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| Overview of the studies carried out on Agenda item 1.5 | |
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# 1 Introduction

This document provides a short overview of the studies which has been carried out on Agenda item 1.5 of WRC-15 for considering in committee 4 and relevant working group on Agenda item 1.5.

# 2 Background

At WRC-12, the spectrum requirements of UAS were considered and several new allocations were made to support UAS operations under Agenda item 1.3.

At that conference there was a proposal from a few administrations to allow UAS to use FSS allocations; however, WRC-12 did not address this proposal for beyond-line-of-sight (BLOS) operation because of a lack of supporting studies (Report ITU-R M.2233 was not sufficient to address all technical, operational, interference environment, regulatory and safety aspects of the UAS CNPC). This proposal was instead carried over to WRC‑15 in Agenda item 1.5 for further consideration. Therefore, at WRC-12 no new satellite allocations were made to support BLOS UAS CNPC. The aeronautical mobile satellite (R) service (AMS(R)S) in the frequency range 5 000-5 150 MHz, previously allocated through footnote No. 5.367, is now in the Table of Frequency Allocations in Article 5 of the RR. The requirement for BLOS (satellite) communications (56 MHz) may not be satisfied in the limited spectrum available in the frequency bands 1.5/1.6 GHz, and no AMS(R)S satellite system currently operates in the frequency range 5 000-5 150 MHz to support current/near-term UAS CNPC.

It was mentioned that existing systems operating in the FSS in the frequency ranges 10.95-14.5 GHz, 17.8-20.2 GHz and 27.5‑30 GHz may be used for BLOS communications for UAS CNPC, if, and only if, all technical, operational, interference environmental and its proper management and regulatory as well as safety aspects including principles of UAS as referred to in Resolution 153 (WRC-12) are fulfilled. It is worth to emphasize that the FSS is not recognized by the ITU as a safety service and thus does not benefited from the safety conditions referred to in No. 4.10 of the Radio Regulations. It is also worth to emphasize that almost 50% of the FSS network have been notified for registration under Article 11.41and as a consequence are subject to harmful interference and non-protection which could result in miss-command of the unmanned aircraft intended to operate in a non‑segregated airspace together with other piloted aircraft (passenger and/or cargo aircraft). The assignments and use of frequencies recorded in the MIFR, in particular, those recorded under 11.41 with respect to the application of 4.10 would require multiple redundancy in the event of harmful interference.

Moreover, for those FSS links that are coordinated, the specific agreement are generally not publicly available.

In fact, for those FSS links that are coordinated, the level of coordination negotiated between various satellite operators are not available to enable the thorough examination of the status of probability of interference, taking into account that FSS as used today which are located at orbital positions with just 2-3 degrees separated from each other suffering from considerable amount of interference (in the majority of the cases much beyond the coordination trigger level of overall link noise threshold of Delta T / T of 6%). These links would need to meet the performance availability and service availability of the communication links required for the safe operation of UAS CNPC in order to satisfy 4.10. Moreover there is no mechanism or provisions to prevent the occurrence of instantaneous or repeated interference to FSS links used for UAS CNPC.

WRC-12 resolved to study this topic further and without taking due consideration of the above fundamental and crucial requirements agreed on Agenda item 1.5 of WRC-15 to consider, the use of certain frequency bands allocated to the fixed satellite service, except those allocated under Appendices 30, 30A and 30B, are appropriate for the CNPC of UAS in non-segregated airspace. UAS already operate in segregated airspace using FSS frequency bands for unmanned aircraft to satellite links under No. 4.4 of the Radio Regulations together with the conditions associated with that Provision, **non-interference and non-protection**.

It is also necessary to take into account existing and future satellite networks when planning for growth of the use of FSS resources for UAS with their associated status in the MIFR.

Based on the Report ITU-R M.2171, the maximum amount of spectrum required for UAS CNPC links is 56 MHz for the satellite component assuming regional beams with suitable antenna discrimination. However this estimation could rise to 169 MHz when using small aperture antenna with limited discrimination in lower frequency bands, not allowing frequency re-use between satellites. In this case, the frequency bands used by UAS CNPC links by one satellite, could also not be used for any other FSS applications by any other satellite in the visible portion of the geostationary arc.

The studies carried out in response to Resolution 153 (WRC-12)have considered the bidirectional links between an unmanned aircraft earth station and associated FSS space station (E to s and s to E) as well as the FSS space station and the unmanned aircraft control earth station (E to s and s to E). They have been developed in co-operation with ICAO. It should be noted that the UA Earth station is considered as an aeronautical mobile Earth station intended to operate with the FSS. Such use has two major deficiencies: a) the interference environment of aeronautical mobile Earth station has not yet been studied at all and b) from the regulatory and procedural point of view an aeronautical mobile earth station cannot use FSS links due to the fact that under the current regulations the class of station of such earth station does not match with the class of station of the corresponding space station. This would result that the UA earth station cannot be notified under Article 11 of the RR to benefit from international recognition and protection from potential interference which are two essential elements required for the safety of flight for UAS CNPC.

At the same time ICAO has been working on the aeronautical operational, institutional and technical requirements. Neither ICAO nor ITU-R have not been able to provide the technical performance characteristics in terms of service availability, performance availability, reliability and continuity against which FSS links ensure that the expected safety aspects of the links are duly met.

In the absence of any technical performance requirements from ICAO and ITU-R, it has not been possible to assess whether an FSS network, which may include one or more satellite links to the unmanned aircraft, is capable of supporting the expected performance requirements. However the following radio regulatory issues have been identified that any method would have to address:

1 The current definitions in Article 1 the use of an aeronautical mobile aircraft earth station communicating to or operating within the fixed satellite service are inconsistent (the link between an unmanned aircraft earth station and a fixed satellite station);

2 The status of fixed satellite assignments recorded in the MIFR, including the implications for the protection of those networks and consistency as a safety service.

