IWG-1/38 Rev. 1

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UNITED STATES OF AMERICA

Draft Proposals for the Work of the conference

Agenda Item 1.3: *To consider spectrum requirements and possible regulatory actions, including allocations, in order to support the safe operation of unmanned aircraft systems (UAS), based on the results of ITU-R studies, in accordance with Resolution* ***421 (WRC-07)***

Background Information: Unmanned aircraft systems (UASs) enable the remote piloting of aircraft over short or long range distances within or out-of-sight of the remote pilot. These flight operations currently take place in segregated airspace to ensure the safety of the air vehicle and other airspace users.

Some administrations expect deployment of UASs throughout the airspace structure, i.e. within both segregated and non-segregated airspace. As UAS deployment increases, it will be impractical for some users to deploy in segregated airspace. Some UASs will need to integrate with the current non-segregated airspace users in a safe and seamless manner. To accomplish integration into non-segregated airspace, UASs will require high integrity communication links between the unmanned aircraft (UA) and remote control centers capable of relaying the necessary air traffic control (ATC) messages and flight critical aircraft information. The UAS pilot will need sense and avoid functions for situational awareness.

The International Civil Aviation Organization (ICAO) future communications study may be able to identify technologies with some capability to meet the requirements for command and control, including the relaying of ATC communications. The ITU-R is currently examining existing aeronautical allocations to satisfy UAS spectrum requirements prior to studying new allocations.

***Command & Co*ntrol**

In non-segregated airspace, the remote pilot must reliably monitor the status of the UA, pass control instructions to the UA, and interact with the appropriate air traffic controllers monitoring the airspace within which the UA is flying. A line-of-sight link might provide these capabilities for UA flying and maneuvering in a localized area. A combination of a terrestrial radio and satellite network could provide these capabilities to UA flying trans-horizon.

Relay of Air Traffic Control (ATC) Communications

Safe operation of manned or unmanned aircraft depends on ATC communications. Pilots act based on ATC instructions. When the aircraft is piloted remotely, the pilot and ATC

must maintain a communication channel to relay information from a radio in the aircraft to the pilot on the ground. Early concepts assume that this function, if digitized, could be part of the command and control links.

Sense and Avoid

The safe flight operation of UA necessitates advanced techniques to detect and track nearby aircraft, terrain, and obstacles to navigation. Unmanned aircraft must avoid these objects in a manner equivalent to that of a manned aircraft. The remote pilot will need to be aware of the environment within which the aircraft is operating, be able to identify the potential threats to the continued safe operation of the aircraft, and take the appropriate action. The radiodetermination service allocations could potentially accommodate the sense and avoid function. The ITU-R is examining existing aeronautical radionavigation service (ARNS) allocations for suitable bandwidth prior to studying new ARNS allocations. The UAS industry is studying the suitability of various technologies for sense and avoid.

Payload

Resolution **421 (WRC-07)** *Resolves 1* specifically excludes the allocation of spectrum at WRC-11 for payload applications. However, *invites ITU-R 3* does call for the development of an ITU-R report or recommendation on how to accommodate the radiocommunication requirements for UAS payloads. The purpose of this agenda item is not to seek new spectrum allocations to meet payload requirements.

UAS control link communication could potentially be accommodated by the FSS through the use of portions of the existing 11/12/14 GHz and 20/30 GHz FSS allocations. Specifically through the addition of an appropriate footnote to the Table of Frequency Allocations that would in turn reference a New ITU-R Recommendation. The use of the aforementioned FSS bands can contribute to satisfying the UAS beyond line-of-sight communications requirements. Another method that can be used to satisfy the UAS beyond line-of-sight communication requirements would be the addition of new AMS(R)S allocations within portions of the 22.50 – 22.55 GHz or 23.55-23.60 GHz bands.

Studies indicate that the existing ARNS allocations can support UAS Sense and Avoid operations so no change to the existing ARNS allocations is proposed. Thus, no regulatory and procedural considerations are required to address the UAS Sense and Avoid portion of Resolution **421 (WRC-07)**.

