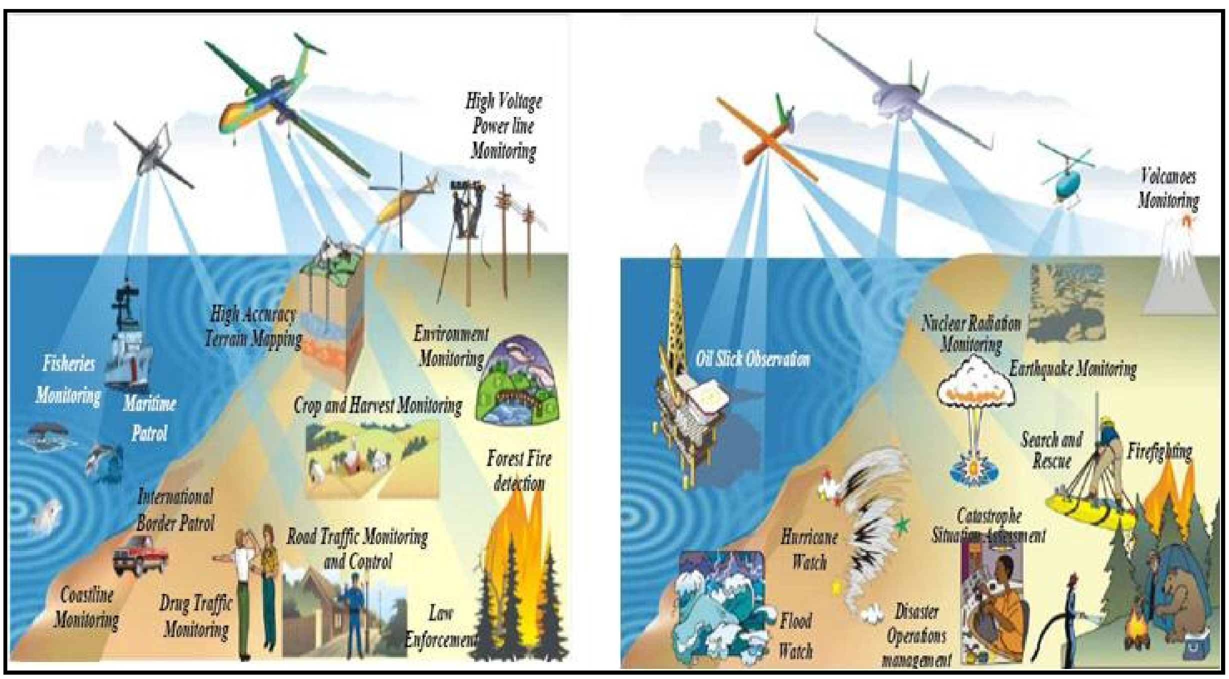

Figure 2: UAS Deployment and usage scenarios

5. UAS deployment methodologies

Various regulatory methods can be employed to mitigate the safety risks associated with the integration of drones in the civil aviation airspace. The chief being;

5.1. Segregation

The method which has been applied historically is airspace segregation, where unmanned aircrafts are simply required to remain outside of the airspace open to civil aviation. When a need arises for a drone to operate within the latter, a dedicated airspace volume is defined for the duration of the activities within which the device will be authorised to fly. Air Traffic Services (ATS) personnel will be required to give instructions to aircraft under their responsibility in order to prevent these aircraft to enter the limits of the reserved airspace.

5.2. Visual Line of Sight operations

This method, which applies specifically to Remote Piloted Aircraft Systems (RPAS) consists in requiring the remote pilot to retain permanent visual contact with its aircraft and to take any necessary action to avoid a collision between the latter and ordinary aircraft or other drones. While this strategy allows RPAS to fly closer or even into airspace open to civil aviation, it constrains drone operations to a relatively short radius around the position of the RPAS operator.

5.3. Beyond Visual Line of Sight

Beyond Visual Line of Sight (BVLOS) operations are based on methods which allow both RPAS and autonomous aircraft to fly, including within civil aviation airspace, without the need for a human operator to retain permanent visual contact with the drone.

