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COMMUNICATIONS COMMAND AND CONTROL

The crowded spectrum

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ABSTRACT

Two key issues arise when the crew are removed from the aircraft. The first is how to get data to and from the aircraft (communications); and the second is how to operate the aircraft effectively (Command and Control). All the various methods used rely on the electromagnetic spectrum and useable space in this spectrum is becoming increasingly scarce. The provision and protection of this resource for the aviation community is an important issue. For UAV systems it could be the difference between success and failure.

Whilst the number of UAVs remains small the problem may be contained. However if the UAV industry is to experience the growth it expects, this may well be the most limiting factor.

1 INTRODUCTION

1.1 UAV communications

Communications plays a much more important part in the overall operation of a UAV than it does for manned aircraft because the men-in-the-loop are on the ground. All operations with a UAV must be made with due regard to the fact that all the decision making processes occur on the ground, either before the flight or during the flight operation.

The prime aim of most flights is to ensure that the payload is positioned in the right place to do its job. Therefore the whole mission revolves around the payloads and not around the aircraft. This is a fundamental departure from the majority of the manned world where more then 95% of flights are concerned with moving people and freight. Despite what might be thought, most military flights do the same.

The big issue for communications is what frequencies to use and how much data there is to be transmitted. Useable frequencies are in short supply worldwide and so design of the UAV must take into account where the major processing of data is carried out as this leads to design criteria for where communications takes place and how much needs to take place. The American Global Hawk UAV has on board a very powerful computer to process its data to cut down the amount of data that needs to be transmitted.

1.2 Current aircraft systems

Today's manned aircraft are equipped with a bewildering array of systems for communications purposes including:

- Landing Aids
- En-route navigation
- Dependent Surveillance
- Air/Ground ATC Communications

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- Operations control
- Collision Avoidance
- Passenger Telephones

These systems work in a variety of frequency bands that are subject to increasing depletion through an ever increasing demand on spectrum by other industries outside the aviation industry. For the UAV industry to emerge into the 21st century it must address these issues.

2 COMMUNICATIONS INSTITUTIONAL FRAMEWORK

2.1 International Telecommunications Union (ITU)

The forerunner of the present ITU was originally established in 1863 to be the international organisation dealing with line communications, and was later extended to cover also radio communications. The organisation was renamed to become the ITU in 1932. In 1947 it was accorded Specialised Agency status by the UN (for Telecommunications), some months after ICAO was similarly treated (for civil aviation). Membership of both organisations is similar and in excess of 180 signatory governments. Its primary members come from the Telecommunications Administrations, or the Radiocommunications Agency of its Members States.

The organisation has three quite distinct sectors of interest - Radio communications, Telecommunications Standardisation (mostly line communications standards), and Telecommunications Development. The General Secretariat in Geneva provides the technical support and administration. The executive body of ITU is the Administrative Council, with a representative membership of some 15 countries, which meets yearly for two weeks and approves, inter alia, the Agenda of the next two yearly WRC as well as defining policy issues referred to it by Conferences, etc.

Nowadays however there is a second and lower tier of membership from commercial and industrial sources, laboratories, etc., with reduced rights and privileges. There are around 150 of these, who have the choice of subscribing to any one, or all, of the three ITU sectors. In institutional terms, the incorporation of this large commercial segment has the potential to have a significant influence on events and this is becoming more evident as pressures on the spectrum grow.

The World Radio Conferences (WRC) are held at two yearly intervals, the items discussed at World Radio Conferences (WRC) concern the Radio Regulations which contains the Table of Frequency Allocations to the individual services, such as the aeronautical services. Whilst ICAO and Eurocontrol attend as Observers, they are not permitted to make Proposals, or to vote, and this can be a very severe constraint on the capability to influence events. Furthermore, in regard to discussing aeronautical matters, the ITU does not consider it is barred from discussing and agreeing technical aspects affecting aviation, provided only that the discussion contains a sufficient number of delegates professing to be aviation experts.

The record of aviation support to ITU-R meetings is very poor with rarely more than 3 or 4 delegates, having to present and defend vital subjects against very well organised opposing interests. ITU makes no distinction between experts from aviation authorities and others claiming similar expertise, who are often operating with a brief from, and occasionally employed by, the competing interest. Good organisation and briefing for these meetings is of prime importance in securing objectives.