Proposal:

10-11.7 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
10-10.45 FIXED MOBILE RADIOLOCATION Amateur 5.479	**10-10.45** RADIOLOCATION Amateur 5.479 5.480	**10-10.45** FIXED MOBILE RADIOLOCATION Amateur 5.479
10.45-10.5	RADIOLOCATION Amateur Amateur-satellite 5.481	
10.5-10.55 FIXED MOBILE Radiolocation	**10.5-10.55** FIXED MOBILE RADIOLOCATION	
10.55-10.6	FIXED MOBILE except aeronautical mobile Radiolocation	
10.6-10.68	EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE except aeronautical mobile RADIO ASTRONOMY SPACE RESEARCH (passive) Radiolocation 5.149 5.482 5.482A	
10.68-10.7	EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) 5.340 5.483	
10.7-11.7 FIXED FIXED-SATELLITE (space-to-Earth) 5.441 5.484A 5.YYY (Earth-to-space) 5.484 MOBILE except aeronautical mobile	**10.7-11.7** FIXED FIXED-SATELLITE (space-to-Earth) 5.441 5.484A 5.YYY MOBILE except aeronautical mobile	

11.7-14 GHz

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td rowspan="2">11.7-12.5
FIXED
MOBILE except aeronautical mobile
BROADCASTING
BROADCASTING-SATELLITE
5.492

5.487 5.487A</td><td>11.7-12.1
FIXED 5.486
FIXED-SATELLITE (space-to-Earth) 5.484A 5.488 5.YYY
Mobile except aeronautical mobile
5.485</td><td rowspan="2">11.7-12.2
FIXED
MOBILE except aeronautical mobile
BROADCASTING
BROADCASTING-SATELLITE
5.492

5.487 5.487A</td></tr>
<tr><td>12.1-12.2
FIXED-SATELLITE (space-to-Earth) 5.484A 5.488 5.YYY
5.485 5.489</td></tr>
<tr><td rowspan="2">12.5-12.75
FIXED-SATELLITE (space-to-Earth) 5.484A 5.YYY (Earth-to-space)

5.494 5.495 5.496</td><td>12.2-12.7
FIXED
MOBILE except aeronautical mobile
BROADCASTING
BROADCASTING-SATELLITE
5.492

5.487A 5.488 5.490</td><td>12.2-12.5
FIXED
FIXED-SATELLITE (space-to-Earth) 5.YYY
MOBILE except aeronautical mobile
BROADCASTING
5.484A 5.487</td></tr>
<tr><td>12.7-12.75
FIXED
FIXED-SATELLITE (Earth-to-space)
MOBILE except aeronautical mobile</td><td>12.5-12.75
FIXED
FIXED-SATELLITE (space-to-Earth) 5.484A 5.YYY
MOBILE except aeronautical mobile
BROADCASTING-SATELLITE 5.493</td></tr>
<tr><td>12.75-13.25</td><td colspan="2">FIXED
FIXED-SATELLITE (Earth-to-space) 5.441
MOBILE
Space research (deep space) (space-to-Earth)</td></tr>
<tr><td>13.25-13.4</td><td colspan="2">EARTH EXPLORATION-SATELLITE (active)
AERONAUTICAL RADIONAVIGATION 5.497
SPACE RESEARCH (active)
5.498A 5.499</td></tr>
<tr><td>13.4-13.75</td><td colspan="2">EARTH EXPLORATION-SATELLITE (active)
RADIOLOCATION
SPACE RESEARCH 5.501A
Standard frequency and time signal-satellite (Earth-to-space)
5.499 5.500 5.501 5.501B</td></tr>
<tr><td>13.75-14</td><td colspan="2">FIXED-SATELLITE (Earth-to-space) 5.484A [5.ZZZ]
RADIOLOCATION
Earth exploration-satellite
Standard frequency and time signal-satellite (Earth-to-space)
Space research
5.499 5.500 5.501 5.502 5.503</td></tr>
</table>