6. Communication aspects in UAS

6.1. Communication is key in UAS systems due to the remote nature of human presence. Safety-of-flight is the driving factor when the seamless flight of UAS within civilian air traffic is at stake. In the end, safe operation of UAS relies on communications which represents a critical step in enabling UAS operations in non-segregated airspaces. The ITU-R Report M. 2171 lists out the following aspects of radiocommunication pertaining to a UAS.

6.1.1. Types of radiocommunications links

For safe operations of UA under LoS and BLoS conditions, three types of radiocommunications between the UA and the UACS are required, which are as follows:

- radiocommunications in conjunction with air traffic control relay;
- radiocommunications for UA command and control;
- radiocommunications in support of the sense and avoid function.

It is left to the UA system designer to combine two or more of these three radiocommunications into a common physical link.

6.1.2. Radiocommunications for air traffic control relay

In non-segregated airspace, a link between air traffic control and the UACS via the UA, called ATC relay, will be required to relay ATC and air-to-air communications received and transmitted by the UA. For communicating with ATC, the UA uses the same equipment as a manned aircraft. This report only considers the downlink bringing the ATC information from the UA to the UACS and the uplink from the UACS to the UA allowing the UACS to communicate with ATC. As these communications are critical for a safe management of the controlled airspaces, especially in terminal approach areas with high density of aircraft, future ICAO standards are obviously mandatory for these kinds of communications.

6.1.3. Required radiocommunications for command and control

Command and control is the typical link between the UACS and the UA. The following two ways of communications are:

The uplink: To send telecommands to the aircraft for flight and navigation equipment control.

The downlink: To send telemetry (e.g. flight status) from the UA to the UACS.

It is anticipated that in some flight conditions or in specific airspaces it could be necessary to downlink video streams. This consideration is of a high importance for the work of the ITU-R related to Resolution 421 (WRC-07) and it must also be considered with the similar requirement that may come from the support of sense and avoid function. Such a requirement could lead to data rates of several hundreds of kbit/s per UA. In areas under the responsibility of the aeronautical authorities, it is expected that the command and control communications will have to be compliant with ICAO standards to be further specified on this function. Nevertheless, in the periods where the UA will follow a full autonomous flight, the up and down links could have very low data rates.

6.1.4. Required radiocommunications in support of "sense and avoid"

Sense and avoid (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 (e.g. weather).

To determine appropriate spectrum requirements related to the S&A function, two aspects must be considered:

– Firstly, all the RF equipments designed to collect raw data related to the "sense" function will have specific requirements depending on the ITU-R services involved. For example, the evaluation of the close proximity of the UA using radar equipment will operate in radiodetermination service bands. It should be studied if this functionality can be developed by using existing

systems such as radar, ACAS, ADS-B and UAT. The data derived by the sensors could either directly be processed inside the UA or be transmitted to the UACS.
- Secondly, the control of the proper operation of this S&A function will be permanently or regularly checked at the UACS. If necessary, S&A parameters may be modified by the UACS, depending upon the area of flight, the weather conditions or the level of autonomy assigned to the UA. In these bi-directional communications between the UACS and the UA for the S&A function, two different information streams must be considered:
– The S&A data uplink will allow the UACS to control the operation of this function according to the conditions of the flight. Identical to the Control uplink, it is expected that such a communication will not require high bit rates.
– The S&A data downlink from the UA to the UACS which indicates that the S&A function operates as desired. Similar to the Control downlink requirement, the need to send video streams under this S&A function must be considered avoiding duplication between Command and Control and S&A video downlinks.

Similar to the command and control considerations, it is expected that the "S&A data" RF communication requirements will have to be compliant with future ICAO standards for the safe flight of the UA in areas under the responsibility of the aviation authorities.

6.2. VLOS (Visual Line of Sight) and BLOS (Beyond Line of Sight) communication in UAS

As per the ITU-R Report M. 2171, the following figure depicts the links and the spectrum requirements for VLOS deployment scenario of UAS.

