

Research Project EASA.2008/8

# Preliminary Impact Assessment on the Safety of Communications for Unmanned Aircraft Systems

Volume 2 Annexes

#### **Disclaimer**

This study has been carried out for the European Aviation Safety Agency by an external organization and expresses the opinion of the organization undertaking the study. It is provided for information purposes only and the views expressed in the study have not been adopted, endorsed or in any way approved by the European Aviation Safety Agency. Consequently it should not be relied upon as a statement, as any form of warranty, representation, undertaking, contractual, or other commitment binding in law upon the European Aviation Safety Agency.

Ownership of all copyright and other intellectual property rights in this material including any documentation, data and technical information, remains vested to the European Aviation Safety Agency. All logo, copyrights, trademarks, and registered trademarks that may be contained within are the property of their respective owners.

Reproduction of this study, in whole or in part, is permitted under the condition that the full body of this Disclaimer remains clearly and visibly affixed at all times with such reproduced part.



Final Report of the Preliminary Impact Assessment On the Safety of Communications for Unmanned Aircraft Systems (UAS)

**Volume 2 Annexes** 

08 December 2009 Issue 1.0





#### Prepared by:

	Title	Adrian Clough, Mike Ainley, Sarah Hunt
	Signature	Adrian Cloug, Mike Ainley, Sarah Hunt
	Date	08 December 2009
Authorised by: Mike Ainley		
	Title	Project Manager
	Signature	Mike Ainley
	Date	08 December 2009

# **Record of changes**

This is a controlled document.

Additional copies should be obtained through the issuing authority.

Proposals for change should be forwarded in writing to the issuing authority.

Issue	Date	Detail of Changes
0.1	26 September 2009	First draft
0.2	06 November 2009 Final draft for PSC review	
1.0	08 December 2009	First release

# Contents

REC	ORD OF CHANGES	2
CON	ITENTS	3
Α	CANDIDATE ARCHITECTURES DIAGRAMS	4
В	RISK ANALYSIS SCORES	46
С	BOUNDED ARCHITECTURES	66
D	GROUP 2 STAKEHOLDER QUESTIONNAIRE	77
Е	GLOSSARY	86

# A Candidate Architectures Diagrams

The following diagrams represent the 20 candidate architectures and their equivalent schematic diagrams

# A.1 Definitions

The following definitions are used in the functional and schematic diagrams.

UA	Unmanned Aircraft
UAS	Unmanned Aircraft System (comprises the UA the GCS and the radio link for command and control between the two).
ATC Relay	An architecture where the ATC voice and/or data communications path is relayed via the UA.
Non-ATC Relay	An architecture where the ATC voice and/or data communications path is not relayed via the UA.
DL	Data link (used for either ATC voice/data, and/or UA command and control)
GS	(radio) Ground Station (facility used to support either ATC voice/data, and/or UA command and control communications equipment)
GCS	Ground Control Station (from where the UAS pilot governs the flight of the UAV) and associated UAV monitoring/control systems
CSP	Communications Service Provider (used to provide voice/data communications between two specified points – independent of national ATC system).
DLSP	Data link Service Provider (used to provide aeronautical data communications between ATC and aircraft)
SCSP	Satellite Communications Service Provider. This includes routing signals to/from satellite earth stations, along satellite feeder links and transmission/reception of signals by satellites.
Direct Communications	Where there is a direct communications path between the UA or GCS with ATC (i.e. not routed via a third party voice or data communications network).
Non-Direct Communications	Where the communications path between the UA or GCS with ATC is routed via third party voice or data communications network.
ATC-N	Air Traffic Control – part of a national networked ATC system.
ATC-I	Air Traffic Control – independent service provider without connection to the national networked ATC system.

# **A.2 Conventions**

The following conventions apply to all candidate architectures in this paper:

Colour coding on functional diagrams

- RF links are denoted by dashed lines
- Wired links are denoted by solid lines

- Single line = half duplex channel
- Parallel line = full duplex channel
- Colour shading (on schematic diagrams):
- Light blue denotes systems physically installed on the unmanned aircraft
- Orange shapes are current and future ATC systems
- Magenta lines represent ATC voice/data
- Blue lines represent telecommand links
- Green lines represent telemetry links
- Black lines represent a combined ATC communications, telecommand and telemetry

A mnemonic is used to reference each of the architectures.

- The first letter categorises the architecture in terms of having ATC relay (R) or non-ATC relay (N).
- The second letter defines whether the architecture has a dedicated (D) or networked (N) communications path to ATC.
- The third letter defines whether the architecture has radio (R) or wired (W) connection to ATC.
- Where there is more than one path in the architecture, a second mnemonic block is used.

