UK Civil Aviation Authority

C2 Link policy concept for SAIL 1 to 3 consultation

CAP3154

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Chapter 1
Introduction

Background and Context

1.1 There is strong industry demand for Beyond Visual Line of Sight (BVLOS) operation of Specific category UAS and certified category Remote Piloted Aerial Systems (RPAS) within the UK. Whilst forecast estimates vary, they consistently show a large increase in the sector over the next decade.

1.2 A key enabler for BLVOS operations is sufficiently robust command and control (C2) links that can take advantage of the radio links and telecoms services that are available to best suit each operation.

1.3 This work forms part of the Future Air Traffic Management and Air Navigations (Future ATM/ANS) program within the CAA that works to deliver to the aims of the UK Government Future of Flight Industry Group.

1.4 This policy concept is in support of Specific category operations operating BVLOS and that would apply using the UK SORA (UK Specific Operational Risk Assessment) process detailed in [1].

Basis of this policy concept consultation

1.5 This policy concept consultation is intended to show how the CAA is approaching the C2 link policy for specific category UAS assessed under UK SORA as SAIL 1, 2, or 3; and to seek feedback on this approach. Nothing in this policy concept consultation can be construed to be acceptable means of compliance nor can it be considered as guidance material.

Purpose of the Document

1.6 This consultation is a result of a review of the C2 link technologies appropriate for Specific category UAS in SAIL 1, 2 and 3 (Specific Assurance and Integrity Level) as defined by UK SORA. Work is ongoing on SAIL 4, 5 and 6 and consultation on these is expected in due course.

1.7 Where appropriate, the CAA prefers to use existing telecoms standards and guidelines for the C2 Links, especially where bought-in telecoms services are employed, as these are widely understood in the telecoms sector.

[1] AMC1 Article 11 Conducting a UK Specific Operation Risk Assessment (UK SORA)

1.8 This policy concept consultation makes some proposals related to this and seeks feedback on these proposals; the purpose of this document is to give an early sight of our emerging proposal, and to get feedback so we can update the Policy Concept and learn more before creating finalised policy.

Scope of the C2 Link

1.9 A C2 link carries the command-and-control data between the Remote Pilot (RP) at the Command Unit (CU) and the UA.

1.10 C3 (command, control, and communicate) is a terminology used when Air Traffic Control (ATC) communication services (such as VHF voice) are added to the C2 link. In this document this link is generically referred to as the C2 link even if carrying communication services. Where the ATC communication is carried over the C2 link, the RP needs to be able to check the ATC frequencies and change them if needed. This ATC communication command and control data is also carried over the C3 Link where, for example, a VHF radio on the UA that performs the onward link to ATC.

1.11 One fundamental question to understand is what control and non-payload communication (CNPC) traffic is carried over the C2 link. This will vary between operators, other systems employed, phases of flight, and the kind of operation envisaged. The impacts of this variation include defining the data rates, the link integrity and availability needed that will ultimately need to be defined by the UAS operator for each application within the UK SORA process.

Document Structure

1.12 The rest of this document is structured as follows:

- Chapter 2 summarises some of the identified standards and guidelines.
- Chapter 3 summarise the C2 Link technical options considered for BVLoS specific category within the scope of UK SORA.
- Chapter 4 looks at some illustrative use cases and then identifies which technologies better fit operations in the three lower SAIL categories.
- Chapter 5 introduces the related topic of Lost C2 Link procedures.
- Chapter 6 looks in detail at UK SORA and C2 links. This chapter contains several proposed ways of delivering sufficiently robust C2 links.

Chapter 2

Standards and guidelines

2.1 The CAA has an ongoing activity to review the standards, and guidelines that may apply to the provision and operation of C2 Links from both aeronautical and telecoms sectors as appropriate.

2.2 Where the UAS uses telecommunications services as part of the C2 link then the CAA understands that the use of appropriate telecoms standards, and guidelines can be preferred.

2.3 Appendix C is an initial list of standards, and guidelines that the CAA has identified that could be applicable to the UAS operators' C2 link and how this link can comply with UK SORA.

1. **Question – How strongly do you agree with our approach to existing telecoms standards and guidelines?**

2. **Question – Are there any specific guidelines, standards, regulations or gaps you feel we've missed?**

2.4 The spectrum that can be used for the radio connections in the C2 links is regulated by Ofcom. The CAA is in ongoing conversations with Ofcom on the appropriate use of spectrum for C2 links. It should be noted that not all the potential frequency bands are currently covered by the Ofcom UAS operator radio license[2].

[2] Apply for an aeronautical or Unmanned Aircraft System licence - Ofcom

Chapter 3

Technical options

3.1 In line with ICAO's (International Civil Aviation Organization) definition in the Standards and Recommended Practices and guidance material on the Communication Systems and Procedures Relating to Remotely Piloted Aircraft Systems C2 Link – volume VI of Annex 10, [3], so for UK specific category the C2 link carries the data between the UA and the remote pilot (RP) at the CU (command unit).

3.2 Where the C2 link is a dedicated point-to-point radio link owned by the UAS operator there are no third-party services such as internet service providers (ISPs) involved in the C2 link.

3.3 In many cases the UAS operator will make use of third-party systems and network capacity. This means the typical link consists of a chain of connections such as:

- The radio link such as 4G or satellite connection to one or more central antenna or antennas.
- Some kind of core network managing the traffic.
- Either a dedicated link to the CU or a connection across the Internet and thence via one or more ISPs to the CU.

3.4 The C2 link may consist of several connections in series to provide the end-to-end connectivity; and in parallel to provide the primary, alternate, and emergency connectivity as needed and appropriate for the operation.

3.5 An automated log of which connections are active, and their status needs to be maintained whenever the UA is operational.

3.6 The Joint Authorities for Rulemaking on Unmanned Systems (or JARUS) has published a document "Required C2 Link Performance (RLP) concept" in 2016.[4] This includes the following parameters that can be used to differentiate the RLP:

- Communication transaction time (TT "The maximum time for the completion of the operational communication transaction after which the initiator should revert to an alternative procedure"), with two specified values;

[3] Annex 10 - Aeronautical Telecommunications - Volume VI - Communication Systems and Procedures Relating to Remotely Piloted Aircraft Systems C2 Link | ICAO Store

[4] RPAS C2 link Required Communication Performance (C2 RCP) Concept

- Communication nominal time (TT 95%),
- Communication expiration time (ET).

- Continuity (C, The “Probability that a transaction can be completed within the communication transaction time given that the service was available at the start of the transaction (either ET or TT of 95%)”).
- Availability (A, “*The probability that an operational communication transaction can be initiated when needed.*”).
- Integrity (I, “*The probability of one or more undetected errors in a completed communication transaction*”).

3.7 ICAO are also developing their own RLP concept that would apply for the C2 Links in certified category remotely piloted aerial systems (RPAS).

3.8 The Specific Operational Risk Assessment (SORA, for specific category UAS) leads to the required quality of service and hence the service level required from any third-party providers of connections that go together to make the C2 Link. Where the service is bought in as a standard product it is up to the UAS operator to ensure the service is fit for purpose. CAA is considering adopting the JARUS RLP as a way to ensure the service is fit for purpose.

3. Question – How strongly do you agree with adopting the JARUS RLP concept?

4. Question – Is there a preferred alternative approach?

3.9 In generic terms security means the state of being free from danger or threat. The C2 link can be prevented from operating correctly by radio frequency interference to the radio connection or by some form of IP attack from the Internet such as a distributed denial of service or man-in-the-middle attacks to the endpoints or intermediate nodes. The C2 link can also be compromised by spoofing the radio signal or the IP endpoints.

