UNMANNED AIRCRAFT SYSTEMS STUDY GROUP (UASSG)

TENTH MEETING

Rio de Janeiro, 24 to 28 September 2012

Agenda Item 3d: C3 SARPs

Command and Control (C2) link provision, link certification and requirement for Annex 10 SARPs (brainstorming)

(Presented by the Secretariat)

EXECUTIVE SUMMARY

This paper takes a very high level look at some fundamental issues as regards C2 (and C3) link provision for Remotely Piloted Aircraft Systems (RPAS). These include:

- Line of Sight (terrestrial) and Beyond Line of Sight (satellite) link peculiarities and design issues
- Potential Operator/Service provider quality of service issues,
- Technical certification, service provision contracts – or both
- Requirement for categorization of service provision capabilities
- Efficient use of frequency spectrum
- Annex 10 SARPs development task

Action: The UASSG is invited to discuss, validate and expand the brainstorming exercise provided in this paper.

REFERENCES

None
1. **INTRODUCTION, C2 AS A COMPONENT OF THE RPAS**

A C2 link operator will in many cases be different from the RPAS operator. During a flight, the remotely piloted aircraft (RPA) may even traverse between several different C2 link operator coverage areas and the remote pilot station (RPS) may be connected to the various C2 link providers through commercial ground telecommunication network providers of varying quality.

The total airworthiness of the RPAS will be dependent on the quality of the C2 link, strongly delineated by the operational coverage and the various quality-of-service (QOS) parameters of the radiocommunication media used.

For example, a satellite has a fixed and limited footprint. The footprint may vary in size depending on the gain of the antenna installed on the RPA. Sensitivity to rain attenuation may further limit the size of the footprint, or cause link outages altogether unless the RPA is flying above weather.

The frequency asset used may be shared with other radiocommunication operators (not participating in the provision of the C2 link), each providing its own service and serving its own designated operational coverage area which may overlap the area of the C2 link provision. The frequency asset used may even be unprotected (not an aeronautical safety allocation), in which case there is a much weaker radio regulatory protection provided against any potential interference, and little or no legal/regulatory recourse or mitigation may be possible in case such interference happens.

**Example Availability of C2 Links**

- **LOS:** 99.99%
- **BLOS:** 99%
- **LOS:** 99.99%
- **BLOS:** 99%
2. DISCUSSION

2.1 Not all C2 links are created equal

Large bandwidth dedicated line of sight (LoS) links can be used for real time video streaming in addition to piping C2 and Air Traffic Control communications as well as Detect and Avoid related information. Low bandwidth LoS links using a shared frequency resource have much more limited capabilities. The range capability of a LoS link is governed by a variety of factors depending on the link design; while the maximum achievable distance is governed by the radio horizon, typically 25 – 200 nautical miles depending on the altitude of the RPA, the actual distance achieved may be considerably less.

A beyond line of sight (BLoS) link using a geostationary satellite has a turnaround link latency of 0.48 seconds or more. The useable satellite footprint of a BLoS link depends on the capabilities of the particular satellite providing the service. Factors include beamwidth (spot beam, regional beam, wide beam...), link power budget (signal to noise margin) and variable ionospheric/atmospheric attenuation examples: scintillation and rain fade).

Frequency allocations in the fixed satellite service (FSS) are used to support C2 link in a number of currently existing RPAS applications. According to the ITU Radio Regulations, unlike aeronautical frequency allocations intended to support safety of flight requirements, the FSS is not a safety service and does not enjoy international protection through special measures to avoid and eliminate harmful interference. The ITU World Radiocommunication Conference in 2015 (WRC-15) will consider possible radio regulatory actions to support the use of FSS frequency bands for the C2 links, i.e. consistent with a safety service.

If WRC-15 can agree to sufficient radio regulatory measures to support safe operations of RPAS in non-segregated airspace, then the FSS Ku (14/18 GHz) and Ka (20/30 GHz) frequency bands may be capable of providing large bandwidth for BLoS C2 services. On the other hand, the very short wavelengths of the Ku and Ka bands make these bands susceptible to outages due to weather, for instance when flying below cloud cover (rain fade). Ka band links are even worse affected by weather than Ku band links.

WRC-12 modified an existing aeronautical mobile satellite (route) service (AMS(R)S) allocation in the C band (5 GHz) to make it suitable for use by Unmanned Aircraft Systems (UAS). In addition to being an appropriately protected aeronautical safety allocation, this frequency band is far less susceptible to outages due to rain fade than the Ku and Ka bands. As of yet, there is no service provider or satellite resource capable of providing BLoS service in this frequency band.

2.2 Not all Service Providers are created equal

Air Traffic Control (ATC) communications are traditionally operated by Air Navigation Service Providers (ANSPs). ANSPs are State “certified” operators. The State certification, while usually treated as a package, includes the entirety of the service including the operation of ATC communications facilities. A programme of regular safety oversight, both on a national and international level, ensures that the operation adequately reflect the internationally agreed safety requirements.