2.2 European Conference of Postal and Telecommunications Administrations

The European Conference of Postal and Telecommunications Administrations (CEPT) was set up in 1959 and has 43 members drawn from EU, EFTA and adjacent States. Its objectives are to improve the co-ordination between members. CEPT is a voluntary body but operates as the quasi-official voice in the matters in which it specialises. Its relations with the EC are defined in a Memorandum of Understanding.

CEPT has three main committees - Postal , General Telecomms, and Radiocommunications. The European Radiocommunications Committee (ERC) with its permanent support in the European Radiocommunications Office (ERO) based in Copenhagen, acts as the machinery to maintain the co-ordination. The CEPT through the ERO is very active on radio regulatory matters and the preparations for WRC.

The ERC produces Decisions, and Recommendations, the former dealing with more significant matters than the latter. A consultation process for Decisions after which they become agreements within CEPT is a standard feature. The ERO is the centre of expertise and carries out studies, many funded from EC resources and many dealing with spectrum matters.

The CEPT is essentially composed of telecommunications interests, and mobile communications matters receive considerable attention. Their spectrum work however touches all other radio interests (broadcast, maritime, defence, etc.), but their expertise in these, as with aviation, is noticeably less. A view within CEPT which has prevailed for some time is that aviation in the past were treated too liberally and as a consequence is holding spectrum which it will never utilise. The view has not been helped by the failure of aviation to use the satellite, and the MLS spectrum.

Aviation has traditionally operated within its own envelope of a strong co-operation throughout the globe with ICAO SARPs and airborne MPS being developed in isolation within a well understood framework. Partly as a consequence of this the role of radio in air operations is not well understood by others. A primary problem is to place the safety element in perspective, to articulate it in meaningful terms, and wherever possible to illustrate it with data and information from real life, stressing to an appropriate degree the consequences when things go wrong. Any action which will increase the appreciation and lead to a higher degree of sensitivity in these organisations can assist in the task of retaining needed allocations.

2.3 European Telecommunications Standards Institute

The European Telecommunications Standards Institute (ETSI) is the European standards body for telecommunications, and works very closely with the other standards bodies in Europe. Their standards are voluntary only, but these 3 bodies are franchised to carry out standards work for the European Union.

In this process the voluntary European Standard is converted to become a Technical Basis for Regulation (TBR) and circulated amongst its 28 National Standards Members for agreement to conversion to become a European Telecommunications Standard. In 1997 ETSI had published over 50 standards, with a further 100 standards in the mobile field under discussion.

The membership of ETSI is very wide, including not only radio administrations but many industrial companies, research laboratories, manufacturers, national standards organisation, network and service providers, and many others.

2.4 Ad Hoc Aeronautical Spectrum Protection Group

Communications systems provide the basis for the safe and efficient support of operations for air navigation and Air Traffic Management services. In recent years, all of the spare capacity in the usable radio frequency spectrum - from about 9 kHz to 60 GHz - has been depleted. New services can now only be accommodated either by the removal of existing allocations or by an acceptance of frequency sharing between two compatible services. In this situation aviation has no special privileges and must defend and compete for its requirements in the same way as any other user. The radio spectrum is also taking on a more commercial and economic dimension with the advent of buying and selling spectrum, "spectrum pricing".

Because of this it has been agreed within the ECAC and by the Eurocontrol Committee of Management that a framework should be created to defend the civil aviation interests in the radio frequency spectrum by obtaining favourable decisions in :

- International radio band allocation: to provide sufficient capacity for the operation and deployment of existing systems and for the development of future systems ,
- Safety and Quality: to ensure that emissions from non-aeronautical systems do not cause harmful interference to, or degrade the quality of, aeronautical systems.

The exclusive world wide frequency allocations to terrestrial aeronautical services in the ITU Radio Regulations, with the exception of HF frequencies, are controlled and co-ordinated by aviation itself as a special recognition by radio regulators that it is a safety service. As a further element in this recognition the system specifications (except for Electromagnetic Magnetic Compatibility requirements) for international communications and navigation are developed and agreed on a world wide basis within ICAO, RTCA (Radio Technical Communications Agency), and EUROCAE (European Organisation for Civil Aviation Equipment). This is considered by many radio regulators to be a sensible, although not an automatic, delegation of powers.

Space systems, due to their multi-purpose and multi-national involvement, can not be treated in an identical manner. Here the target for aviation is to ensure that the frequency provision is adequate in capacity terms for ongoing, and long term expansion needs, and that its quality is appropriate to the needs of a safety service with high integrity requirements. In this change of emphasis the co-ordination processes of regional, and world wide bodies, becomes even more important, to firstly define global policies, and secondly to identify regional variations or supplements.