3.10 The use of services delivered to the CU via the Internet does significantly benefit affordable scalability whilst increasing the security risks that need to be assessed and managed. The use of modern tools such as end-point authentication with end-to-end secure connections or virtual private networks (VPNs) and intrusion management systems at the CU may all play a role depending on the risk assessment. The UK government provides useful guidelines on business broadband services that offers good advice for internet service providers (ISPs) and managing the cyber-security risks of connecting systems to the internet.

3.11 The C2 Links require significant power levels to transmit the data from the UA along the radio connection. Some of these signals may be in bands adjacent to the L band signals used for global navigation satellite service (GNSS) purposes.

This means appropriate design and testing is needed to ensure the C2 links do not interfere with the location determination or other electronics-based aspects relating to flight safety operating in the same band or adjacent bands, for example the flight control, navigational aids, EC, and DAA sub-systems.

3.12 The following table shows how a variety of different radio link technologies that can be used for C2 Links compare with each other.

Table 1: Some key observations when comparing C2 Link radio technologies

Technology	Summary	Strengths	Limitations
ISM (instrumentation scientific and medical bands)	Using low power radio devices to provide a point-to-point radio link	Low cost, very low size weight and power (SWAP) UA equipment. Simple to implement	Short range Very limited protection against radio interference
4G	Use mobile network operator capacity and connect over the Internet.	Wide UK coverage and no limitations on distance between UA and CU. Fairly low cost, low SWAP. Scalable to many UA connected simultaneously. Some protection against radio interference. Mobile network operator (MNO) can know lat/long of UA.	Requires protection against Internet based attacks to UA and CU along with end-to-end secure connection. UK not totally covered especially in very rural and remote regions. Limited to operation not exceeding about, say, 400ft (120m) AGL. The benefits from specific service plans to prioritise UAS data and without data limits or widely commercially available.
5G	As 4G except a newer technology.	Allows MNO to also measure the altitude of the UA and has other UAS specific enhancements.	5G and especially the fully implemented 5G standalone service is generally limited to cities and towns.
5GHz LoS radio	A point-to-point line of sight (LoS) radio link using an aviation protected frequency.	Very robust service with potentially ICAO compliant robustness.	Not deployed widely. Only trial & innovation licenses currently available.
MSS (mobile satellite services)	Mobile satellite services use L band frequencies.	Good coverage of UK. Very robust service with inherent good performance in heavy rain and ICAO compliant.	Limited bandwidth to UA. Limited capacity constrains total number of UA in the UK.

Technology	Summary	Strengths	Limitations
		Fairly low size weight ad power (SWAP) UA equipment.	
FSS LEO (fixed satellite services)	Satellite broadband service from mega-constellations in low-earth orbit (LEO).	Good UK coverage. Significant capacity to support many UA.	No specific UAS services. No specific UA equipment, and available equipment has greater SWAP that MSS. Service can be reduced by heavy rain.
Other satellites	Many other satellite options are possible from low band IoT, through extension of 5G services delivered via satellite, to broadband services delivered by traditional satellites.	To be assessed.	To be assessed.

5. Question – How strongly do you agree with summary assessment of different C2 Link radio technologies for SAIL I–III operations?

6. Question – Which technologies (if any) do you feel have been inaccurately characterised or omitted, and why?

Chapter 4

C2 Link technology for differing use cases

4.1 A series of use cases have been partially developed and reviewed from a C2 link perspective, for now these illustrate cases assessed to vary from SAIL I to III. The UK SORA provides detail on these different SAILs and the requirements for the operational safety objectives (OSOs), and this is summarised in appendix one.

4.2 From the review of these cases, identifying the relevant OSOs and looking at the technical solutions it is clear that many but by no means all these solutions are either an external service or rely in some part on external services. Both OSO6 ("C3 link performance is appropriate for the operation") and OSO13 ("External services supporting UAS operations are adequate to the operation") are therefore relevant.

4.3 A summary of the analysis of these partial use cases is provided in appendix B.

4.4 From the reviews of technologies for each of the partial use cases the viability and scalability findings for each technical solution for the radio connection part of the C2 Link is shown below in Table 2. This table is not intended to be prescriptive; it is included to provide a guide as to which kind of solution is potentially an appropriate fit.

Table 2: Indicative fit of the different radio connection technologies for SAIL I to III

	SAIL I	**SAIL II**	**SAIL III**
ISM – RLoS	OK for primary	OK for primary or secondary connection if sufficient range	Probably OK for primary, secondary and/or emergency connection
ISM – LoRaWAN	Possibly OK for primary	Possibly OK for secondary and/or emergency connection	Possibly OK for secondary and/or emergency connection
MNO – 4G	Probably OK for primary	Probably OK for primary and/or secondary with dual SIM or dual radio	Probably OK for primary and/or secondary with dual SIM or dual radio
5GHz – RLoS	Unlikely to be a good fit	Unlikely to be a good fit	Possibly OK for some users

	SAIL I	SAIL II	SAIL III
FSS – LEO	Unlikely to be a good fit	Unlikely to be a good fit	May be viable for primary or secondary for small isolated communities and offshore operation
MSS – L band	Very unlikely to be a good fit	May be viable for primary or secondary for very remote and offshore operation	May be viable for primary or secondary for very remote and offshore operation
MSS – IoT (Internet of things)	Unlikely to be a good fit	May be viable secondary or emergency connection for very remote and offshore operation	May be viable secondary or emergency connection for very remote and offshore operation

7. **Question – How strongly do you agree with summary the analysis of these partial use cases is provided?**

8. **Question – Are there other technologies (e.g. LDACS - L-band Digital Aeronautical Communications System) or communication services you would like us to consider to ensure that this policy concept is practical?**

Chapter 5

Lost C2 Link

5.1 In parallel to this analysis the CAA is looking at the implications of losing the C2 link and what this means for lost C2 link processes. A separate consultation on this is planned to be issued in due course.

Chapter 6

C2 link requirements in UK SORA

UK SORA and OSOs

6.1 The UK SORA defines a process to determine the SAIL (Specific Assurance and Integrity Level) and this defines the level of robustness need for the relevant OSOs (please see appendix A and UK SORA for more information).

6.2 The feedback to this consultation will be used to inform future updates to UK SORA.

OSO 6 and C2 Links

6.3 For OSO6 “C3 Link performance is appropriate for the operation” the UK SORA requires:

- **SAIL 2:** No defined robustness.
- **SAIL 2 & 3**: “L” robustness, so both OSO6.L.I (Integrity) and OSO6.L.A (Assuredness) apply.

6.4 CAA makes the following proposals related to UK SORA SAIL 1-3:

Proposal 1.1 – Use of TCP/IP provides adequate C2 Link Integrity for SAIL 1 to 3 as long as the checksum checks are not disabled (this relates to OSO6.L.A). This applies to 4G and satellite services as part of the C2 Link and may apply to others. Where this is not used then other ways of meeting the Integrity requirement can also be considered.

Proposal 1.2 – A periodic log should be maintained showing which connections are active and the status of all connections in the C2 Link (this relates to OSO6.L.I). This should include data on C2 link performance and how this meets the operational requirements.

Proposal 1.3 – EASA’s means of compliance for C3 Links in OSO6 and SAIL3 UAS[5] can be used for C2 Link SAIL 2 and SAIL 3 compliance.