14-15.4 GHz

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>14-14.25</td><td colspan="2">FIXED-SATELLITE (Earth-to-space) 5.457A 5.457B 5.484A 5.506 5.506B 5.ZZZ
RADIONAVIGATION 5.504
Mobile-satellite (Earth-to-space) 5.504B 5.504C 5.506A
Space research
5.504A 5.505</td></tr>
<tr><td>14.25-14.3</td><td colspan="2">FIXED-SATELLITE (Earth-to-space) 5.457A 5.457B 5.484A 5.506 5.506B 5.ZZZ
RADIONAVIGATION 5.504
Mobile-satellite (Earth-to-space) 5.504B 5.506A 5.508A
Space research
5.504A 5.505 5.508</td></tr>
<tr><td>14.3-14.4
FIXED
FIXED-SATELLITE (Earth-to-space) 5.457A 5.457B 5.484A 5.506 5.506B 5.ZZZ
MOBILE except aeronautical mobile
Mobile-satellite (Earth-to-space) 5.504B 5.506A 5.509A
Radionavigation-satellite
5.504A</td><td>14.3-14.4
FIXED-SATELLITE (Earth-to-space) 5.457A 5.484A 5.506 5.506B 5.ZZZ
Mobile-satellite (Earth-to-space) 5.506A
Radionavigation-satellite
5.504A</td><td>14.3-14.4
FIXED
FIXED-SATELLITE (Earth-to-space) 5.457A 5.484A 5.506 5.506B 5.ZZZ
MOBILE except aeronautical mobile
Mobile-satellite (Earth-to-space) 5.504B 5.506A 5.509A
Radionavigation-satellite
5.504A</td></tr>
<tr><td>14.4-14.47</td><td colspan="2">FIXED
FIXED-SATELLITE (Earth-to-space) 5.457A 5.457B 5.484A 5.506 5.506B 5.ZZZ
MOBILE except aeronautical mobile
Mobile-satellite (Earth-to-space) 5.504B 5.506A 5.509A
Space research (space-to-Earth)
5.504A</td></tr>
<tr><td>14.47-14.5</td><td colspan="2">FIXED
FIXED-SATELLITE (Earth-to-space) 5.457A 5.457B 5.484A 5.506 5.506B 5.ZZZ
MOBILE except aeronautical mobile
Mobile-satellite (Earth-to-space) 5.504B 5.506A 5.509A
Radio astronomy
5.149 5.504A</td></tr>
<tr><td>14.5-14.8</td><td colspan="2">FIXED
FIXED-SATELLITE (Earth-to-space) 5.510
MOBILE
Space research</td></tr>
<tr><td>14.8-15.35</td><td colspan="2">FIXED
MOBILE
Space research
5.339</td></tr>
<tr><td>15.35-15.4</td><td colspan="2">EARTH EXPLORATION-SATELLITE (passive)
RADIO ASTRONOMY
SPACE RESEARCH (passive)
5.340 5.511</td></tr>
</table>

15.4-18.4 GHz

<table>
<tr><th colspan="3">Allocation to services</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td>15.4-15.43</td><td colspan="2">AERONAUTICAL RADIONAVIGATION
5.511D</td></tr>
<tr><td>15.43-15.63</td><td colspan="2">FIXED-SATELLITE (Earth-to-space) 5.511A
AERONAUTICAL RADIONAVIGATION
5.511C</td></tr>
<tr><td>15.63-15.7</td><td colspan="2">AERONAUTICAL RADIONAVIGATION
5.511D</td></tr>
<tr><td>15.7-16.6</td><td colspan="2">RADIOLOCATION
5.512 5.513</td></tr>
<tr><td>16.6-17.1</td><td colspan="2">RADIOLOCATION
Space research (deep space) (Earth-to-space)
5.512 5.513</td></tr>
<tr><td>17.1-17.2</td><td colspan="2">RADIOLOCATION
5.512 5.513</td></tr>
<tr><td>17.2-17.3</td><td colspan="2">EARTH EXPLORATION-SATELLITE (active)
RADIOLOCATION
SPACE RESEARCH (active)
5.512 5.513 5.513A</td></tr>
<tr><td>17.3-17.7
FIXED-SATELLITE
(Earth-to-space) 5.516
(space-to-Earth) 5.516A 5.516B 5.YYY
Radiolocation
5.514</td><td>17.3-17.7
FIXED-SATELLITE
(Earth-to-space) 5.516
BROADCASTING-SATELLITE
Radiolocation
5.514 5.515</td><td>17.3-17.7
FIXED-SATELLITE
(Earth-to-space) 5.516
Radiolocation
5.514</td></tr>
<tr><td rowspan="2">17.7-18.1
FIXED
FIXED-SATELLITE
(space-to-Earth) 5.484A 5.YYY
(Earth-to-space) 5.516
MOBILE</td><td>17.7-17.8
FIXED
FIXED-SATELLITE
(space-to-Earth) 5.517 5.YYY
(Earth-to-space) 5.516
BROADCASTING-SATELLITE
Mobile
5.515</td><td rowspan="2">17.7-18.1
FIXED
FIXED-SATELLITE
(space-to-Earth) 5.484A 5.YYY
(Earth-to-space) 5.516
MOBILE</td></tr>
<tr><td>17.8-18.1
FIXED
FIXED-SATELLITE
(space-to-Earth) 5.484A
(Earth-to-space) 5.516
MOBILE
5.519</td></tr>
<tr><td>18.1-18.4</td><td colspan="2">FIXED
FIXED-SATELLITE (space-to-Earth) 5.484A 5.516B 5.YYY
(Earth-to-space) 5.520
MOBILE
5.519 5.521</td></tr>
</table>