It is foreseeable that the C2 links will be provided by various commercial operators, some as an integral part of the RPAS and some on a contractual basis, some transient and some more permanent in nature. The size of the coverage areas of each C2 link operator will vary and the provided quality of the service (QOS) will vary based on a number of factors such as power link budget, frequency dependent atmospheric fading, protection level of frequency asset, etc.
Currently existing air traffic satellite service providers (Inmarsat, Iridium, MTSAT) provide their service on a contractual basis. To date, the various ICAO planning and regional implementation groups (PIRGs) have established sub-groups to oversee controller pilot datalink communications (CPDLC) and automatic dependent surveillance – contract (ADS-C) trials and limited operation. Thus far it is noteworthy that there appears to be an order of magnitude difference between the QoS goals indicated by the satellite operators and the outcome of some of these trials (>99.9% claimed vs. <99% link measured availability). Also it is worth to note the problems of the failing Inmarsat 3 ground station infrastructure in 2007 and 2008 due to a seemingly weak business case and aging equipment of certain independent ground station providers, with numerous resulting outages.

2.3 **Potential C2 link failure modes**

The various failure modes of any typical radiocommunication link include:

1. Outage due to limited size of coverage area;
2. Outage due to ionospheric/atmospheric/rain attenuation;
3. Outage due to equipment or ground infrastructure failure;
4. Outage due to unintentional interference;
5. Outage due to malicious interference; and
6. Malicious spoofing/link takeover

2.4 **Technical Certification, Service Provision Contracts – or both**

Aviation being a rigorously safety regulated industry, components that affect the airworthiness of an aircraft are certified (example: TSO certification). An aircraft’s airworthiness is rated with different capabilities based on the certification of the various components (example: ETOPS certification).

An RPAS may use various and different C2 link service providers, based on the route or area being covered by the RPA. The C2 link is an integral part of the overall airworthiness of the RPAS.

The quality of the C2 link service provided by a terrestrial or a satellite communications service provider may depend on a number of factors, such as equipment reliability and intra-link redundancies, link-power margins used as basis for the establishment of the size of the service area, the regulatory protection level of the frequency assets used, etc. Many of these parameters will typically be invisible or not dealt with at all in a contract of service provision.

If no safety-oversight/certification of the individual service providers – then this would be a significant departure from current levels of safety regulation.

2.5 **Categorization of Service Provision**

In order to determine the compatibility of an RPAS with various airspaces, the capabilities of the C2 links need to be categorized.

A LoS link may be wide band or narrow band, it may have the capability of streaming video in real time, it may or may not have the capability of relaying ATC communications. Latency in the LoS link may be insignificant or significant, based on its design and overall frequency resource loading in an area.

BLoS links relying on geostationary satellites suffer from high turnaround latencies.
A BLoS link operating in the AMS(R)S segments in the L band (1500/1600 MHz) or in the C band is relatively immune to weather, however there may be limited capabilities to cater for high bandwidth requirements. There will also be variable service quality concerns, for instance near the edge of a coverage area.

A BLoS link operating in the FSS bands is capable of supporting high bandwidths, however unless satisfactory regulatory action by WRC-15, FSS may not be capable of supporting RPAS in non-segregated airspace. There is a significant, and frequency band dependent availability degradation when flying at lower altitudes (rain fade).

For LoS and BLoS links, as the designated operational coverage areas (DOC) do not conform to flight information regions (FIRs), there needs to be an agreed way of indicating the DOC.

2.6 Efficient use of Frequency Spectrum

Allocations are available for RPAS LoS and BLoS use in the frequency band 5030 – 5091 MHz. These allocations are shared between the aeronautical mobile (route) and the aeronautical mobile satellite (route) services, and shared with the aeronautical radionavigation service as well. The use of these frequency allocations is limited to internationally standardized aeronautical systems; i.e. ICAO SARPs are required for their use.

Prior to WRC-12, ITU-R determined that a bandwidth of 34 MHz is required in support of LoS and 56 MHz in support of BLoS. WRC-12 afforded an overall bandwidth of 61 MHz in the C band, in support of both LoS and BLoS, also to be shared with the existing ICAO standardized Microwave Landing System (MLS) in the same frequency band.

In order to efficiently manage the shared use of this frequency band, and to fulfill the ITU Radio Regulations requirement for international aeronautical standards associated with it use, ICAO needs to develop Annex 10 SARPs, defining frequency access schemes, link budget, bandwidth characteristics and frequency assignment planning criteria.

3. CONCLUSION, ANNEX 10 SARPS DEVELOPMENT TASK (BRAINSTORMING)

A C2 link is an integral component of the specific RPAS, linking the RPA and the RPS. The overall C2 link design and capabilities will be governed or driven by the overall design of the individual RPAS package and airspace classification / airworthiness requirements. Hence, the link requirements may be highly variable, based on the particular application. On the other hand, there are fundamental aspects that are invariable and can best be addressed through Annex 10 (radiocommunication) SARPs.

The development of SARPs in Annex 10 would mainly address the following aspects:

- In case of shared aeronautical allocations (see section 2.6):
  - frequency access schemes;
  - link budget;
  - bandwidth characteristics; and
  - frequency assignment planning criteria

- General:
  - requirements for aeronautical safety allocations,
  - safety margins against services using adjacent or shared frequencies
end-to-end QOS parameters, reflecting and categorizing the capabilities of the various LoS and BLoS services (see section 2.2) and to be used as a basis for technical certification of service providers (see section 2.4)

4. ACTION BY THE UASSG

The UASSG is invited to discuss, expand and validate the brainstorming exercise provided in this paper.

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