9. Question – How strongly do you agree with proposals related to OSO6 for SAIL 1 to SAIL 3?

10. Question – What other evidence or mitigations do you believe would be acceptable to demonstrate OSO6 compliance for SAIL 1 to 3?

[5] Means of compliance (MoC) for the design of UAS operated in SAIL III | EASA

OSO 13 and C2 Links

6.5 For OSO13 “External services supporting UAS operations are adequate to the operation” the UK SORA requires:

- **SAIL 1 & 2:** “L” robustness, so OSO 13 both OSO13.L.I (Integrity) and OSO13.L.A (Assuredness).
- **SAIL 3:** “M” robustness, so both OSO13.M.I (Integrity) and OSO13.M.A (Assuredness) apply on top of those for SAIL 1 & 2.

6.6 CAA makes the following proposals for UK SORA SAIL 1 to 3 relating to OSO13:

Proposal 1.4 – Where the data is routed via the Internet then an authenticated and secure connection or VPN is required with at least 128bit AES encryption for SAIL 1 to 3. This applies to 4G and satellite services as part of the C2 Link and may apply to others (relates to OSO13 L.A.).

Proposal 1.5 – The primary ISP connection at the CU should follow the Ofcom recommended code of practice for business broadband services, an ISP service with suitable service level agreements is needed (relates to OSO13 L.I.).

Proposal 1.6 – Where the CU is connected to the Internet the CU implementation should follow the UK’s national cyber security centre guidance[6] that provides advice and guidance for different aspects of cyber-security covering devices, networks and different deployment scales (relates to OSO13 L.A.).

Proposal 1.7 – The use of 4G (and 5G) services should be limited in altitude (a maximum operating altitude of 400ft (120m agl) subject to further analysis and unless agreed specifically by the MNO) (relates to OSO13 L.I. (a)).

Proposal 1.8 – Where 4G/5G services are being considered the use of UAS specific SIMs and service plans is recommended. Signal quality should be logged (e.g. RSSI, RSSP, CQI, latency, etc.), and latency spikes during handover between base stations should be considered in the design (relates to OSO13 L.I.).

Proposal 1.9 – Where satellite services are being considered then if UAS specific service plans are available these are recommended. Signal quality should be logged, and latency variation should be considered in the design (relates to OSO13 L.I.).

11. Question – How strongly do you agree with proposals related to OSO13 and C2 links for SAIL 1 to SAIL 3?

[6] All topics - NCSC.GOV.UK

12. Question – What other evidence or mitigations do you believe would be acceptable to demonstrate OSO13 compliance for and C2 links for SAIL 1 to SAIL 3?

Other OSOs and C2 links

6.7 The following OSOs described in UK SORA may also apply to C2 Links for UAS in SAIL 1 to 3 operations.

Table 3: Other OSOs relating to C2 Links for SAIL I to III

OSO	Title	Possible C2 Link aspects	SAIL 1	SAIL 2	SAIL 3
2	UAS manufactured by competent and/or proven entity	C2 link equipment manufactured and integrated to acceptable and appropriate standards			
4	UAS components essential to safe operations are designed to an Airworthiness Design Standard	The electro-magnetic compatibility (EMC) and equipment design – not relevant no specific requirements for SAIL I to III.	-	-	-
5	UAS is designed considering system safety and reliability	The EMC of the C2 link system with other systems on the UA need to be considered. Standards such as BS EN 4709-001 may provide relevant guidance as could two RTCA documents DO-160G and DO-357.	-	-	L
7	Conformity check of the UAS configuration	Link parameters configured correctly in UA and CU. Automatic failover, if implemented, between redundant C2 Link connections needs to be checked.	L	L	M
8	Operational procedures are defined, validated and adhered to	Processes define how to correctly configure the C2 link including when and how to check these including pre-flight checks	L	M	H
19	Safe recovery from human error	The lost C2 Link behaviour – this is being considered separately from this policy.	-	-	L

OSO	Title	Possible C2 Link aspects	SAIL 1	SAIL 2	SAIL 3
23	Environmental conditions defined for safe operations defined, measurable and adhered to	Over and above the general UA design two C2 link specific points should be noted: a) FSS satellite links in particular can be degraded by very heavy rain. b) Antennas may need to be protected from icing (and salt ingress where applicable) which can reduce signal strength and may damage the equipment.	L	L	M

6.8 No proposals have been identified relating to C2 Links, these OSOs, and covering SAIL 2 to 3.

13. Question – How strongly do you agree with there being no specific proposals related to these OSOs?

14. Question – What suggestions do you have for proposals to demonstrate compliance against these OSOs for the C2 links and SAIL 1 to 3?

Chapter 7

How to respond to this consultation

7.1 We have sought to make this consultation as accessible as possible by presenting the key points on our dedicated consultation website. The longer document you are reading is for stakeholders wanting more detail. The questions in each case are the same.

7.2 The consultation will close at 23.59 on 22 December 2025 and we cannot commit to taking into account comments received after this date. Please let us have your comments by answering the questions online:

https://consultations.caa.co.uk/safety-and-airspace-regulation-group/c2-link-policy-concept

7.3 Our strong preference is that you complete the online consultation. We understand that some stakeholders prefer not to be constrained by the questions alone and will want to send a self-contained response. While we will accept these submissions, we ask that they are structured around our questions. Otherwise, we will not be able to analyse the submissions in the same way that we analyse the online responses.

7.4 We will assume that all responses can be published on our website. When you complete the online consultation, there will be an option for you to hide your identity or refuse publication. (In any event, your email address will not be published.) In the interests of transparency, we hope people will not refuse publication. If you do send us a separate submission and it includes any material that you do not want us to publish, please also send us a redacted version that we can publish. You should be aware that information sent to and therefore held by the CAA is subject to legislation that may require us to disclose it, even if you have asked us not to (such as the Freedom of Information Act and Environmental Information Regulations). Therefore, if you do decide to send information to the CAA but ask that this be withheld from publication via redacted material, please explain why, as this will help us to consider our obligations to disclose or withhold this information should the need arise.

7.5 If you would like to discuss anything about how to respond to the consultation, please email airspacemodernisationdelivery@caa.co.uk.

Chapter 8
Conclusion

8.1 CAA's work on the C2 link forms part of the Future Air Traffic Management and Air Navigation Services program that also includes aspects such as detect and avoid (DAA), electronic conspicuity (EC), and UAS Traffic Management (UTM).

8.2 The CAA policy for C2 Links recognises that the C2 Link requirements for each SORA will vary each application depending on factors such as the SAIL, how the DAA and EC implemented, where and when the UA is intended to fly.

8.3 The C2 link can be directly provided by the UAS operator, equally may rely on services bought in from a variety of different telecoms providers. Different solutions have different strengths and limitations. The telecoms sector has many regulations, standards, and guidelines; some of these are intended specifically for the aviation environment, many have not intended specifically for the aviation environment but may have some relevant use (e.g. minimising battery power consumption).

8.4 To allow the most effective deployment of appropriate C2 Links the CAA is keen to follow the appropriate regulations, standards, and guidelines from both the aviation and telecoms sectors. The proposals in this policy concept are intended to be the first step in identifying these for C2 links at SAIL I to III according to UK SORA.