18.4-22 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
18.4-18.6	FIXED FIXED-SATELLITE (space-to-Earth) 5.484A 5.516B 5.YYY MOBILE	
18.6-18.8 EARTH EXPLORATION-SATELLITE (passive) FIXED FIXED-SATELLITE (space-to-Earth) 5.522B 5.YYY MOBILE except aeronautical mobile Space research (passive) 5.522A 5.522C	**18.6-18.8** EARTH EXPLORATION-SATELLITE (passive) FIXED FIXED-SATELLITE (space-to-Earth) 5.516B 5.522B 5.YYY MOBILE except aeronautical mobile SPACE RESEARCH (passive) 5.522A	**18.6-18.8** EARTH EXPLORATION-SATELLITE (passive) FIXED FIXED-SATELLITE (space-to-Earth) 5.522B 5.YYY MOBILE except aeronautical mobile Space research (passive) 5.522A
18.8-19.3	FIXED FIXED-SATELLITE (space-to-Earth) 5.516.B 5.523A 5.YYY MOBILE	
19.3-19.7	FIXED FIXED-SATELLITE (space-to-Earth) (Earth-to-space) 5.523B 5.523C 5.523D 5.523E 5.YYY MOBILE	
19.7-20.1 FIXED-SATELLITE (space-to-Earth) 5.484A 5.516B 5.YYY Mobile-satellite (space-to-Earth) 5.524	**19.7-20.1** FIXED-SATELLITE (space-to-Earth) 5.484A 5.516B 5.YYY MOBILE-SATELLITE (space-to-Earth) 5.524 5.525 5.526 5.527 5.528 5.529	**19.7-20.1** FIXED-SATELLITE (space-to-Earth) 5.484A 5.516B 5.YYY Mobile-satellite (space-to-Earth) 5.524
20.1-20.2	FIXED-SATELLITE (space-to-Earth) 5.484A 5.516B 5.YYY MOBILE-SATELLITE (space-to-Earth) 5.524 5.525 5.526 5.527 5.528	
20.2-21.2	FIXED-SATELLITE (space-to-Earth) 5.YYY MOBILE-SATELLITE (space-to-Earth) Standard frequency and time signal-satellite (space-to-Earth) 5.524	
21.2-21.4	EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE SPACE RESEARCH (passive)	
21.4-22 FIXED MOBILE BROADCASTING-SATELLITE 5.208B 5.530	**21.4-22** FIXED MOBILE	**21.4-22** FIXED MOBILE BROADCASTING-SATELLITE 5.208B 5.530 5.531

22-24.75 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
22-22.21	FIXED MOBILE except aeronautical mobile 5.149	
22.21-22.5	EARTH EXPLORATION-SATELLITE (passive) FIXED MOBILE except aeronautical mobile RADIO ASTRONOMY SPACE RESEARCH (passive) 5.149 5.532	
22.5-22.55	FIXED MOBILE AMS(R)S	
22.55-23.55	FIXED INTER-SATELLITE 5.338A MOBILE 5.149	
23.55-23.6	FIXED MOBILE AMS(R)S	
23.6-24	EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) 5.340	
24-24.05	AMATEUR AMATEUR-SATELLITE 5.150	
24.05-24.25	RADIOLOCATION Amateur Earth exploration-satellite (active) 5.150	
24.25-24.45 FIXED	**24.25-24.45** RADIONAVIGATION	**24.25-24.45** RADIONAVIGATION FIXED MOBILE
24.45-24.65 FIXED INTER-SATELLITE	**24.45-24.65** INTER-SATELLITE RADIONAVIGATION 5.533	**24.45-24.65** FIXED INTER-SATELLITE MOBILE RADIONAVIGATION 5.533
24.65-24.75 FIXED INTER-SATELLITE	**24.65-24.75** INTER-SATELLITE RADIOLOCATION-SATELLITE (Earth-to-space)	**24.65-24.75** FIXED INTER-SATELLITE MOBILE 5.533