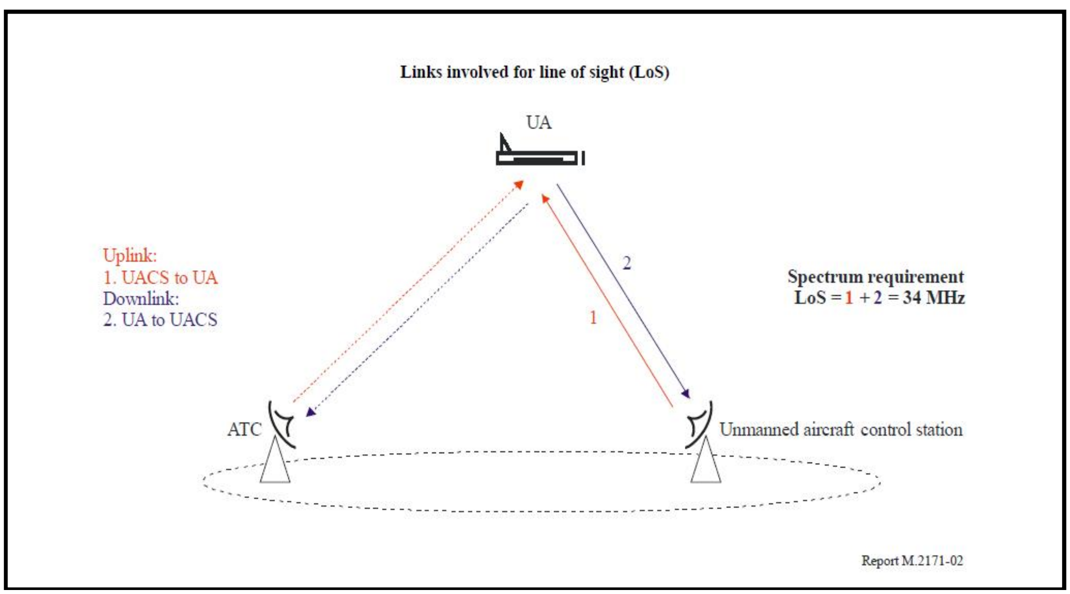

Figure 3 VLOS Links in UAS

The links and the spectrum requirements for BLOS deployment scenario of UAS is depicted by the following figure.

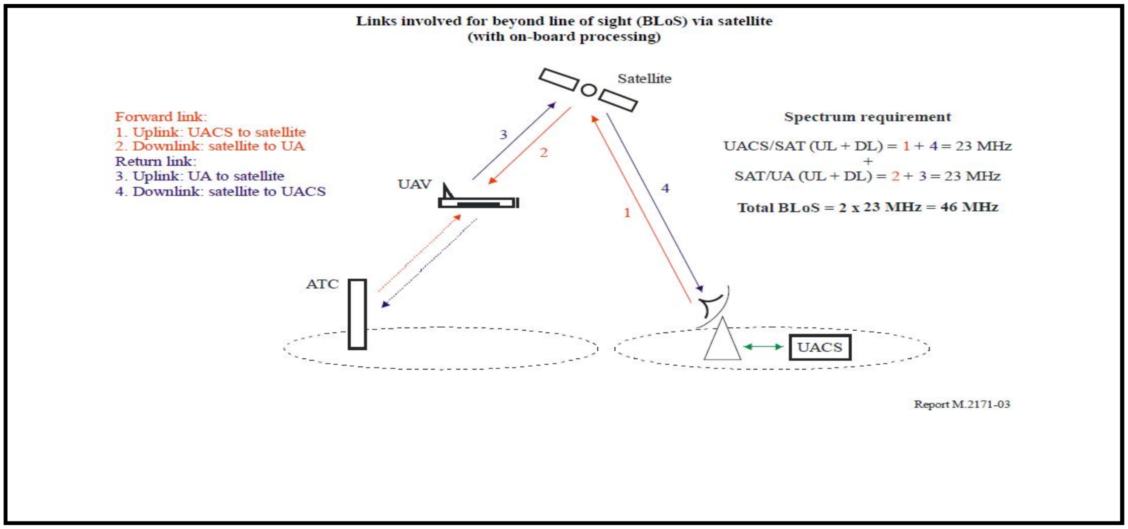

Figure 4 BLOS links in UAS

6.3. Frequency bands of operation for UAS

The category of small UAS generally, uses the unlicensed band of 2.4 GHz, 5.8 GHz unlicensed 900 MHz and UHF bands for communication. The UAS has to comply to the national regulations applicable for operation of other technologies in these bands.

WRC-12 allocated the frequency band 5030 – 5091 MHz to be used for the terrestrial RPAS control links.