List of Appendices:

- Appendix A: Extracts from UK SORA
- Appendix B: Partial use cases
- Appendix C: Regulations standards and guidelines

Glossary of terms

ATC	Air traffic control
AES	Advanced encryption standard
BVLOS	Beyond visual line of sight
C2	Command and control
C3	Command control and communicate
CAA	Civil aviation authority
CNPC	Command and non-payload communications
CRC	Cyclic redundancy check
CU	Command unit
DAA	Detect and avoid
EC	Electronic conspicuity
EMC	Electro-magnetic compatibility
FSS	Fixed satellite service
GNSS	Global navigation satellite service
ICAO	International Civil Aviation Organization
IoT	Internet of things
ISM	Instrument scientific and medical
ISP	Internet service provider
JARUS	Joint authorities for rule making on unmanned systems
LEO	Low earth orbit
MNO	Mobile network operator
MSS	Mobile satellite service
OSO	Operational safety objectives
RLoS	Radio line of sight
RP	Remote pilot
RPAS	Remotely piloted aerial system
SAIL	Specific assurance and integrity level
SORA	Specific operation risk assessment
SWAP	Size weight and power
UA	Unmanned aircraft
UAS	Unmanned aircraft systems
VPN	Virtual private connection

APPENDIX A

Extracts from UK SORA relevant to this policy concept

In the UK SORA [1] the CAA describes its UK Specific Operations Risk Assessment (UK SORA) methodology that is derived from the JARUS SORA 2.5 with adaptations to suit the UK's airspace. For the avoidance of doubt the referenced UK SORA remains the correct source for this information; this appendix extracts some of the key details solely to assist readers of this C2 link policy concept consultation document.

The UK SORA details how the air risk category (ARC) and ground risk (GRC) can be assessed along with any appropriate mitigation strategies. Based on this a Specific Assurance and Integrity Levels (SAIL) determination can be made, see Table 4 below.

Table 4: Relating air risk and ground riks to SAIL

	Residual ARC a	**Residual ARC b**	**Residual ARC c**	**Residual ARC d**
Final GRC ≤2	SAIL 1	SAIL 2	SAIL 4	SAIL 6
Final GRC 3	SAIL 2	SAIL 2	SAIL 4	SAIL 6
Final GRC 4	SAIL 3	SAIL 3	SAIL 4	SAIL 6
Final GRC 5	SAIL 4	SAIL 4	SAIL 4	SAIL 6
Final GRC 6	SAIL 5	SAIL 5	SAIL 5	SAIL 6
Final GRC 7	SAIL 6	SAIL 6	SAIL 6	SAIL 6
Final GRC >7	Certified category	Certified category	Certified category	Certified category

Once the SAIL is established the process then considers the robustness needed for each of the OSOs identified in UK SORA. This shows the required level of robustness needed for each OSO depending on the assessed SAIL, this is shown below in Table 5.

The robustness is defined by the integrity and assurance levels required, these are detailed in UK SORA for each OSO and for each level of robustness. Where:

(i) NR means not required (The applicant should consider using low robustness even if the OSO is not required at the applicable SAIL);
(ii) L means low robustness;
(iii) M means medium robustness;
(iv) H means high robustness.

Table 5: OSOs and SAIL from UK SORA

OSO ID	OSO Description	SAIL 1	SAIL 2	SAIL 3	SAIL 4	SAIL 5	SAIL 6
OSO01	Ensure the operator is competent and/or proven	NR	L	M	H	H	H
OSO02	UAS manufactured by competent and/or proven entity	NR	NR	L	M	H	H
OSO03	UAS maintained by competent and/or proven entity	L	L	M	M	H	H
OSO04	UAS components essential to safe operations are designed to an Airworthiness Design Standard (ADS)	NR	NR	NR	L	M	H
OSO05	UAS is designed considering system safety and reliability	NR	NR	L	M	H	H
OSO06	C3 link performance is appropriate for the operation	NR	L	L	M	H	H
OSO07	Conformity check of the UAS configuration	L	L	M	M	H	H
OSO08	Operational procedures are defined, validated and adhered to address normal, abnormal and emergency situations potentially resulting from technical issues with the UAS or external systems supporting UAS operation, human errors or critical environmental conditions	L	M	H	H	H	H
OSO09	Remote crew trained and current and able to control the normal, abnormal and emergency situations potentially resulting from technical issues with the UAS or external systems supporting UAS operation, human errors or critical environmental conditions situation	L	L	M	M	H	H
OSO13	External services supporting UAS operations are adequate to the operation	L	L	M	H	H	H
OSO16	Multi crew coordination	L	L	M	M	H	H
OSO17	Remote crew is fit to operate	L	L	M	M	H	H
OSO18	Automatic protection of the flight envelope from Human Error	NR	NR	L	M	H	H

OSO ID	OSO Description	SAIL 1	SAIL 2	SAIL 3	SAIL 4	SAIL 5	SAIL 6
OSO19	Safe recovery from Human Error	NR	NR	L	M	M	H
OSO20	A Human Factors evaluation has been performed and the HMI found appropriate for the mission	NR	L	L	M	M	H
OSO23	Environmental conditions for safe operations defined, measurable and adhered to	L	L	M	M	H	H
OSO24	UAS designed and qualified for adverse environmental conditions	NR	NR	M	H	H	H

SAIL I UAS have no integrity or assurance requirements within OSO6 however the integrity expected that is defined in OSO6/LI is not unreasonable.

For UAS assessed as either SAIL 2 and 3 and OSO 6 both OSO6.L.I (Integrity) and OSO6.L.A (Assuredness) apply as per the UK SORA.

OSO6. L.I (a) The performance, RF spectrum usage and environmental conditions for C3 links **must** be adequate to safely conduct the intended operation.

(b) The remote pilot **must** have the means to continuously monitor the C3 performance and to ensure that the performance continues to meet the operational requirements.

OSO6. L.A The Applicant must declare and provide evidence of compliance with the Integrity requirements. The detailed evidence of compliance may be assessed by the CAA.

For UAS assessed as either SAIL 2 and 3 and OSO 13 both OSO13.L.I (Integrity) and OSO13.L.A (Assuredness) apply as per the UK SORA.

OSO13. L.I (a) The applicant **must** ensure that the level of performance for any externally provided service critical for the safety of the flight is adequate for the intended operation.

(b) If the externally provided service requires communication between the Operator and the Service Provider, the applicant **must** ensure there is effective communication to support the service provisions.

(c) Roles and responsibilities between the applicant and the external Service Provider **must** be defined.

OSO13 L.A	The Applicant must declare and provide evidence of compliance with the Integrity requirements. The detailed evidence of compliance may be assessed by the CAA.

For UAS assessed as SAIL 3 and OSO 13 both OSO13.M.I (Integrity) and OSO13.M.A (Assurance) apply on top of those for SAIL 2 & 3 as per UK SORA – however these add no additional requirements. It is important to recall also that similar use cases may have different modus operandi which could impact on the demands of the C2 link.

These are the two primary OSOs that impact on these low SAIL C2 links. Note also that Table 3**Error! Reference source not found.** on page 16 of this document identifies some other OSOs that could be relevant to C2 links and low SAIL applications.

APPENDIX B

Partial Use Cases

Rationale and scope

Each case is intended to be an example of the initial thoughts one might have when considering how a BVLoS operation might be assessed from a C2 Link perspective. This review of these illustrative and example use cases is intended to take the technical art of the possible related to C2 Links and apply this to understand how differing solutions fit differing use cases.

These cases are not complete in detail, and they are entirely fictional, any resemblance to planned or ongoing work is purely coincidental.