24.75-29.9 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
24.75-25.25 FIXED	**24.75-25.25** FIXED-SATELLITE (Earth-to-space) 5.535	**24.75-25.25** FIXED FIXED-SATELLITE (Earth-to-space) 5.535 MOBILE
25.25-25.5	FIXED INTER-SATELLITE 5.536 MOBILE Standard frequency and time signal-satellite (Earth-to-space)	
25.5-27	EARTH EXPLORATION-SATELLITE (space-to Earth) 5.536B FIXED INTER-SATELLITE 5.536 MOBILE SPACE RESEARCH (space-to-Earth) 5.536C Standard frequency and time signal-satellite (Earth-to-space) 5.536A	
27-27.5 FIXED INTER-SATELLITE 5.536 MOBILE	**27-27.5** FIXED FIXED-SATELLITE (Earth-to-space) INTER-SATELLITE 5.536 5.537 MOBILE	
27.5-28.5 MOBILE	FIXED 5.537A FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.539 5.ZZZ 5.538 5.540	
28.5-29.1	FIXED FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.523A 5.539 5.ZZZ MOBILE Earth exploration-satellite (Earth-to-space) 5.541 5.540	
29.1-29.5	FIXED FIXED-SATELLITE (Earth-to-space) 5.516B 5.523C 5.523E 5.535A 5.539 5.541A 5.ZZZ MOBILE Earth exploration-satellite (Earth-to-space) 5.541 5.540	
29.5-29.9 FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.539 5.ZZZ Earth exploration-satellite (Earth-to-space) 5.541 Mobile-satellite (Earth-to-space) 5.540 5.542	**29.5-29.9** FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.539 5.ZZZ MOBILE-SATELLITE (Earth-to-space) Earth exploration-satellite (Earth-to-space) 5.541 5.525 5.526 5.527 5.529 5.540 5.542	**29.5-29.9** FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.539 5.ZZZ Earth exploration-satellite (Earth-to-space) 5.541 Mobile-satellite (Earth-to-space) 5.540 5.542

29.9-34.2 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
29.9-30	FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.539 5.ZZZ MOBILE-SATELLITE (Earth-to-space) Earth exploration-satellite (Earth-to-space) 5.541 5.543 5.525 5.526 5.527 5.538 5.540 5.542	
30-31	FIXED-SATELLITE (Earth-to-space) 5.338A 5.ZZZ MOBILE-SATELLITE (Earth-to-space) Standard frequency and time signal-satellite (space-to-Earth) 5.542	
31-31.3	FIXED 5.338A 5.543A MOBILE Standard frequency and time signal-satellite (space-to-Earth) Space research 5.544 5.545 5.149	
31.3-31.5	EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) 5.340	
31.5-31.8 EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) Fixed Mobile except aeronautical mobile 5.149 5.546	**31.5-31.8** EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) 5.340	**31.5-31.8** EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive) Fixed Mobile except aeronautical mobile 5.149
31.8-32	FIXED 5.547A RADIONAVIGATION SPACE RESEARCH (deep space) (space-to-Earth) 5.547 5.547B 5.548	
32-32.3	FIXED 5.547A RADIONAVIGATION SPACE RESEARCH (deep space) (space-to-Earth) 5.547 5.547C 5.548	
32.3-33	FIXED 5.547A INTER-SATELLITE RADIONAVIGATION 5.547 5.547D 5.548	
33-33.4	FIXED 5.547A RADIONAVIGATION 5.547 5.547E	
33.4-34.2	RADIOLOCATION 5.549	

ARTICLE 5

Frequency allocations

Section IV – Table of Frequency Allocations
(See No.2.1)

ADD

5.YYY Earth stations on board unmanned aircraft and their associated control stations (CSs) that operate as part of an Unmanned Aircraft System (UAS) may receive from geostationary satellite systems on a primary basis in the fixed- satellite service (space-to-Earth) in accordance with Recommendation ITU-R [SAT-UAS-FSS] in the following frequency bands: 10.95 – 11.20 GHz, 11.45 – 11.70 GHz, 11.70 – 12.20 GHz (in Region 2 only), 12.20 – 12.50 GHz (in Region 3 only), 12.50 – 12.75 GHz (in Regions 1 and 3 only), 17.30 – 17.70 GHz (in Region 1 only) and 17.70 – 21.20 GHz. The use of the above frequency bands by the aforementioned (UAS and CS) stations is limited to UAS control link communications in the Space-to-earth direction. Moreover, the operation of UAS control links in any of the above specified frequency bands does not establish priority in the Radio Regulations over any station operating in a primary service allocated to these bands, including stations operating in the fixed-satellite service, nor does it establish priority in relation to other communication links within the fixed satellite service.