3 COMMUNICATIONS ISSUES

3.1 Types of Communication

There are a number of ways that current manned aircraft communicate and a number of reasons why they communicate or receive signals. Aircraft surveillance, navigation and data communications are all functions that require some form of communications as the following list covers some examples:

<u>Surveillance/Collission avoidance</u>

- Secondary Surveillance Radar (SSR) Mode A&C
- Automate Dependent surveillance (ADS)
- Tactical Collision Avoidance System (TCAS)

<u>Navigation</u>

- Satellite Navigation (Satnav)
- Instrument Landing System (ILS)
- Distance Measuring Equipment (DME)
- VHF Omni directional Range (VOR)

<u>Data Communications</u>

- Satellite Datalink
- VHF Datalink
- Mode S Datalink

<u>Voice Communications</u>

- Radio (HF, VHF & UHF)
- Satellite Communications (Satcomms)

Some of these are explained further in Appendix A and B. The primary means of command and control from an ATM perspective is still by voice communications. All voice communication between aircraft and ground stations are accomplished using the English language and by use of standard phraseology which is laid down by ICAO. The exception is that the local language may be used where all stations on a single frequency are fluent in that language. The phraseology has been developed over a number of years such that ATC instructions and advice are clear concise and unambiguous. The information commonly conveyed by voice communications between ground and air comprises:

- ATC clearances
- ATC instructions
- Meteorological information
- Aeronautical Information (e.g. relevant airfield data)
- Traffic information

From an ATM perspective there is also a ground/ground perspective concerning communication requirements between ATC centres. Translated into a UAV scenario there will be need for communications between ATC centres and UAV Control centres.

Apart from Voice Communications UAV systems can be made to utilise most of these in some way or other although some will be more useful than others.

3.2 UAV considerations

From an ATC perspective a UAV is no different from any other aircraft. The vehicle must still be controllable by others outside of the ATC arena and the UAV should communicate with ATC and follow all instructions given.

Currently VHF radio links are normally used for communication and HF radio or satellite links for oceanic control. Since communication between ATC and aircraft is currently procedural and all voice based, the UAV is not easily accommodated at present in the ATM environment. The UAV scenario will require that other aspects be considered such as:

- Safety critical control links
- Communication security
- Reduction of communication load
- Telemetry for aircraft status
- Payload data

With these additional considerations, it is easy to envisage a negative impact on an already crowded and heavily used frequency spectrum. It is unlikely that any part of the spectrum will be any less crowded than others and it is likely that manned aviation will take precedence over unmanned aviation.

Perhaps the key issue is control of the UAV. Whether command and control of the UAV can be adequately addressed in the current ATM framework.

3.3 Air/Ground/Air Communications

The big issue in this area is the shortage of VHF and UHF frequency bands. A system already operates around the world where the same frequency is used more than once, each within a Designated Operating Coverage(DOC). There is still interference from other close frequencies and often the two DOC areas can conflict.

Along with the frequency shortage is the bandwidth limitations so that VHF datalinks are limited to short messages. The transition to digital communications systems will improve this situation, however there is another factor which occurs, that of time delays. This is caused by the air and ground based processing systems especially in multiplexed situations.

3.4 Ground/GroundCommunications

The ground scenario is interesting from the point of view of UAV Control Centres communicating with conventional ATC centres. The newer UAV system may be more capable than their older counterparts and the system performance differences may be an issue. The standards that the UAV control centre will be built to and the availability of suitable links to the ATC centre may cause problems.

As the ATC centres are improved there is increasingly greater reliance on computer processing of data and computer-computer data exchange will become an increasingly important issue.

CONCLUSION

There are a significant number of threats to current and future communications systems as mentioned above and the following list is not exhaustive:

- Frequency management failures (Regulatory/Allocation)
- System failures (equipment based)
- Security/Safety failures
- External interference
- Sideband interference
- Simultaneous transmissions
- Malicious/Hoax transmissions

This brief view of communications from the existing manned aviation view highlights the many issues. Communications is already a fundamental part of the manned aviation world and the spectrum available even for current operations is severely limited. With the advent of the UAV system and its reliance on good communications both for the payload and the aircraft system, there is a need to ensure that safety and effectiveness are not compromised.

The fact that the majority of air transport is carried out in civilian airspace under civilian rules, means that communications, command and control has got to be made effective in peacetime. For this to occur the UAV aviation community must recognise the current institutional framework and its processes and influence them to its benefit. If not then the UAV industry will not progress far and UAV systems will be relegated to a small niche and heavily regulated market place. Even the military will suffer as they will not be able to guarantee the integrity and operational effectiveness of their systems.