The cases are all structured as follows:

- **Context:** This provides the background description.
- **Indicative SAIL assessment:**
  - SAIL: An indicative SAIL assessment is given and hence identifying the key OSOs.
  - C2 Link requirements: An overview of some values expected for this use case.
- **Proposed architecture:** How the C2 Link could be implemented.
- **Summary:** Why this architecture is proposed.
- **Review of technologies:** Looking at the C2 link candidate solutions to see if this is the best fit.
- **Scalability:** How well does this solution scale; for example, can that solution extend the operating range of the UA/RPA, is there sufficient capacity to add many more similar operations across the UK?

Case 1 - Agricultural Surveillance and Crop Monitoring (SAIL 1)

Context

Case 1 is that the:

- Operation takes place in rural England, covering large agricultural fields.
- UA is used to assist precision farming, monitoring crops, identifying irrigation needs, and detecting pest infestations. It is for surveying and less than 3m in dimension.

Indicative SAIL assessment

Following analysis the following indicative assessment applies:

- Based on the UK SORA methodology, this operation qualifies as **SAIL 1**.

Operational Safety Objective (OSO)	Compliance Strategy
OSO #06: C2 Link Performance	Low latency RF link with encryption

C2 Link Requirements

These are summarised below.

Requirement	Details
Communication Range	Up to 500m
Redundancy	Not required but optional
Latency	≤ 100ms
Security	Encrypted RF link (AES-128)
Lost C2 link action	RTH upon link loss

Other parameters that might reasonably be considered in a more complete analysis include some expectation of the link error rate, how the lost C2 link condition is detected and the pilot informed, the types of data being carried, and how the pilot's control system authenticates with the UA.

Proposed architecture

The proposed architecture for use case 1 is:

- **Primary connection:** Direct RF link using the 2.5GHz ISM band and low power radios between the UA and the Ground Control Station (GCS).
- **Backup connection:** Not required for SAIL I, but an optional short-range Bluetooth-based fallback may be used in case of disconnection. The pilot may need to walk towards the UA to re-establish the C2 Link connection.

Note that Bluetooth class 1 devices transmit at 100mW in the 2.4GHz ISM band and can have an outdoor range of up to 100m. A handheld device for the pilot using a recent (and hence reasonably secure version of Bluetooth) is envisaged. NIST have a issued a document that details Bluetooth security risks for the different versions of Bluetooth.

Summary

The proposed architecture for this use case ensures operational simplicity while maintaining safety and regulatory compliance. The low complexity of the mission and minimal risk exposure justify the use of a single C2 link without redundant backup. However, the optional Bluetooth redundancy can further enhance reliability.

Review of technologies

Primary / alternate / emergency C2 Link connections

The primary connection using an ISM band would appear to be fit for purpose.

Given the low altitude of operation the use of a 4G connection might also be worth considering but only if the coverage was adequate. This use case is not likely to be a good fit for MSS or FSS satcom as primary connection due to the SWAP of the terminals.

The use of an optional Bluetooth connection should the primary connection fail is sensible. The process for switching over is not defined.

Another alternative could be LoRaWAN with greater range though this may depend on the manufacturer offering this. An MSS IoT type terminal might also be a technically viable option offering greater range.

Link performance

Given this is SAIL I and the link is provided directly by the operator only OSO6 directly applies and there are no specific requirements for C2 Link Integrity or Assuredness. The C2 link service is not bought in therefore OSO13 does not need to be considered.

Scalability

Given the use case is rural and uses the 2.4GHz ISM band this should be able to scale appropriately noting the constraints on the range of any given link.

Case 2 – Medical Supply Delivery in Rural Scotland (SAIL 2)

Context

Case 2 is that the:

- Operation is Beyond Visual Line of Sight (BVLOS), delivering critical medical supplies between two hospitals in Scotland, these are 40km apart.
- Flight path crosses remote areas, with minimal infrastructure and sparse population.

Indicative SAIL assessment

Following analysis the following indicative assessment applies:

- The operation is classified as **SAIL 2**.

Operational Safety Objective (OSO)	Compliance Strategy
OSO #06: C2 Link Performance	Dual redundant LTE and RF connections
OSO #06: C2 Link Robustness	Automatic handover configured between redundant C2 Link connections
OSO #13: C2 Link service provided by MNO	Drone specific SIM and service plan used.
OSO #19: Procedural Safety Measures	RTH and loiter mode protocols

C2 Link Requirements

These are summarised below.

Requirement	Details
Communication Range	20–50km
Redundancy	Dual link (LTE + RF)
Latency	≤ 500ms
Security	AES-256 encryption

Fail-Safe Mechanism	Auto-switch to RF or loiter mode

Other parameters that might reasonably be considered in a more complete analysis include some expectation of the link error rate, how the lost C2 link condition is detected and the pilot informed, the types of data being carried, and how the pilot's control system authenticates with the UA.

Proposed architecture

The proposed architecture is summarised below.

Component	Primary connection	Backup connection
Technology	LTE-based C2 link	Low-frequency RF fallback (900MHz ISM)
Provider	UK national LTE network	Direct RF from mobile relay stations
Encryption	End-to-end VPN	AES-256
Latency	≤ 500ms	≤ 300ms

The use of 4G services (LTE) requires the UAS operator buy in service from an MNO, the proposed architecture defines the use a drone specific SIM and service plan; and that this is registered with Ofcom.

The CU will be connected to the Internet using an entry-level business grade ISP connection with a 4G dongle on the router providing backup connection to the Internet.

Summary

This BVLOS medical delivery operation requires a robust C2 Link architecture to ensure continuous connectivity in remote areas. The dual-link approach (LTE + RF) guarantees resilience against network disruptions and provides compliance with SORA risk mitigation requirements.

Review of technologies

Primary / alternate / emergency C2 Link connections

The use of 4G (LTE) for the primary connection is sensible if there is reasonable coverage and the flights remain below the operational ceiling (e/g/ 100m agl) of this kind of connection. Use of a flight planning tool linked to information about the 4G coverage is recommended.

The use of 900MHz for the secondary connection would work well at each end of the flight but may need to have relay stations along the flightpath to provide connectivity for the whole flight depending on the bit rate required. The connections to these intermediate relay stations would then need to be considered. The process for switching over is not defined.

This use case is not likely to be a good fit for MSS or FSS satcom as a connection due to the SWAP of the terminals. A low bit-rate lightweight IoT type MSS satcom terminal might

make a good secondary or emergency connection option. Alternatively a dual SIM modem on the UA might be adequate.

Link performance

Given this is SAIL 2 and the primary connection is provided by an MNO and the secondary connection is provided by the operator both OSO6 and OSO13 apply. and they have “L” robustness as defined by UK SORA requirements for C2 Link Integrity or Assuredness.

The use of TCP/IP and a VPN over the primary connection will deliver the required Integrity, and the use of two different systems should deliver the required Availability and Continuity. More details are required to confirm the secondary connection Integrity. Both connections should be capable of meeting the defined latency.

Lost C2 Link

A formal review would need to define:

a) How the pilot knows the C2 link is lost.
b) How long the system waits before the UA returns to home (Lost C2 Link timer).
c) How the optional C2 Link connection is used.

Scalability

The MNO capacity would be expected to scale well.

The use of ISM band for the alternate connection should also scale appropriately across the UK however the range limitations could require repeaters.

Case 3 – Urban Infrastructure Inspection (SAIL 3)

Context

Case 3 is that the:

- Operation takes place in a major UK city, inspecting critical infrastructure such as bridges, power lines, and rooftops for maintenance and structural integrity.
- UAV is flown in Beyond Visual Line of Sight (BVLOS) conditions, primarily above urban areas, for a maximum distance of 15km.