ADD

5.ZZZ Earth stations on board unmanned aircraft and their associated control stations (CSs) that operate as part of an Unmanned Aircraft System (UAS) may transmit to geostationary satellite systems on a primary basis in the fixed- satellite service (Earth-to-space) in accordance with a Recommendation ITU-R [SAT-UAS-FSS] in the following frequency bands: [13.75 – 14.00 GHz], 14.00 – 14.50 GHz and 27.50 – 31.00 GHz. The use of the above frequency bands by the aforementioned (UAS and CS) stations is limited to UAS control link communications in the Earth-to-space direction. Moreover, the operation of UAS control links in any of the above specified frequency bands does not establish priority in the Radio Regulations over any station operating in a primary service allocated to these bands, including stations operating in the fixed-satellite service, nor does it establish priority in relation to other communication links within the fixed satellite service.

DRAFT NEW RECOMMENDTION ITU-R [SAT-UAS-FSS]*

* This recommendation is under development in ITU-R Study Group 4 (Working Party 4A)

Use of FSS frequency bands not subject to Appendix 30A/30B for the control communications of unmanned aircraft systems in non-segregated airspaces with geostationary satellites operating in the fixed-satellite service

The ITU Radiocommunication Assembly,

considering

a) that worldwide use of unmanned aircraft systems (UAS) is expected to increase significantly in the near future;

b) that unmanned aircraft need to operate seamlessly with piloted aircraft in non-segregated airspace and that there is a need to provide spectrum for that purpose;

c) that the operation of UAS in non-segregated airspace requires reliable communication links, in particular to relay the air traffic control communications and for the remote pilot to control the flight;

d) that the operation of UAS in non-segregated airspace on a worldwide basis requires the development by the civil aviation community (e.g. ICAO) of international aeronautical standards and recommended practices (SARPs) for the airworthiness certification of supporting terrestrial and satellite systems;

e) that satellite radiocommunications are an essential part of UAS operations, in particular to relay transmissions beyond the horizon and include links between the unmanned aircraft (UA) and the satellite, and links between the UA Control Station (CS) and the satellite;

f) that satellite systems operating in the fixed satellite service (FSS) bands have the capability to provide the communication links mentioned in *considering* e);

g) that Annex 10 of the Convention of the ICAO contains SARPs for aeronautical radionavigation and radiocommunication systems used by international civil aviation,

further considering

a) that there is a need to limit the number of communication equipments onboard an UA;

b) that, as a dedicated satellite system for UAS is not likely, it is necessary to take into account the existing and future satellite systems to accommodate the growth of the use of UAS;

c) that there are various technical methods that may used to increase the reliability of digital communication links, e.g. modulation, coding, redundancy, etc.;

d) that for the UAS communications for the control of UA, relay of ATC voice communications, and sense and avoid, relate to safety and regularity of flight and have certain technical, operational, and regulatory requirements;

e) that the requirements in *further considering d)* can be specified for UAS use of FSS networks,

recognizing

a) that existing aeronautical satellite systems providing links for the safety and regularity of flight and recognized by ICAO do not use AMS(R)S allocations,

recommends

1 that for the communications for control of the unmanned aircraft (UA), relay of ATC voice communications through the UA, and passing of sense and avoid data between an UA and

the UA control station (CS) via geostationary satellites, the frequency band(s) allocated worldwide on a primary basis to the FSS (except those covered by Appendices **30A** and **30B**) should be used, provided that such FSS satellite systems and the Earth Station on board the UA meet the technical requirements contained in Annex 1 of this Recommendation;

2 that the information in Annex 2 be considered as example link budgets for the UA links described in recommends 1, based on the technical characteristics defined in Annex 1 of this Recommendation;

3 that the information in Annex 1 of this Recommendation be updated as needed through consultation with ICAO and other civil aviation organizations as necessary,

requests the Secretary-General

to bring this Recommendation to the attention of ICAO in order to study the development of appropriate SARPs.

Annex 1

Technical characteristics of fixed-satellite service systems to support control communication links of unmanned aircraft systems (UAS)

1 Introduction

UAS that fly beyond-line-of-sight (BLOS) need satellite communications to maintain aircraft control, relay ATC voice communications through the UA, and pass sense and avoid data between the UA and the UA Control Station (UA CS). It is likely that UA will utilize terrestrial radio communications for critical low-altitude operations, such as takeoff and landing, but switch over to satellite communications for the majority of their flight. These satellite links need to achieve high availability to meet national and international aviation requirements when flying in non-segregated airspace.