Any method would have to address these issues and the ICAO conditions.

The responsible group for WRC-15 Agenda item 1.5, ITU-R Working Party (WP) 5B has developed draft CPM text as included in the draft CPM Report ([Document CPM15-2/1](http://www.itu.int/md/R12-CPM15.02-C-0001/en)) and the associated working document towards a preliminary draft new Report ITU-R M. [UAS-FSS] – *Technical and operational characteristics, interference and regulatory environments associated with the use of frequency bands allocated to the fixed-satellite service not subject to Appendices 30, 30A, and 30B for the control and non-payload communications of unmanned aircraft systems in non-segregated airspace*.

In its introductory text to the Draft CPM Report ([Document CPM15-2/1](http://www.itu.int/md/R12-CPM15.02-C-0001/en)), the CPM-15 Management Team identified a number of issues that should be taken into account by administrations in the preparation of contributions to the second session of the CPM. For Chapter 3, agenda item 1.5, section 3/1.5/4, the CPM Management Team noted that no texts with regard to the analysis of the results of studies were developed as no agreement on this issue was reached by the responsible group and that text for this section needs to be developed in line with the requirements of Resolution ITU-R 2-6. CPM15-2 received several contributions from the membership with a view to include relevant material in this section. However, after lengthy discussions and extensive exchange of views it was not possible to include any agreed text in this section. It was therefore concluded that various views regarding the “analysis of results of studies” be included in this section with the understanding that these views were neither discussed nor agreed by the CPM as they reflect the opinion of the proponents of each view that has its own stand and the views are diverging significantly.

Extensive efforts were spent during the WP5B July 2015 meeting. The meeting received 20 contributions in addition to the Annex 18 of the WP5B Nov 2015 Chairman Report. Unfortunately, there was no agreement on further development and upgrade of the document to higher category and thus kept it as WORKING DOCUMENT TOWARD PDNR. At the end, it was not agreed in the WP5B to retain the draft as contained at November meeting. It was agreed to delete the editor's note at the beginning of the document and include a text in the WP5B chairman report to report the status of the document and carry forward all the contributions and the current version WD-PDN Report ITU-R M.[UAS-FSS] to the next study cycle while statements from some countries would be recorded.

The statement to be included in the WP5B Chairman Report July 2015 meeting is shown below:

“There was no agreement

a) on WD towards preliminary draft Report ITU-R M [UAS-FSS] and

b) on updating this report based on the materials received in the July meeting of WP5B due to the complexity of the issues and the divergence of views”

Consequently these input contributions together with the Annex 18 to document 5B/761 are carried forward to the next meeting.”

Working Document towards Preliminary draft new Report ITU-R M.[UAS-FSS] initiated studies that are aimed to identify the performance capability of FSS networks as well as the radio regulatory issues that would have to be addressed for an FSS link to be capable of supporting a UA CNPC link.

In fact the study even after several years is at its very early stage and the activities of the ITU-R are in form of document toward Preliminary Draft New Report which is far from being considered to yield a tangible result.

This Administration in its contribution [(ITU-R WP5B Contribution 5B/846 rev1-E)](http://www.itu.int/md/R12-WP5B-C-0846/fr) indicating that:

*Quote*

“*This Administration maintains its position and is of the strong believes that:*

1. *The introductory text should remain as it is until all questions are answered and all doubts are removed.*
2. *The document, irrespective of its development should NOT BE UPGRADED to a PDNR. Until administrations which have raised concerns ,including this administration have the opportunity to attend the meeting and discuss the matters further with an objective that are divergence views are reconciled.*
3. *The document should continue to be placed in physical bold square bracket until the subsequent meeting of WP 5B in 2015 in which this administration would have the opportunity to attend that meeting and discuss the pending issues in detail with other administrations.”*