Indicative SAIL assessment

Following analysis the following indicative assessment applies:

- Based on SORA methodology, the operation qualifies as **SAIL 3**.

Operational Safety Objective (OSO)	Compliance Strategy
OSO #06: C2 Link Performance	5G network ensures low latency
OSO #06: C2 Link Robustness	Automatic switching between 5G and LoRa RF

OSO1 #13: C2 Link service provided by MNO	Drone specific SIM and service plan used.

C2 Link Requirements

These are summarised below.

Requirement	Details
Communication Range	5-15 km
Redundancy	Dual-link required
Latency	≤ 200ms
Security	AES-256 encryption
Fail-Safe Mechanism	Hover-and-land protocol

Proposed architecture

The proposed architecture is summarised below.

Component	Primary Connection	Secondary connection
Technology	5G/LTE Network	LoRaWAN
Provider	Commercial MNO	Tbd
Encryption	End-to-end VPN over 5G/LTE	Secure connection (TLS)
Latency	≤ 200ms	<300ms
Other	UAS SIM and service plan	Tbd

The ISP connections will be provided by two broadband routers using Wi-Fi as the local area network, the first router connecting to a commercial grade broadband service and the second to a 4G service. Each router transmits its own local Wi-Fi signal, and the CU computer being configured to use the former Wi-Fi as its normal connection and the 4G Wi-Fi if Internet connectivity is lost via the former.

Summary

This case demonstrates the feasibility of BVLOS UAV operations in urban environments, where sufficiently reliable C2 links are crucial for safety and regulatory compliance. The integration with UTM systems and dual-redundant C2 links ensures operational robustness.

Review of technologies

Primary / alternate / emergency C2 Link connections

The use of 5G / 4G (LTE) for the primary link is sensible if there is reasonable coverage and the flights remain below the operational ceiling of this kind of connection. Coverage of 5G is likely to be reasonable in these urban environments but it can be by no means assured so the ability to switch to 4G is important. It is worth noting that switching from 5G to 4G may add a short spike to the latency during the handoff process.

The use of LoRaWAN for the secondary connection should work well at each end of the flight but connectivity for the whole flight may depend on the bit rate required. Alternatively, a dual SIM modem on the UA might be worth considering, allowing the LoRaWAN to operate as an emergency connection. The use of two different technologies and Wi-Fi networks for the ISP connections is reasonable. The process for switching over is not defined.

This use case is not likely to be a good fit for MSS or FSS satcom as a connection due to the SWAP of the terminals. A low bit-rate lightweight IoT style MSS satcom terminal might make a good secondary or emergency connection option.

Link performance

Given this is SAIL 3 and the primary connection is provided by an MNO and the secondary connection is either provided by the operator or by a third party both OSO6 and OSO13 apply and there have “L” requirements for C2 Link Integrity or Assuredness.

The use of TCP/IP and a VPN over the primary connection should delivery the required Integrity, and the use of two different systems should deliver the required Availability and Continuity. More details are required to confirm the secondary connection Integrity. Both connections should be capable of meeting the defined latency (as long as the transaction data size is not too large that the LoRaWAN data rate would impact this).

Scalability

The MNO capacity would be expected to scale well.

The use of LoRaWAN in an ISM band for the alternate connection should also scale well across the UK however the range limitations could tend to constrain this.

APPENDIX C

Regulations and standards

An incomplete and indicative list of possible regulations, guidance material, standards, and reports that have been identified as potentially having relevance to C2 links are summarised in the table below.

Body	Type	Sector	Document reference	Title	Date	Description	Possible relevance to C2 Link
ICAO	Regulation	Aero	SARPS Annex 6 part IV	International operations for remotely piloted aircraft	Current 07/24 Updates expected 2028	Refers to annex 10 vol VI which is not available	tbc - will direct the certified category C2 link requirements and have relevance for high SAIL spec cat UAS
ICAO	Regulation	Aero	SARPS Annex 10 volume III Chapter 4	Aeronautical mobile-satellite (route) service (AMS(R)S)	07/2007	-	Aviation safety band in L band MSS
UK Gov	Regulation	Aero	945/2019	Design and manufacture	Current	Defines the requirements for the design and manufacture of UAS	May need changes for certified RPAS C2 links
UK Gov	Regulation	Aero	965/2012	Air operations	Current	Defines technical requirements and administrative procedures related to air operations	May need changes for certified RPAS C2 links
ICAO	Guidance	Aero	tbd	RPAS C2 Link Manual	Due 2028		For certified RPAS. Concepts relevant for specific category UAS
JARUS	Guidance	Aero	SORA 2.5	JARUS guidelines on Specific Operations Risk Assessment (SORA)	5/2024	This process is intended to provide a risk-proportionate method to determine the required evidence and assurances needed for an Unmanned Aircraft System (UAS) to be acceptably safe within the “Specific” category of UAS Operations	Provides the basis for the UK SORA process defined by the CAA
JARUS	Guidance	Aero	JAR_DEL_WG5_D.04	Required C2 Performance (RLP) concept	5/2016	This provides a process and description of the key characteristics needed to define the C2 Link performance	Will help UAS operators in defining SORA

Body	Type	Sector	Document reference	Title	Date	Description	Possible relevance to C2 Link
EASA	Guidance	Aero	MOC to OSO#6-01	SAIL III Means of Compliance with OSO#6 “C2 Link”	12/2023	Includes useful guidance for checking C3 characteristics are appropriate for the operation against JARUS SORA 2.5 OSO6 (and OSO13 as it pertains to C2 links)	Includes useful guidance in meeting OSO6 & OSO13 for C2 Link services that are reasonable in the UK, referenced also by EUROCAE in ED-325
EUROCAE	Guidance	Aero	EUROCAE ED-325	Guidance Document for Special Condition Light - UAS - Medium Risk - Volume 1	12/2024	Chapter 10 provides guidance on C2 links for specific category UAS against JARUS SORA OSO6. This specifically excludes services provided by satellite and mobile network operators; however it does include any equipment on the UA that communicate via these external services.	They state that the applicant should derive the minimum performance for the C2 link considering parameters such as: • Operating range and/or coverage as appropriate. • Availability. • Continuity. • Integrity. • Latency. Medium risk (SAIL III and IV) a qualitative assessment is sufficient, and provide an indicative list of link performance parameters that may be used to assess the minimum performance. This performance should be included in the flight manual.
EUROCAE	Guidance	Aero	EUROCAE ED-tbd	Software development assurance for Lower-Risk Aviation Application	Due 9/2025	Not yet reviewed in C2 context	May be relevant to the software managing C2 links