This annex contains the performance criteria that must be met and the technical characteristics of UAS control links necessary to meet them. Meeting these technical criteria will allow UAS to use FSS allocations.

The UA CS Earth Station and UA Earth Station are operated to the same regulatory limits as a conventional FSS Earth Station.

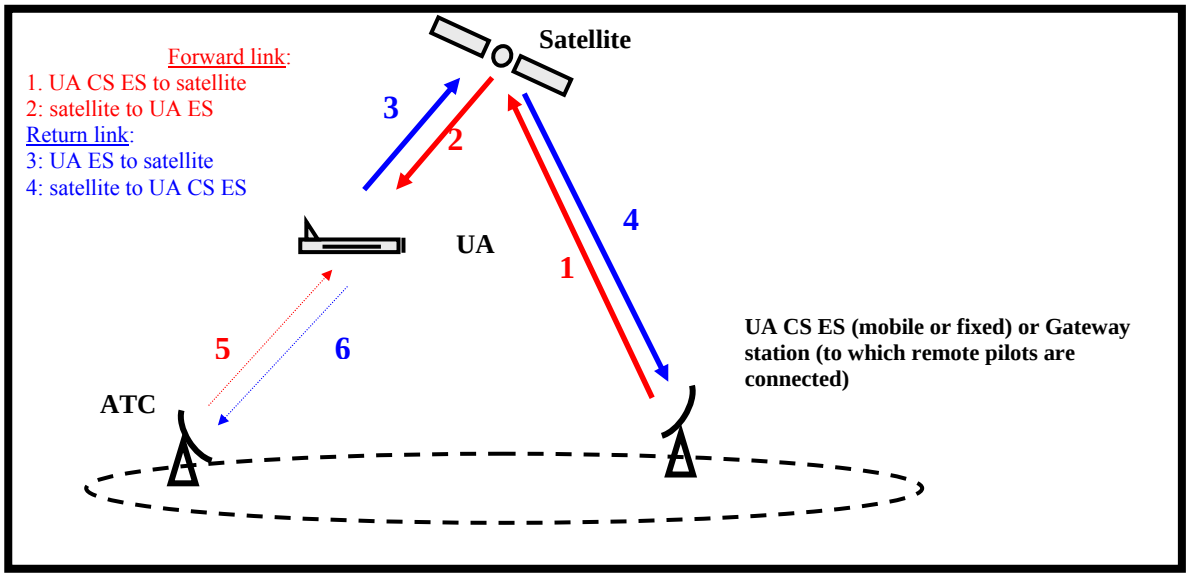

FIGURE 1: UA Earth Station, UA CS Earth Station and Satellite Links

2 Technical requirements

The technical characteristics of UAS to be used in assessing the forward and return (UAS) link performance via a FSS network is provided below. It is emphasized that an administration may implement an UAS with characteristics different than those listed below within its national airspace.

a) Frequency bands.

Space-to-Earth
10.95 – 11.20 GHz

11.45 – 11.70 GHz
11.70 – 12.20 GHz [Region 2 only]
12.20 – 12.50 GHz [Region 3 only]
12.50 – 12.75 GHz [Regions 1 and 3 only]
17.30 – 17.70 GHz in Region 1
17.70 – 21.40 GHz

Earth-to-Space
[13.75 – 14.00 GHz]
14.00 – 14.50 GHz
27.50 – 31.00 GHz

b) Minimum required availability for the end-to-end Forward (up 1 and down 2) Link and end-to-end Return (up 3 and down 4) Link – refer to figure 1.

End-to-end Forward (UA CS ES to UA ES) Link Availability: exceed 99.8% .

End-to-end Return (UA ES to UA CS ES) Link Availability: exceed 99.8% .

c) Geographic coverage area where the UAS requirements will have to be met.
The UAS requirements are expected to be met within the [-3 dB] relative (to the beam peak) gain contour of the satellite's receive and transmit beam coverage areas.

d) The rain conditions (i.e. rain rates) in which the links must operate.

The rain rate to be associated with the UA CS ES is that specified in Recommendation ITU-R P-837 for .01% of the average year for the particular CS location. Recommendation ITU-R P-837 should be [used/referenced] with regard to any other rain rate related information.