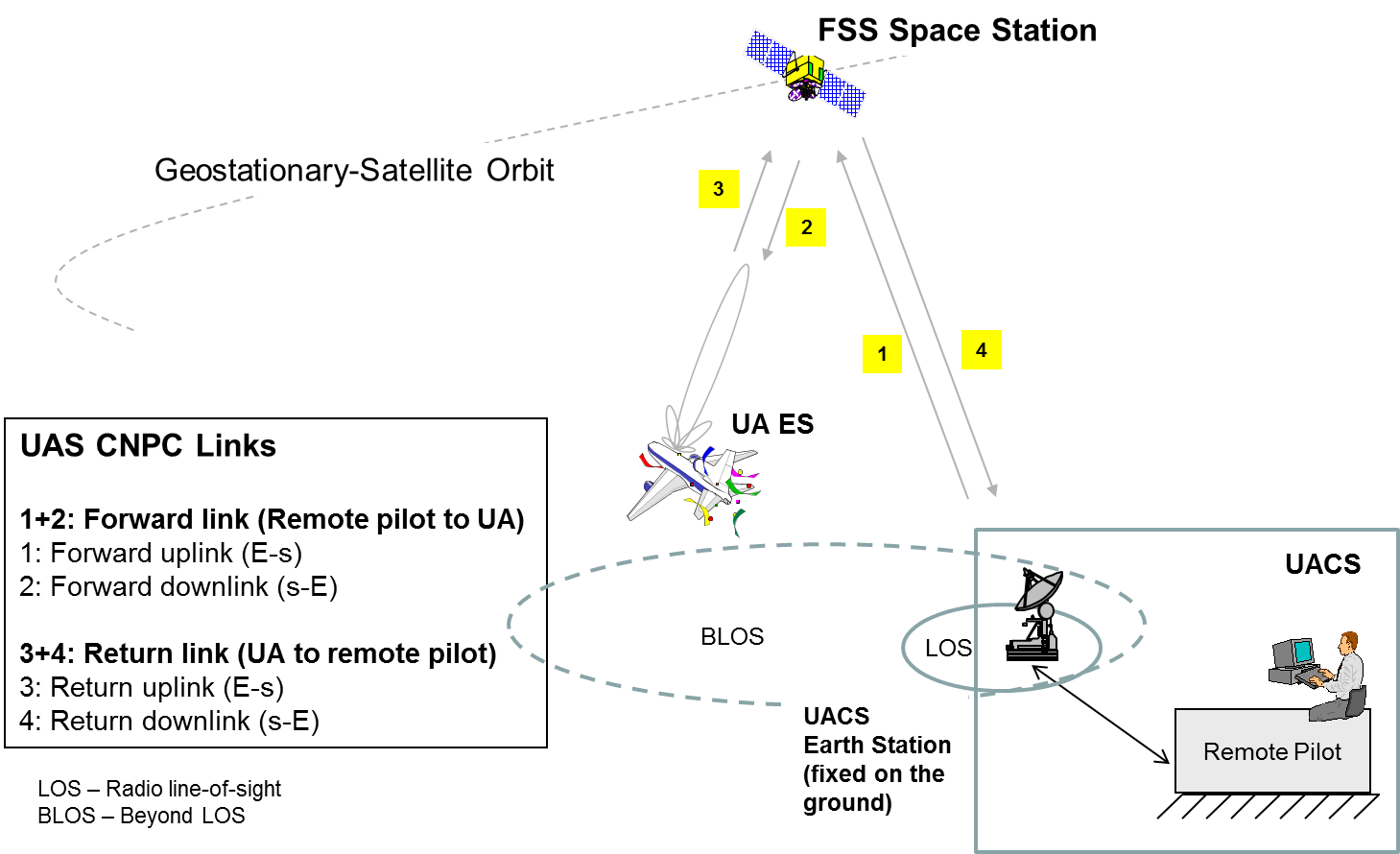
*Unquote*

# 3 Overview of the case study

As a contributing group, WP 4A has developed preliminary draft new Recommendation ITU-R S.[FSS-REF\_FOR\_UA] *Technical and operational characteristics of unmanned aircraft control and non-payload satellite communication links operated in certain frequency bands allocated to the fixed-satellite service not subject to RR Appendices 30, 30A and 30B* (annex 14 to [4A/591](http://www.itu.int/md/R12-WP4A-C-0591/en)). However, based on the agreement reached at the Working Party 4A this preliminary draft Report will not be further developed until WRC-15 decides on the Agenda item 1.5. In other words, this Report would in no way be used or considered to be suitable for the purpose of satisfying some or all difficulties of the technical and operational characteristics of UAS CNPC, until a decision has been made whether or not to support the provision of this Agenda item at WRC-15.

Figure 1

Typical BLOS CNPC links in an Unmanned Aircraft System



## 3.1 Suitability of FSS for UAS control and non-payload communication

As invited by Resolution 153 (WRC-12), all studies have focused on radio regulatory conditions for UA CNPC applications operating in the FSS under flight conditions applicable for non-segregated airspaces. Studies are ongoing for links 1 and 4 (between UAS control stations and the FSS satellite network) as well as links 2 and 3 (between UAS and the FSS satellite network). These studies addressed sharing between these links and the existing services in certain bands allocated to the FSS, but excluded the effect of **accidental interference** due to **malfunctioning equipment, mispointed antennas, power limits exceeding coordinated limits**, **exceeding uncoordinated operation of networks** etc. The results of the sharing studies to the extent carried out using FSS interference environment for links 2 and 3 **which are in fact aeronautical mobile earth stations and not FSS earth stations** fare provided in Sections 3 and 4, as well as Annexes 5 through 7, of ITU-R Report M.[UAS-FSS]. Additional aspects of this agenda item were also studied (e.g., technical and operational feasibility as well as the regulatory environment) were initiated and yet to be completed, which are also provided in other sections and annexes of the report.

For links 1 and 4:

For links 1 and 4, the sharing study results lead to the following conclusions:

Technical and operational aspects are to be within the envelope of typical characteristics of the Earth station as coordinated and recorded in the MIFR under the relevant provisions of Articles 9 and 11of the Radio Regulations. However if, the characteristics are more sensitive than those of specific or typical Earth stations regulatory consequences of that situation are to be addressed in the document towards preliminary draft new Report ITU-R RS.[UAS-FSS]. This implies that the characteristics of earth station be individually notified to the Bureau enabling Administrations and the Bureau to verify that whether in practice such notified characteristics are or are not within the envelope of specific or typical earth stations of satellite transponder coordinated and notified to the Bureau. Moreover, if the characteristics are different from those coordinated and notified in the sense that the earth station become more sensitive with respect of reception of interference these would cause serious difficulties in regard with safety aspect of the flight. It is therefore very important to carefully consider such occurrence due to the fact that accepting to receive interference than those coordinated would run the risk of safe flight of the UA.

A serious ambiguity of the regulatory status of the Radio link between the unmanned aircraft control stations and the fixed satellite service space station (Links 1 and 4) exist if the earth station is not at fixed point due to the fact that the use of mobile earth stations in the FSS is not compatible with the FSS definition.

Moreover, 50% of the FSS links intended to be used for this purpose have not completed the required coordination and operating under RR 11.41 and as a consequence cannot cause interference nor claim protection from interference with respect to networks previously recorded in the MIFR for which agreement has not been obtained. The remaining of the FSS links are also coordinated under the traditional FSS use for commercial operation under the probability of interference they accepted during coordination. The assignment and use of these frequencies for UAS CNPC would require the satellite operator to meet a high degree of performance availability and service availability of the communication links required for the safe operation of UAS CNPC in order to satisfy 4.10.

It was noted that studies are yet been carried out in regard to compatibility with other services for Link 1 and Link 4.