Body	Type	Sector	Document reference	Title	Date	Description	Possible relevance to C2 Link
SAE	Report	Aero	SAE AIR 5645A	Joint Architecture for Unmanned Systems (JAUS) Transport Considerations	9/2014	This SAE Aerospace Information Report (AIR) discusses characteristics of data communications for the JAUS. This document provides guidance on the aspects of transport media, unmanned systems and the characteristics of JAUS itself that are relevant to the definition of a JAUS transport specification.	-
RTCA	Report	Aero	AWP-2	Command and Control (C2) Data Link White Paper	2014	Studying issues around the MOPS for C2 links to UAS focusing on L band (974-1164MHz) and C band (5030-5091MHz)	May have some impact on C band RLoS targeted at higher SAIL
RTCA	Report	Aero	AWP-4	Command and Control (C2) Data Link White Paper Phase 2	2017	Studying issues around the MOPS for C2 links to UAS focusing on L band, C band, KU band and Ka band	
RTCA	Report	Aero	DO-254	Design assurance guidance for airborne electronic hardware	4/2000	Provides guidance to assist organisations with design assurance for the development of airborne electronic hardware such that it safely performs its intended function in the specified environments	Defines the design assurance levels needed related to failure conditions
RTCA	Report	Aero	DO-357	User guide supplement to DO-160G	12/2014	See DO-160G	See DO-160G
RTCA	Standard	Aero	DO-160G	Environmental conditions and Test procedures for airborne equipment	12/2024	Defines a series of minimum standard environmental test conditions and applicable test procedures for airborne equipment	The section on EMC tests may be particularly relevant to UA/RPA design and verification
RTCA	Standard	Aero	DO-178C	Software considerations in airborne systems and equipment certification	12/2013	Provides guidance for the production of software for airborne systems and equipment that performs its intended function with a level of confidence in safety that complies with airworthiness requirements.	May apply to the C2 Link software components especially for higher SAIL in
RTCA	Standard	Aero	DO-262	MOPS for Avionics supporting next generation satellite links	5/2017	Defines satcom services to all kinds of aircraft, for example including satellite equipment that provides in-flight broadband services to the passengers.	Very equipment focussed, probably not very relevant to UA

Body	Type	Sector	Document reference	Title	Date	Description	Possible relevance to C2 Link
RTCA	Standard	Aero	DO-362C	MOPS for C2 links (terrestrial)	12/2020	Defines requirements for the C band RLoS radio link	Will probably input into higher SAIL
RTCA	Standard	Aero	DO-377B	Minimum Aviation system performance for C2 links supporting UAS in US airspace	12/2023	Provides a methodology for operators to design the C2 Link in the RPAS to an acceptable level, they also state this is just one way to do this.	The example concepts pf operation (conops) may help UAS/RPAS operators develop their own conops. The methodology may be used.
RTCA	Standard	Aero	DO-379	Internet protocol suite profiles [for an Aeronautical telecommunications Network]	9/2016	Describes how to use TCP or an alternative on conjunction with UDP to ensure data integrity	Not overly relevant but does indicate use TCP/IP is a good approach
ASTM	Standard	Aero	ASTM F3478-20	Standard Practice for Development of a Durability and Reliability Flight Demonstration Program for Low-Risk Unmanned Aircraft Systems (UAS) under FAA Oversight	11/2020	This provides standard practice for development of a durability and reliability flight demonstration program for low-risk UAS under FAA oversight in the USA	Potentially helpful in developing SORA responses
ASTM	Standard	Aero	ASTM F3002-22	Standard Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems	12/2022	This specification covers general command and control (C2) requirements, C2 system spectrum requirements, C2 link requirements, UA requirements, and fly-away functionality.	To be assessed
STANAG	Standard	Military	STANAG 4660	Interoperable Command and Control Data Link For Unmanned Systems (IC2DL) - AEP-77 Edition A	2016	Classified NATO document providing a top-level description for interoperable command and control data link for unmanned systems	-
ITU	Regulation	Telecoms	RR	Radio regulations	2024	Defines all use of spectrum, implemented in UK by Ofcom	Defines which frequencies can be used for UAS/RPAS and how robust they are
ITU	Regulation	Telecoms	Res. 155	Regulatory provisions related to earth stations on board unmanned aircraft which operate with geostationary-satellite networks in the FSS…	2024	Review on use of GEO FSS for C2 links	Suggests GEO FSS is OK for C2 links but LEO is for review in 2027, impacts certified RPAS
Ofcom	Regulation	Telecoms	-	The United Kingdom Frequency Allocation Table, online	Current	Defines the UK wide allocation of frequencies	Radio frequency and power level requirements must be adhered to

Body	Type	Sector	Document reference	Title	Date	Description	Possible relevance to C2 Link
Ofcom	Regulation	Telecoms	-	Frequency bands designated for industrial, scientific and medical (ISM) use	8/2022	Defines the UK wide allocation of frequencies available for ISM use	Radio frequency and power level requirements must be adhered to
Ofcom	Guidance	Telecoms	-	Spectrum for Unmanned Aircraft Systems (UAS) licence	1/2023	Information on how Ofcom licences UAS under their UAS Operator Radio Licence. The document describes which devices are covered by the UAS Operator Radio Licence, how you go about obtaining a licence and what terms and conditions you must adhere to	The UAS operator will need to obtain licenses
Ofcom	Guidance	Telecoms	-	Business Broadband Code of Practice	1/2016	The Code aims to provide business customers with accurate and transparent speed information on standard business broadband services at point of sale.	Clarity on the service being provided by the ISP to the CU
UK Government national cyber security centre	Guidance	Telecoms	-	Advice and guidance	Current	Provides a broad range of cyber security related topics that our advice and guidance	Useful guidance on sensible ways to protect devices and systems connected to the internet from cyber threats such as the UA and CU
BSI	Guidance	Telecoms	BS EN 4709-001	Unmanned Aircraft Systems. - Part 001: Product requirements and verification	4/2025	This document provides means of compliance with rgw regulations on making available on the market of unmanned aircraft intended for use in the ‘open’ category	Whilst open category some aspects relating to EMC design and testing may be relevant
	Standard	ICT	BS EN 60529	Degrees of protection provided by enclosures (IP Code)	2013	The IPxy number defines the protection against objects and dust (x) and water (y).	By choosing the right IP code for the airborne electronics the operator may be able to demonstrate that this aspect of the design is adequate
ITU	Report	Telecoms	ITU-R M.2171	Characteristics of unmanned aircraft systems and spectrum requirements to support their safe operation in non-segregated airspace	2009	Provides interesting analysis and identifies issue with data density for multiple UAS/RPAS in close proximity	Background information, possibly out of date

Body	Type	Sector	Document reference	Title	Date	Description	Possible relevance to C2 Link
ITU	Standard	Telecoms	ITU-T F.749.10	Requirements for communication services of civilian unmanned aerial vehicles	5/2019	Specifies communication services of civilian unmanned aerial vehicles (CUAVs), including comms, flight control, flight data transport requirements	Provides clear division between CNPC and payload communications
ITU	Standard	Telecoms	ITU-T Y.4480	Low power protocol for wide area wireless networks	11/2021	Specifies LoRaWAN	LoRaWAN may be considered for alternate or emergency C2 Link connectivity
ITU	Standard	Telecoms	ITU-T F.749.12	Framework for communication application of civilian unmanned aerial vehicles	8/2020	Presents the general framework for communication application of civilian unmanned aerial vehicle (CUAV) and its functional entities, reference points, etc.	The well-defined reference points may help prioritise CNPC data over payload data
ITU	Standard	Telecoms	ITU-T F.749.14	Requirements of coordination for civilian unmanned aerial vehicles	06/2021	Presents a framework to allow collaborative communications between UA	Currently out of scope of C2 Link (between UA and CU)
ITU	Standard	Telecoms	ITU-T Y.4421	Functional architecture for unmanned aerial vehicles and unmanned aerial vehicle controllers using IMT-2020 networks	10/2021	Provides a functional architecture for UAVs and UAV controllers using 5G networks and functionalities defined in the application layer, service and application support layer, and security capabilities. The intent is to solve the issues of civilian UAVs accessing and communicating in 5G networks	Provides the framework for 3GPP TS to be developed in to define 5G UAS services It does request transmission of service quality data to the CU
ISO	Standard	Telecoms	ISO 20206:2015	Space data and information transfer systems - IP over CCSDS space links	2015	Describes sending data using IP datagrams over the deep space network	-
ISO	Standard	Telecoms	BS ISO/IEC 4005:2023	Telecommunications and information exchange between systems — Unmanned aircraft area network (UAAN) —Physical and data link protocols for control communication	2023	Defines a network that can provide C2 Link capability. Includes CNPC, video and mesh communications	Not clear if it's being deployed
IEEE	Standard	Telecoms	IEEE 1936.1-2021	IEEE Standard for Drone Applications Framework	12/2021	The standard establishes a support framework for drone applications. It specifies drone application classes, application scenarios, and required application execution environments.	Framework may help define requirements of C2 links and could useful way to design higher SAIL UAS