The maximum rain rate to be associated with UA ES is 20 mm/hr for .01% of the average year. Recommendation ITU-R P-837 should be [used/referenced] with regard to any other rain rate related information.

e) Carrier characteristics:
Information rate. Forward Link 10 kbit/s. Return Link 320 kbit/s.
Occupied bandwidth. Forward Link 9 kHz. Return Link 290 kHz.
Modulation type. QPSK
Forward error correction rate. Rate ¾ concatenated with Reed Solomon (212,236).
Minimum required C/(N+I). 3.8 dB.

f) Minimum and maximum antenna sizes and corresponding gains of the UA CS Earth Station and UA Earth Station antennas.
UA CS Earth station antennas should be sized to achieve the availability defined in b) for the rain rates experienced at their location d), as well as the other technical requirements in this Annex (such as the off-axis e.i.r.p. density levels in h)).

The minimum UA Earth Station antenna diameter is 0.5 meters (20/30GHz) and 0.8 meters (12/14GHz). The maximum UA antenna diameter is limited by the size and weight constraint of the UA airframe so maximum antennas sizes of 1.2m are anticipated The peak antenna gain values to be used in UAS forward and return link calculations with the aforementioned antennas are provided below:

14GHz UA antenna transmit gain 38 dBi (0.8 meter) – 42 dBi (1.2 meter).
12GHz UA antenna receive gain 36 dBi (0.8 meter) – 40 dBi (1.2 meter).
30GHz UA antenna transmit gain 40 Bi (0.5 meter) – 48 dBi (1.2 meter).
20GHz UA antenna receive gain 37 dBi (0.5 meter) – 44dBi (1.2 meter).

g) Pointing accuracy of the UA Earth Station antenna.

The 12/14GHz UA Earth Station antenna tracking error would not exceed +/- [0.40]* degrees peak.

The 20/30GHz UA Earth Station antenna tracking error would not exceed +/- [0.40]* degrees peak.

h) Maximum and minimum e.i.r.p density of the UA CS Earth Station and UA Earth Station.

The off-axis e.i.r.p. density levels below must be met taking into account the maximum antenna pointing error.
14 GHz UA CS Earth Station and UA Earth Station should meet the following off-axis e.i.r.p. density levels under clear sky conditions in the plane of the geostationary satellite orbit location:

Angle off-axis	***Maximum e.i.r.p. per 4 kHz***
$1.5° \leq \theta \leq 7°$	15 – 10 log 10 (N) - 25log10θ dBW/4 kHz
$7° < \theta \leq 9.2°$	-6 – 10 log 10 (N) dBW/4 kHz
$9.2° < \theta \leq 48°$	18 – 10 log 10 (N) - 25log10θ dBW/4 kHz
$48° < \theta \leq 85°$	-24 – 10 log 10 (N) dBW/4 kHz
$85° < \theta \leq 180°$	-14 – 10 log 10 (N) dBW/4 kHz

where θ is the angle in degrees from the line connecting the focal point of the antenna to the target satellite, and the geostationary orbit plane is determined by the focal point of the antenna and the line tangent to the arc of the geostationary satellite orbit at the position of the target satellite. Additionally N is the number of co-frequency simultaneously transmitting earth stations in the target satellite receiving beam.

30 GHz UA CS Earth Station and UA Earth Station should meet the following off-axis e.i.r.p. density levels under clear sky conditions:

Angle off-axis	***Maximum e.i.r.p. per 40 kHz***
$2.0° \leq \Theta \leq 7°$	(18.5 – 25 log Θ) – 10 log (N) dB (W/40 kHz)
$7° < \Theta \leq 9.23°$	-2.63 – 10 log (N) dB (W/40 kHz)
$9.23° < \Theta \leq 48°$	(21.5 – 25 log Θ) – 10 log (N) dB (W/40 kHz)
$48° < \Theta \leq 180°$	-10.5 dB – 10 log (N) (W/40 kHz).

where Θ is the angle in degrees from the line connecting the focal point of the antenna to the target satellite, and the geostationary orbit plane is determined by the focal point of the antenna and the line tangent to the arc of the geostationary satellite orbit at the position of the target satellite. Additionally N is the number of co-frequency simultaneously transmitting earth stations in the target satellite receiving beam.

i) Minimum G/T of the receiving UA CS Earth Station and UA Earth Station.

The UA Earth Station system noise temperature would not exceed 270K at the antenna feed flange. G/Ts will depend on the antenna size used. UA CS Earth station G/Ts are the same as conventional FSS systems.