For links 2 and 3:

For links 2 and 3, the sharing study results lead to the following conclusions:

For the radio links between the unmanned aircraft earth station and the fixed satellite service space station (links 2 and 3) it is worth mentioning that, unmanned aircraft earth station is of mobile nature (aeronautical mobile earth station) and thus is not compatible with the definition of the FSS to operate within that service. Should WRC-15 authorize such use by adopting new footnotes, it would be in full contradiction with its earlier decision taken at WRC-12 under agenda item 1.2 not to modify the definitions relating to any satellite service as currently contained in Article 1 of the Radio Regulations. Any, reconsideration of the matter at WRC-15 would entirely modify the scope of the space services definition in the RR Consequently the operation of Radio links between the unmanned aircraft Earth Station and the fixed satellite service space station (Links 2 and 3) would be in full contradiction with the spirit and the letter of the Radio Regulations and create a series of complex regulatory environment which hamper the operation of the Space Service.

Moreover, the compatibility of the earth station on board aircraft (aeronautical mobile earth station) with incumbent services needs to be separately examined. When doing such compatibility with other space services, the notion of network coordination needs to be strictly pursued. In such approach the class of the earth station on board aircraft and that of the space station (FSS) does not match as the class of station of the on board aircrafts TJ and the class of station of the space station is EC. **Consequently no compatibility analysis could be carried out in order to address the coordination and compatibility issues.**

The mobile nature and the wide area of operation of the earth stations on board aircraft have been taken into account in sharing studies assuming the interference environment prevailing for fixed earth station which is inconsistent with the actual environment; **however, these studies have not been completed**.

ITU-R working documents mentioned above refer to the potential for interference from incumbent services to earth station receivers on unmanned aircraft operating in the frequency bands 10.95-11.20 GHz, 11.45‑11.70 GHz, 11.70-12.20 GHz in Region 2, 12.20-12.50 GHz in Region 3, and 12.50‑12.75 GHz in Regions 1 and 3 based on the unrealistic interference environment. These incumbent services are FSS, FS, MS, RDS, SRS, MSS and BSS. The compatibility between incumbent services and UAS-CNPC networks are discussed in annexes 5, 6 and 7 of Document Towards a Preliminary Draft Report ITU-R M. [UAS-CNPC]. However, this document apart from using irrelevant interference environment is still at very early stage of development and no consensus has been emerged on any of the studies. The introductory part of this Report describes the non-agreement and divergence of views on all parts of the Report.

The conducted studies are based on the assumption that UA CNPC links will have the same technical characteristics as the FSS traditional systems operating in the same frequency bands. However absence of information from ICAO about the required service and performance availability level of UA CNPC links does not allow to determine their protection criteria. Since for the systems in the services having allocations in the considered frequency bands the protection criteria are available the compatibility study results of UA CNPC link on board transmitter with the systems in the fixed service in the frequency bands 14.0-14.5 GHz, 27.5-29.5 GHz are provided in WD towards PDNR ITU-R M.[UAS-FSS]. These study results show that under some conditions (for example flight altitude will exceed 3000 feet) the compatibility of UA CNPC link on board transmitters with FS station receivers is feasible. However these results were obtained for the protection criteria of FS stations extracted from Recommendations ITU-R F.758-5 and ITU-R F.1494 that do not specify the basic period of time for which the time percentage is determined. In addition the usage of cumulative distribution function with respect to meeting the indicated criteria is under question. Due to absence of the protection criteria for UA CNPC links it is impossible to carry out the compatibility studies of the systems in the services having allocation in the considered FSS frequency bands not subject to RR Appendixes 30, 30A and 30B with UA CNPC links. Therefore WD towards PDNR ITU-R M [UAS-FSS] contains the results of parametric studies of interference which allows to estimate the time percent when the given value of interference to noise ratio at UA CNPC receiver input. Currently WD towards PDNR ITU-R M [UAS-FSS] contains only estimation results of interference impact caused by FS stations.

It should be noted that the study results given in WD towards PDNR ITU-R M [UAS-FSS] do not allow solving the issue related to possible usage of the frequency bands allocated to FSS not subject to RR Appendixes 30, 30A and 30B for operation of UA CNPC.

In addition it should be noted that in the conducted studies the technical and regulatory conditions to meet the earlier achieved coordination agreements by UA CNPC are not determined. It does not allow ensuring that the stations currently operating in the terrestrial and satellite services can operate without failure in case UA CNPC operates in the frequency bands allocated to FSS.

## 3.2 Status of assignments recorded in the Master International Frequency Register (MIFR)

Today there are over 300 FSS satellites in the geostationary-satellite orbit, operating in frequency bands regulated by and filed for processed under Articles 9 and 11 of the Radio Regulations together with the relevant Appendices, almost one satellite per degree along the geostationary arc. When applying Article 11 of the Radio Regulations to enter the satellite network into the MIFR, administrations which have not succeeded to complete the process of coordination may ask the Bureau to carry out C/I calculations to determine whether incoming assignments could cause interference to the existing assignments. Should the result of that examination be unfavourable, the notifying administration may request the Bureau to enter the assignment into the MIFR under RR **No. 11.4 with outstanding coordination under the conditions mentioned in RR 11.41**. All geostationary satellites operating in frequency bands allocated to the fixed-satellite service (FSS) not subject to RR Appendices 30, 30A or 30B are subject to coordination with other satellite networks as required pursuant to RR No. 9.7. In addition to the above coordinating, administrations having specific earth stations in the FSS within their territory need to carry out the required coordination under RR No. 9.17 or 9.17A with respect to terrestrial services (the territory of the notifying administration of these terrestrial services are located inside the coordination contour of the earth station, established by the relevant provisions of the Radio Regulations) to gain the required protection from interference from terrestrial services and also to ensure that emissions from the typical earth stations do not interfere with terrestrial networks. It should be noted that the coordination contours are generated with a methodology developed for earth stations on ground **and not for airborne earth stations**. From the submission of the Advance Information Publication under RR No. 9.1, administrations need to submit the first notification under RR Article 11and bring the satellite network into use within the maximum regulatory time limit of 7 years.