Body	Type	Sector	Document reference	Title	Date	Description	Possible relevance to C2 Link
ETSI	Standard	Telecoms	ETSI TS 124257 V 18.4.0	5G; Uncrewed Aerial System (UAS) Application Enabler (UAE) layer; Protocol aspects; Stage 3 (3GPP TS 24.257 version 17.4.0 Release 17)	10/2024	Refines the associated procedures for UAS application communication between the UE and the UAE server and among UEs.	May help design services using 5G based C2 links
SAE	Standard	Telecoms	SAE AS 5710A	JAUS Core Service Set	04/2015	A set of protocol interfaces for interchange of C2 data within JAUS framework	-
3GPP	Standard	Telecoms	3GPP TS 22.125	Unmanned Aerial System (UAS) support in 3GPP	6/2024	Defines the “stage 1” requirements for UAS related communications over 5G covering both payload communications and CNPC	May become relevant when 5G coverage adequate for BVLoS operation and features enabled by MNOs
3GPP	Standard	Telecoms	3GPP TS 23.255	LTE - Application layer support for Uncrewed Aerial System (UAS) - Functional architecture and information flows	1/2025	Provides specifications for C2 link services running over 4G	May provide options for C2 Link services provided over 4G links if these are made available by the MNOs
3GPP	Standard	Telecoms	3GPP TS 23.256	5G - Support of Uncrewed Aerial Systems (UAS) connectivity, identification and tracking - Stage 2	12/2024	Builds on TS22.125 and specifies architecture enhancements for supporting Uncrewed Aerial Systems (UAS) connectivity, identification and tracking, according to the use cases and service requirements	May become relevant when 5G coverage adequate for BVLoS operation and features enabled by MNOs
3GPP	Standard	Telecoms	3GPP TS 24.257	5G - Uncrewed Aerial System (UAS) Application Enabler (UAE) layer - Protocol aspects - Stage 3	12/2024	Specifies the protocols for application layer support for UAS services as specified in 3GPP TS 23.255	May become relevant when 5G coverage adequate for BVLoS operation and features enabled by MNOs
3GPP	Standard	Telecoms	3GPP TS 29.255	5G - Uncrewed Aerial System Service Supplier (USS) Services - Stage 3	3/2025	Specifies the stage 3 protocol and data model for the UAS-specific Naf Service Based Interface. It provides stage 3 protocol definitions and message flows, and specifies the API for each service offered by the UAS-specific AF (access function)	May become relevant when 5G coverage adequate for BVLoS operation and features enabled by MNOs
3GPP	Standard	Telecoms	3GPP TS 29.256	5G - Uncrewed Aerial Systems Network Function (UAS-NF) - Aerial Management Services - Stage 3	3/2025	Specifies the stage 3 protocol and data model for the UAS-NF functionality	May become relevant when 5G coverage adequate for BVLoS operation and features enabled by MNOs

Body	Type	Sector	Document reference	Title	Date	Description	Possible relevance to C2 Link
3GPP	Standard	Telecoms	3GPP TS 29.257	5G - Application layer support for Uncrewed Aerial System (UAS) - UAS Application Enabler (UAE) Server Services - Stage 3	3/2025	Specifies the stage 3 Protocol and data model for the UAS Application Enabler (UAE) Server services, for enabling the support of Uncrewed Aerial System (UAS) applications over 3GPP networks. It provides stage 3 protocol definitions and message flows and specifies the API for each service offered by the UAE Server.	May become relevant when 5G coverage adequate for BVLoS operation and features enabled by MNOs
3GPP	Standard	Telecoms	3GPP TS33.163	Battery Efficient Security for very low throughput Machine Type Communication (MTC) devices	3/2024	Defines communication security processes designed for very low throughput Machine Type Communication (MTC) devices that are battery constrained	May be a good specification to use, in conjunction with TS33.220, to minimise power demand for the authentication and security process on the UA
3GPP	Standard	Telecoms	3GPP TS33.220	Generic Bootstrapping Architecture	3/2024	A procedure to authenticate the user based on the SIM	May be a good way to provide end-point authentication
3GPP	Standard	Telecoms	3GPP TS 33.256	5G - Security aspects of Uncrewed Aerial Systems (UAS)	3/2024	Specifies the security features in support of the architecture enhancements for supporting Uncrewed Aerial Systems (UAS) connectivity, identification, tracking and pairing authorization defined in TS 23.256, according to the use cases and service requirements defined in TS 22.125	May become very relevant for securing and protecting the C2 Links when 5G coverage adequate for BVLoS operation and features enabled by MNOs
3GPP	Standard	Telecoms	3GPPP TS 33.401	3GPP System Architecture Evolution (SAE); Security architecture	9/2024	Defines the internal security of the MNO service and networks	To be aware of when defining C2 Links using 4G or 5G connections
ETSI	Standard	Telecoms	ETSI EN 302 186	[…] Satellite mobile Aircraft Earth Stations (AESs) operating in the 11/12/14 GHz frequency band […]	1/2021	System and antenna performance requirements for Ku band airborne satellite terminals	Specification for Ku band FSS airborne satellite terminals
ETSI	Standard	Telecoms	ETSI EN 302 340	[…] Harmonised Standard for satellite Earth Stations on board Vessels (ESVs) operating in the 11/12/14 GHz frequency bands allocated to the Fixed Satellite Service (FSS) […]	5/2016	System and antenna performance requirements for Ku band maritime satellite terminals	Information only

Body	Type	Sector	Document reference	Title	Date	Description	Possible relevance to C2 Link
ETSI	Standard	Telecoms	ETSI EN 302 977	[…] Harmonised Standard for Vehicle-Mounted Earth Stations (VMES) operating in the 14/12 GHz frequency bands […]	6/2016	System and antenna performance requirements for Ku band land vehicle mounted satellite terminals	Information only
ETSI	Standard	Telecoms	ETSI EN 303 978	[…] Harmonised Standard for Earth Stations on Mobile Platforms (ESOMP) transmitting towards satellites in geostationary orbit, operating in the 27,5 GHz to 30,0 GHz frequency band […]	10/2016	System and antenna performance requirements for Ka band airborne satellite terminals	Specification for Ka band FSS (GEO only) airborne satellite terminals
ETSI	Standard	Telecoms	ETSI EN 303 979	[…] Harmonised Standard for Earth Stations on Mobile Platforms (ESOMP) transmitting towards satellites in non-geostationary orbit, operating in the 27,5 GHz to 30,0 GHz frequency band […]	5/2016	System and antenna performance requirements for Ka band airborne satellite terminals	Specification for Ka band FSS (nGSO only) airborne satellite terminals