APPENDIX A

NAVIGATION SYSTEMS

VHF Omni-Directional Radio Range (VOR)

This is a VHF transmitter which radiates in a form which enables precise directions from the beacon to be derived by an aircraft based receiver. These directions are called radials and very accurate navigation along radials is possible. The VOR has been the standard airways navigational aid for many years. Reception is limited to comparatively short ranges (usually less than 100 miles). There is a Morse code identification voice recordings superimposed on the VOR carrier signal.

Distance Measuring equipment (DME)

This is a UHF responding beacon on the ground. They are usually associated with a VOR. An aircraft requiring distance information from a particular DME transmits a coded signal on a discrete frequency which is received by the DME beacon and retransmitted to the aircraft. The DME receiver on the aircraft derives slant range by measuring the time taken for the signal to travel between aircraft and beacon. DME measurements are very accurate, typically to within 0.1 mile.

Tactical Aid to Navigation TACAN

This is primarily a military aid that combines the features of the VOR and DME (operating in the UHF band). Bearing and distance measurements are provided simultaneously by the beacon. Civil aircraft can make use of the DME element of a TACAN facility.

Instrument landing System (ILS)

This is a ground based landing aid which comprises two elements. The localiser is a VHF transmitter which indicates the extended runway centre line in the horizontal plane. The aircraft receiver gives the pilot an indication of being left or right of the desired approach path and whether to turn left or right to regain the centre line. The glide slope indicates the approach path in the vertical plane and is set tot he required approach angle (usually three degrees). The pilot is informed of his position relative to the required path and whether to reduce or increase his rate of descent. ILS is currently the standard civil approach aid. In some instances it can provide capability to land in very limited or even zero visibility.

Microwave Landing System (MLS)

This is the future replacement for ILS which is now in limited service. Its method of operation is similar to ILS in that two beams are provided for guidance in the horizontal and vertical planes. However, the nature of microwaves produces greater accuracy and a wider area of service. Thus it provides the capability to use more than one approach path or for paths which are not straight lines.

Inertial navigation System (INS)

This is a self contained system within an aircraft which navigates by very accurate dead-reckoning. Accelerometers measure aircraft movement in all directions and input is taken from other aircraft sensors (for example altimeter). Accuracies in the order of 1 mile drift per hour can be achieved and even these can be eliminated when cross checking with other navaids is carried out periodically. However, system accuracy depends on correct input of the originating co-ordinates of the flight and failure to do so may lead to gross navigational errors.

Global Positioning System (GPS)

This is a satellite-based navigation system. Messages (both encrypted and unencrypted) are transmitted from a series of satellites in earth orbit. By comparing time of arrival differences with the messages and the satellite positions the aircraft position can be calculated. Accuracies of the order of a few metres can be obtained from the encrypted codes. GPS is however not certified for sole means navigation and is purportedly easy to jam. Despite this it is becoming heavily utilised by a number of different industries such as road hauliers.

APPENDIX B

SURVEILLANCE SYSTEMS

Secondary Surveillance Radar (SSR)

SSR operates by the radar broadcasting out a signal which is received by aircraft equipped with transponders. The aircraft then transmit data which allows the ATC to obtain its position, is identity (Mode A), and its height (Mode C). Mode S radars and suitable equipped aircraft can also send data.

Automated Dependent Surveillance (ADS)

Most of the globe is not covered by radar. Using ADS, however, an Air Traffic Control Centre (ATCC) can see the current position of an aircraft almost anywhere in the world. A controller can also examine the aircraft's intended flight path and other information held in their onboard navigation systems. This data can be downloaded even in airspace not covered by radar, such as the oceans or sparsely populated areas.

An aircraft reports its position via an orbiting satellite. The message is routed to the current ATCC for that aircraft. If the ATCC needs to send instructions to the pilot, it can do this using other datalink systems to send data messages, or satellite voice services to speak to the crew directly.

There are already aircraft trialling the system and the concept will revolutionise the management of aircraft in remote regions.

Tactical Collision Avoidance System (TCAS)

Aircraft that are TCAS equipped emit a signal (Mode S) which is received by participating aircraft and advisory de-confliction messages are provided to the pilot. This allows the pilot to take avoiding action when necessary. The difficulty faced however is that aircraft that are not equipped are not seen.