Coordination of satellite networks under Article 9 of the Radio Regulations is a regulatory obligation, however, the details of the agreements reached is a matter stemmed from bilateral or multilateral negotiations. Nevertheless, the Bureau needs to be informed that coordination has been completed with affected administrations, without a need to be informed on the details of the agreement i.e. the level of interference which has been accepted among the concerned administrations as results of the global coordination of several satellite networks, which were negotiated during the coordination process. At the time of notification, when the Bureau examines the notified assignment it also examines the status of coordination to determine its finding under RR No. 11.32 or RR No. 11.32A as the case may be.

It should be noted that most satellite networks are today seen to be brought into use without completion of all the required coordination with other satellite networks; that is these networks do not have favourable findings in the MIFR with respect to RR No. 11.32. This means that both the operational limitations (in terms of protecting other networks) and interference scenario (in terms of being protected against interference from other networks) are not fully determined.

– Coordinated limits are set out in bilateral agreements between countries and the details of these are seldom released to ITU and are normally not publicly available.

– The degree of safe and predictable operation of the UAS depends amongst others on:

i) The degree of coordination of the used satellite network as well as that of neighbouring satellite networks;

ii) The licensing conditions of the various countries involved in the operation of the used and the neighbouring satellite networks;

iii) The contractual arrangements of the satellite operators in the vicinity of the used satellite network with their service providers and in turn their end users and the degree of protection obtained through the conditions prescribed in these contracts and licenses;

iv) The ability to safeguard and ensure compliance with prescribed limits and avoidance of harmful interference.

At its May 2012 meeting, ITU-R WP 4A received a liaison statement from WP 5B on use of the fixed-satellite service to support safe operation of UAS in non-segregated air space. During the discussion associated with this liaison statement, WP 4A agreed to “request the BR to provide information on the status of FSS frequency assignments currently within the MIFR (e.g. initially recorded under No. 11.38or No. 11.41, currently recorded provisionally or definitively, etc.)”, (see § 4.2 of Document 4A/61, Chairman’s Report). The Radiocommunication Bureau provided a summary of the status of frequency assignments recorded in the MIFR (status 50) in the bands 14-14.5 GHz, 10-95-12.75 GHz, 17.7 20.2 GHz and 27.5-30 GHz. The total number of groups of FSS assignments in the MIFR as at 20 July 2012, in all the bands listed above, is 32,348 and a break-up of the number of groups recorded with and without the need for application of RR No. 11.41are shown below:

– No. of Groups without application of RR No. 11.41(coordination complete): 15,415

– No. of Groups for which RR No. 11.41has been applied:16,933

– No. of Groups considered definitive (recorded on or before 20.09.2005): 9,419

– No. of Groups considered definitive (recorded with CR/C on or before 20.09.2005): 4,916

– No. of groups which may not yet be considered definitive: 2,598

It was noted that the above survey reveals that more than 50% of the assignments for FSS are recorded in the MIFR under RR No. 11.41 - that is non-protection and non-interference basis. The question was raised that how an assignment which is recorded with non-protection could be used to provide the radio link for unmanned aircraft system which is a safety of life and safety of fight application?

The situation may be worse today in respect of the increase number of uncoordinated satellite Networks due to the fact that RR 11.41 together with corresponding regulatory provisions were much simplified at WRC-12 in favour of uncoordinated satellite i.e. the number and interfering conditions of non-coordinated satellite networks have been increased.

## 3.3 Impact of the provision of RR No. 11.41 on UAS CNPC links operating in fixed satellite service allocations

When considering the impact of RR No. 11.41 on UAS CNPC links in FSS bands, there are four issues to be considered:

Issue 1: the UAS operates in a frequency assignment notified under No. 11.41 and cause harmful interference to a recorded assignment which was the basis of the unfavourable finding;

Issue 2: the UAS operates in a frequency assignment notified under No. 11.41 and receives harmful interference from a recorded assignment which was the basis for the unfavourable finding;

Issue 3: the UAS operates in a frequency assignment notified under No. 11.41and receives harmful interference from an assignment of another satellite network which is recorded under No. 11.41in respect of the assignment under which the UAS CNPC links are operating;

Issue 4: the UAS operates in a frequency assignment notified under No. 11.32and/or No. 11.32Abut could receive interference from a frequency assignment notified under No. 11.41in another network.

Regarding Issue 1, the UAS might have to **immediately cease operation** on the assignment notified under No. 11.41, in the case that the “victim” network, with which coordination could not be completed, claims that the assignment notified under No. 11.41 causes harmful interference (as per No. 11.42). As a consequence, before allowing the UAS CNPC service on its network, the satellite operator would need to examine those networks with which coordination could not be completed and make a judgement about the risk of causing harmful interference to those networks. If such networks do not exist, the UAS satellite operator might reasonably conclude that there is no risk of causing harmful interference and that the assignment notified under No. 11.41 is suitable for UAS operations. **If the satellite operator considers that there is a risk of harmful interference being caused, the assignment notified under No. 11.41 should not be used at all or should be used with reduced power. This might make such a frequency assignment unsuitable for UAS operations,** however, a detailed assessment should be carried out on a case-by-case basis.

Regarding Issue 2, if the UAS satellite operator receives harmful interference from an assignment against which No. 11.41has been used by the assignment under which the UAS CNPC link operates, there is no obligation on the administration of the interfering network ( used for CNPC ) to eliminate the interference. The UAS satellite operator therefore would need to make an assessment as to the probability of receiving harmful interference, possible mitigation techniques, alternative solutions and the implications on the safe operation of the UAS. This makes the use totally unreliable and uncertain and in fact put the safety of flights of UA and other manned aircrafts at full risk.