Subsequently, WRC-15 identified the following spectrum to be used by satellite systems controlling drones. However, it was also noted that ICAO is to develop the relevant SARPS before the spectrum can be used and there will be a progress report to WRC-19 and WRC-23 will review the effectiveness of the allocation. There are power limits associated with some of these frequency bands.

Region 1	Region 2	Region 3
12.5 – 12.75 GHz space to Earth	10.95 – 11.2 GHz space to Earth	12.2 – 12.75 GHz space to Earth
14.0 – 14.47 GHz Earth to space	11.45 – 11.7 GHz space to Earth	14.0 – 14.47 GHz Earth to space
19.7 – 20.2 GHz space to Earth	11.7 – 12.2 GHz space to Earth	19.7 – 20.2 GHz space to Earth
29.5 – 30.0 GHz Earth to space	14.0 – 14.47 GHz Earth to space	29.5 – 30.0 GHz Earth to space
	19.7 – 20.2 GHz space to Earth	
	29.5 – 30.0 GHz Earth to space	

7. Typical Regulation Regime for UAS

In this section a typical regulation regime which is also under study by ICAO, EASA has been described. This regulatory framework also draws from the FAA (Federal Aviation Agency), USA regulations on UAS. The ultimate objective of the framework should be to achieve an environment where drones' operation does not require any human attention, in the sense that these devices are capable of detecting themselves the presence of other flying objects, whether ordinary aircraft or other drones, and to take appropriate measures to avoid any collision.

7.1. *Open category:* The open category, which will comprise the vast majority of unmanned aerial vehicles. In a first step, the avoidance of collisions between these drones and ordinary aircraft will be achieved by the means of airspace segregation. These devices, for the foreseeable future are meant to operate at low altitudes, below the airspace sectors used for civil aviation purposes and maintaining a safe distance from airspace reserved for airport operations. VLOS operations can support drones' activity close to or even within airspace sectors open to civil aviation (such as aerodrome control zones).

7.2. *UAS Traffic Management (UTM):* It is however becoming apparent that some sort of infrastructure will need to be deployed to ensure the safety of drones' operations also outside of the airspace open to civil aviation. The purpose of such an infrastructure would be primarily to keep drones separated from each other, but also from the few aircraft such as low flying helicopters with which they may need to share the airspace. That infrastructure should also integrate a function preventing drones to enter airspace sectors where their operation is prohibited. The concept of UAS Traffic Management (UTM) which is being considered in the USA responds to such a need.

7.3. *Specific category:* A similar strategy should be pursued to regulate special purpose operations into civil aviation airspace. Until drones are capable of assuring their own separation from other aircraft, airspace segregation and VLOS operations will remain the primary means to ensure separation.

7.4. *Certified category:* The certified category comprises those drones which are expected to operate on a routine basis within the airspace open to civil air navigation. The civil ATM system is presently excessively complex both from an operational and a regulatory perspective and the primary objective must be to achieve integration without adding another layer of complexity.

8. Cellular Technology for UAS operation

Cellular technologies like LTE and emerging 5G technology can be considered as candidate technologies for UAS deployment. Cellular technologies ensure:

- Ubiquitous coverage
- High reliability and QoS
- Robust security

– Seamless mobility

Many telecom manufacturing companies are carrying out trials on UAS operation in cellular networks mainly LTE for now. The challenges that have been identified in these trials are:

- Interference mitigation: As UAs receive signals from multiple base stations when airborne and hence also face interference.
- Handover optimization: As UAs receive signals from multiple base stations, and hence handover is very frequent leading to heavy signaling overheads.
- Cellular Network optimization as per drone requirements: Cellular networks need to differentiate UAs from UEs for optimal operation of UAs in cellular networks.

9. Conclusions

The regulatory regime for operations of UAs is in a nascent state. The DGCA issued guidelines for UAS are still in the draft stage. The draft guidelines require as a condition for clearance, the approval of WPC, DoT of all the operating frequencies used in the UAS.

The spectrum requirements for UAS in the frequency bands as elaborated in the previous sections of this paper, be it for control communication or Payload Communication, in the Indian scenario need to be studied and laid down in a framework to facilitate safe and regulated proliferation of UAS in the civil aviation sector.

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