Regarding Issue 3, if the UAS satellite operator receives harmful interference from the assignment notified under No. 11.41in another network, the latter should immediately cease operation, as per No. 11.42. In practice, **this would not happen immediately so it could have serious consequences for a UAS.** Any assignment has some risk of interference and, as for *Issue 1 and 2*, the satellite operator should plan for the eventuality of interference. Which makes the use totally unreliable and uncertain and in fact put the safety of flights of UA and other manned aircrafts at full risk.

It should be noted that, as for *Issue 2 and 3*, the satellite operator would need to plan for such interference.

Regarding Issue 4, if the UAS operates in a frequency assignment notified under No. 11.32and/or No. 11.32A(i.e. coordination completed), it could still receive interference from a frequency assignment notified under No. 11.41in another network. In this case, if harmful interference occurs, the administration and/or satellite operator of the assignment notified under No. 11.41 is obliged to immediately eliminate this harmful interference as per the application of No. 11.42. This would however be only possible after the interference has occurred, the interfering source has been identified, the interference has been reported and the interfering administration and operator has taken corrective actions.

## 3.4 ICAO air safety conditions and results of ITU-R studies on these

ICAO has identified seven conditions to be addressed by the studies. During the WP5B July 2015 meeting, ICAO has provided its final position and reconfirm the ICAO 3 conditions, which will have to be addressed in the ITU Radio Regulations as follows:

1 That the technical and regulatory actions be limited to the case of UAS using satellites, as studied, and not set a precedent that puts other aeronautical safety services at risk.

2 That all frequency bands which carry aeronautical safety communications be clearly identified in the ITU Radio Regulations.

3 That the assignments and use of the relevant frequency bands be consistent with article 4.10 of the ITU Radio Regulations which recognizes that safety services require special measures to ensure their freedom from harmful interference.

Table below provides a summary of the results of the studies in respect of the conditions based on detailed analyses.

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| **ICAO condition #1** “That the technical and regulatory actions should be limited to the case of UAS using satellites, as studied, and not set a precedent that puts other aeronautical safety services at risk” |
| **Results of studies:** Appropriate radio regulatory provisions would need to be developed for the FSS bands where UAS CNPC application would be provided. These could include a footnote, pointing to a WRC-15 Resolution together with the Annexes/Attachment thereto to precisely describe the condition of use and the associated detailed regulatory procedure, allowing use of FSS by UAS aircraft earth stations at fixed points, describing the characteristics of the service necessary to ensure safe operation, and pointing to a Resolution which provides additional requirements. These provisions should be limited to UAS CNPC and should only become applicable when such an application was provided. However, to what extent such a solution for UAS CNPC links can be stopped from being picked up by others to provide similar solutions for other services and applications later is unknown. |
| **ICAO condition #2** “That all frequency bands which carry aeronautical safety communications need to be clearly identified in the Radio Regulations” |
| **Results of studies:** The FSS frequency bands to support UAS CNPC should be clearly identified in the Radio Regulations through the inclusion of a footnote and associated Resolution. However, how and to what extent the safety nature of these applications can be reflected in the Radio Regulations is unknown.  This condition is interpreted by some parties, as the need for UAS CNPC links to operate in spectrum allocated to an appropriate aeronautical safety service. Direct identification in Article 5 of certain FSS frequency bands for UAS CNPC use should be avoided because it may unduly give the impression that UAS CNPC links should preferably use this allocation, instead of other suitable allocations such as AMS(R)S, AMSS or MSS. |
| **ICAO condition #3** “That the assignments and use of the relevant frequency bands have to be consistent with article 4.10 of the Radio Regulations which recognizes that safety services require special measures to ensure their freedom from harmful interference” |
| **Results of studies:** No explanation on how this condition could be implemented. In consideration under this agenda item, no proposals have been made to introduce UAS CNPC in frequency bands identified for safety services. Consideration under this agenda item has focused on possible use of regular FSS bands, normally shared with other terrestrial services, for providing UAS CNPC.  It should be also noted that any association of RR No. 4.10 to the CNPC is not a matter within the purview of the ICAO and thus shall be discussed and examined by ITU .In this connection it would put a dangerous precedence if the use of FSS transponder for CNPC be associated with RRNo.4.10 or provide these FSS transponders a status of RR No. 4.10 or similar due to the fact that FSS are normally a commercial service and should not have any special status identical or similar to that of RR No. 4.10. |
| **ICAO condition #4** “Knowledge that any assignment operating in those frequency bands:  is in conformity with technical criteria of the Radio Regulations;  has been successfully co-ordinated, including cases where co-ordination was not completed but the ITU examination of probability of harmful interference resulted in a favourable finding, or any caveats placed on that assignment have been addressed and resolved such that the assignment is able to satisfy the requirements to provide BLOS communications for UAS; and  has been recorded in the International Master Frequency Register” |
| **Results of studies:** The regular FSS bands are heavily congested by operational satellites and even more by submissions to ITU for satellite networks and coordination of satellites is becoming increasingly difficult, if not impossible. For these reasons, several issues have been proposed to various WRCs in response to WRC Resolution 86 (Agenda Item 7 of WRC-15) to address the issue. Studies conducted by the Bureau shows that more than 50% of all assignments recorded in the Master International Frequency Register are recorded under RR No. 11.41 which means that coordination is not completed. Furthermore, a large majority of networks recorded in the MIFR today are forced to use RR No. 11.41 because of unfinished coordination.  This means that being listed in the MIFR does not give any indication about completion of coordination or a favourable finding in respect of the probability of harmful interference into other satellite networks with higher priority.  It should be noted that a successful registration in the MIFR (favourable findings under No. 11.32) does not mean that the assignment is free from harmful interference, since it is possible to obtain such a finding by accepting the interference created by prior satellite networks. References to No. 11.42 or No. 11.42A indicate that, in cases of harmful interference, no protection is given. |
| **ICAO condition #5** “That interference to systems is reported in a transparent manner and addressed in the appropriate time-scale” |
| **Results of studies:** Interference between FSS networks happens on a regular basis, often several times per week in various transponders and frequency bands. This may be the result of inappropriate use of satellite transponders, malfunctioning equipment or mispointed antennas, end users exceeding power limits or launch and bringing into use of satellites without the required coordination. Even if the satellite network providing the UAS CNPC has completed all coordination and complies with all limits, this is no guarantee for avoiding interference due to accidental interference or uncoordinated operation of neighbouring satellite networks. Cases of interference are normally sorted out between the satellite operators or countries involved and are very rarely reported to ITU. The ITU databases therefore will provide little information about the actual interference situation. |
| **ICAO condition #6** “That realistic worst case condition with inclusion of a safety margin can be applied during compatibility studies” |
| **Results of studies:** It has been assumed that this application would operate under the envelope of the technical parameters of regular FSS. The results of the sharing studies are provided in Sections 3 and 4, as well as Annexes 5 through 7, of ITU-R Report M.[UAS-FSS]. Additional aspects of this agenda item were also studied (e.g., technical and operational feasibility as well as the regulatory environment) and provided in other sections and annexes of the report. If these studies took into account worst case conditions, regular conditions or more optimistic conditions and if they included the appropriate margins vary throughout the different studies. |
| **ICAO condition #7** “That any operational considerations for UAS will be handled in ICAO and not in  the ITU” |
| **Results of studies:** It is expected that ITU and ICAO will carry out their mutual responsibilities in a cooperative manner. It is important that the respective roles of ICAO and the ITU be fully understood to ensure appropriate separation of regulatory needs to be addressed in the RR and operational issues to be addressed by ICAO processes. In this context, ITU would develop the typical conditions for operation of CNPC links, and then, ICAO would develop further operational conditions to ensure safe operation. |

## 3.5 Experience gained with unmanned aircraft flights under RR no. 4.4

Considering e) of Resolution 153 (WRC-12) states that UAS already operate in FSS frequency bands for UA-to-satellite CNPC links under RR No. 4.4, however, there is no formal documentation on those UA-to-satellite CNPC links deployment history and their impact on other services and other FSS applications. Furthermore, there is no public announcement of such information in any form in the ITU-R publications because there is no obligation for Administrations to make notification under RR No. 4.4 in the FSS frequency bands. Examples of such deployment has not be quoted as there is no information up to the completion of this report.

## 3.6 Occurrence of interference

The 50% of assignments examined by the Radiocommunication Bureau which are recorded with favourable finding, it was noted that the occurrence of harmful interference is a matter which needs careful consideration to decide whether a FSS link subject to such unpredictable interference could be used to provide radio link for an application having safety of life and safety of flight nature. In many areas on the Earth, harmful interference between FSS networks happens on a regular basis, often several times per week in various transponders and frequency bands[[1]](#footnote-1). This is due to amongst others, hijacking and illegal use of satellite transponders, malfunctioning equipment or misprinted antennas, end users exceeding power limits (e.g. when encountering operational problems) and launch, testing and bringing into use of satellites without the required coordination. Even if the satellite network providing the UAS CNPC has completed all coordination and complies with all limits, this is no guarantee for avoiding interference due to accidental interference or uncoordinated operation of neighbouring satellite networks. Cases of harmful interference are normally sorted out between the satellite operators or countries involved and are very rarely reported to ITU. The ITU databases therefore will provide little information about the actual interference situation.

**For amongst these reasons, it would seem likely that harmful interference also for UAS CNPC operation in the FSS bands would be expected in many areas of the Earth on a regular basis, just like that for other FSS operation in the bands.**

It should be noted that interference can occur on FSS links for a variety of reasons, regardless of how the frequency assignments supporting those links are recorded in the MIFR. In the vast majority of cases when interference does occur, satellite operators rapidly contact the suspected source of interference to resolve the issue. It was further noted that given the experience that satellite operators have with such cases, most interference events are resolved quickly; meaning that most interference events are relatively short lived. **However, one of the issues to be considered is whether satellite networks can be operated in such a manner so as to ensure that interference occurrence and time and duration as such is really suitable to meet the performance/availability objectives of UAS CNPC links.**

More importantly, as stipulated in Resolution 153(WRC-12) the safe flight operation of UAS needs reliable communication links and associated spectrum, especially for the remote pilot to command and control the flight and to relay the air traffic control communications, also referred to as control and non-payload communications (CNPC) and that, pursuant to No. 4.10 of the Radio Regulations, Member States recognize that the safety aspects of radionavigation and other safety services require special measures to ensure their freedom from harmful interference; it is necessary therefore to take this factor into account in the assignment and use of frequencies. These conditions are almost impossible, if not totally impossible, to be achieved with FSS links 50% of which are recorded under RR No. 11.41 with non-protection basis. **In addition to that, even those FSS which are recorded with favourable finding under RR 11.31, RR 11.32 or RR 11.32A are subject to the occurrence of interference as mentioned above.**

Moreover, even if, and only if, FSS links could be used for radio link 1 and 4 which have fully coordinated with all identified administrations and recorded in the MIFR with favourable finding RR 11.31 and RR 11.32 the following issues should be considered.

a) When two administrations coordinate under relevant procedure of Article 9 FSS Transponder or Group of emissions and inform the Bureau of the completion of coordination they do not provide the details of coordination i.e. the value and level of interference that they agreed during the coordination. This may not cause major problem for the operation of commercial FSS links due to the fact that some level /degree of interference could be tolerated as an operational environment. However, when that link is considered for use in an unmanned aircraft a fraction of interference could lead to the false signal to guide the aircraft in order to properly function.

b) On the other hand even if all interference level could be matched to achieve the required service availability, any FSS, apart from those which were involved in the coordination and which would be brought into use at later stage could cause harmful interference to the FSS linked already coordinated. In addition the term “harmful Interference “is a subjective term as defined in Article 1 of the RR.

***Quote***

“Harmful interference: Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations”

***Unquote***

This definition has two parts:

**The first part addresses the functioning of a radionavigation service or of other safety services. This part is not relevant to UAS due to the fact that the FSS link intended to be considered for use For UAS is neither radionavigation service nor of other safety services.**

The second part addresses interference which seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations. This is a part which would be applicable to FSS to be considered for use in UAS. **However, the expression seriously degrades or obstructs or repeatedly interrupts FSS is not appropriate for UAS due to the fact that even an interference which not seriously degrade the FSS is dangerous of or the guidance and piloting the aircraft.**

## 3.7 Conformity of UA with technical characteristics and protection criteria associated with the FSS

ITU-R Study Groups concerned are currently dealing with two types of Typical FSS systems characteristics:

a) Those which are used in standard and traditional commercial FSS and

b) Those characteristics assumed for UA CNPC application which in certain area are different from those mentioned in a) above.

Using characteristics referred to in b) above could create regulatory implication to the extent that if they are not within the characteristics of the specific or typical earth station notified FSS network they could require additional coordination. Moreover, even if the conditions mentioned above are met, should the system characteristics be more sensitive than those notified they could be more vulnerable to interference from other satellite networks. Under both of these two circumstances the occurrence of the interference would hamper the reliability and service availability of the unmanned aircraft system.

Currently the ITU-R is studying the required protection criteria for the operation of UAS CNPC using FSS links. However, it is not clear how the FSS links used for CNPC could have different protection criteria than those used in the FSS links employed for this purpose.

It should also be noted that in many cases, the FSS has a nature of operation by a commercial satellite operator. The operation license is issued by a country. Possibly the spacecraft is licensed by a country far away from where the actual operation takes place and different from that of the country licensing the earth stations. Moreover, transmitting and receiving earth stations are often operating in a country without individual licensing or coordination under a class type of license (e.g. VSAT type of networks).

Other issues that may be considered by the ITU-R include the fact that satellite operators are normally not the end user of the services, but will lease capacity to service providers who in turn will sell services to the end users. Those end users could be private entities, broadcaster, government, etc. Normally, these end users will then procure, establish and operate the earth stations accessing the satelliteunder a license which normally will be granted by an administration different from that granting the license for the satellite network. Compliance with coordinated limits has to rely on limitations passed on to the end user from the notifying administration of the satellite network. The ability to pass on and enforce these, not only for the satellite network providing the CNPC links, but even more so for adjacent satellite networks, therefore is important in assessing the ability to control the interference into CNPC links.

In view of the above, the concept of the use of commercial FSS which does not benefit the safety of life aspects as described in RR 4.10 is totally inappropriate.

Under UAS, we are not dealing with commercial and standard communication rather dealing with a very highly sensitive issue of guiding tens of unmanned aircraft in non-segregated air space together with tens of manned aircraft in the airspace in which a small amount of interference could misguide the unmanned aircraft colliding with other unmanned and manned aircraft.

Never ever a radiocommunication which does not benefit the safety of life provision could be used for an application which is even much more sensitive than any other radiocommuncation with safety of life aspect.

Here we are dealing with tens of unmanned aircraft guided by one pilot totally depending on the interference free operation of the FSS which never is available in any commercial FSS.

## 3.8 Compatibility with terrestrial services

Using the on‑board station of UA CNPC links in FSS bands leads to the fact that the protection and coordination distances between these stations and stations of terrestrial services may increase several times compared to the current values. This increase depends on the flight altitude of the unmanned aircraft. This substantially changes the conditions of compatibility and current coordination conditions of the FSS earth stations with stations of terrestrial services.

In the ITU‑R, there have been no studies that determine the technical and regulatory conditions of on‑board station of UA CNPC links operation, ensuring that existing coordination conditions of the FSS earth stations with terrestrial radio services will be met.

WD towards PDNR ITU‑R M.[UAS-FSS] studies the potential compatibility of on‑board station of UA CNPC links with stations in the fixed service in the bands 14.0-14.5 GHz and 27.5-29.5 GHz, but the above-mentioned aspects are not present in these studies and have not been investigated.

## 3.9 Compatibility with satellite services (including compatibility between different FSS networks)

The WD towards PDNR ITU‑R M.[UAS-FSS] presents the interference studies between GSO FSS satellite networks operating in the frequency bands 14/11 GHz and 30/20 GHz when one of the networks use the on-board station of UA CNPC link. However, there were no studies conducted by ITU‑R on the topic of how the conditions of compatibility (coordination conditions) between existing GSO FSS satellite networks will change when using the on‑board station of UA CNPC links instead of a coordinated typical (fixed) earth station located on the Earth’s surface. There was no evidence that these conditions will be preserved. Operating conditions of on-board stations of UA CNPC links (for example, such as a change of location, instability hold the antenna, including the instability caused by the aircraft fluctuation, antenna pattern, etc.) significantly differ from operating conditions for existing earth stations of the FSS networks, fixed on the Earth’s surface. Therefore, additional ITU‑R studies needed to determine the technical and regulatory conditions for use of the on‑board station of UA CNPC link that would ensure that the coordination conditions with other existing and future satellite networks will be met.

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1. At the ITU International Satellite communication workshop: “The ITU – challenges in the 21st century: Preventing harmful interference to satellite systems”, one international satellite operator reported that in 2012, a total of 329 826 minutes of interference had been recorded in the transponders of their fleet of satellites. Another regional satellite operator informed that in the same year, they had recorded 290 cases of interference. [↑](#footnote-ref-1)