#### A.2.1 Functional Diagram

The purpose of the functional diagram is to show the signal path(s) for ATC voice/data, telecommand and telemetry components, which constitute the command and control or C2 link. To aid clarity, the functional diagram does not show other aircraft or UAS. Similarly, it does not show the system elements or institutional aspects of each architecture.

### A.2.2 Schematic Diagram

The schematic diagram provides a more detailed breakdown of the communications paths used for ATC voice/data, telecommand and telemetry. It identifies the systems used, the means of connectivity between systems, and in broad terms, who has responsibility for each system element.

To maintain clarity and to enable maximum flexibility in the functional risk analysis process, the attributes of each system (i.e. availability, integrity, likelihood of failure etc) are not specified.

Key to Schematic diagram

- T Potential to result in total failure of UAS communications
- M Potential for a fault to result in communications being misheard by ATC or the UAV pilot
- P Potential to result in a partial failure of UAS communications
- D Potential for communications to be misdirected (to the wrong aircraft, ground station or ATC unit)
- L Potential for system element to introduce significant latency
- I Potential for system element to be intermittent
- S Potential for system element to fail through loss of synchronisation with other system elements

# A.3ATC Relay Architectures

A.3.1 <u>AR1 – ATC Voice/Data, TLM & TCM Communications via Dedicated Radio (ADR)</u>

AR1 – Functional Diagram



AR1 – Schematic Diagram



#### QinetiQ Proprietary

# A.3.2 <u>AR2 – ATC Voice/Data Communications, TLM & TCM via Networked Terrestrial Radio (ANTR)</u>

AR2 – Functional Diagram



**QinetiQ Proprietary** 

AR2 – Schematic Diagram



**QinetiQ Propriety** 

**QinetiQ Proprietary** 

A.3.3 <u>AR3 – ATC Voice/Data Communications, TLM & TCM via Networked Geostationary Satellite Radio</u> (ANGSR)

AR3 – Functional Diagram



AR3 – Schematic Diagram



# <u>A</u>R4 – ATC Voice/Data Communications, TLM & TCM via <u>Networked Low Earth Orbit Satellite Radio (ANLSR)</u>

AR4 – Functional Diagram





**QinetiQ Proprietary** 

# A.3.4 <u>AR5 – ATC Voice/Data Communications, TLM & TCM via Networked High Altitude Platform Radio (ANHR)</u>

AR5 – Functional Diagram







# A.4Non-ATC Relay Architectures

- A.4.1 NR1 ATC Voice/Data Communications via Dedicated Ground-based ATC Radio, TCM & TLM via Dedicated Terrestrial Data link (NDGR-DTD)
  - NR1 Functional Diagram



NR1 – Schematic Diagram



Copyright © QinetiQ Ltd 2008

**QinetiQ Propriety** 

# A.4.2 <u>NR2 – ATC Voice/Data Communications via Networked Ground-based ATC Radio, TLM & TLC via</u> <u>Networked Terrestrial Data link (NNGR-NTD)</u>

NR2 – Functional Diagram





Copyright © QinetiQ Ltd 2008

**QinetiQ Propriety** 

## A.4.3 <u>NR3 – ATC Voice/Data Communications via Networked Ground-based ATC Radio, TLM & TLC via</u> <u>Geostationary Satellite Data link (NNGR-GSD)</u>

#### NR3 – Functional Diagram





A.4.4 <u>NR4 – ATC Voice/Data Communications via Networked Ground-based ATC Radio, TLM & TLC via Low</u> Earth Orbit Satellite Data link (NNGR-LSD)

#### NR4 – Functional Diagram





## A.4.5 <u>NR5 – ATC Voice/Data Communications via Networked Ground-based ATC Radio, TLM & TLC via Low</u> Earth Orbit Satellite Data link (NNGR-LSD)

#### NR5 – Functional Diagram





**QinetiQ Propriety** 

**QinetiQ Proprietary** 

# A.4.6 <u>NR6 – ATC Voice/Data Communications via Dedicated Wired Interface, TLM & TLC via Dedicated</u> <u>Terrestrial Data link (NDW-DTD)</u>

NR6 – Functional Diagram





**QinetiQ Proprietary** 

# A.4.7 <u>NR7 – ATC Voice/Data Communications via Dedicated Wired Interface, TLM & TLC via Networked</u> <u>Terrestrial Data link (NDW-NTD)</u>

NR7 – Functional Diagram



#### NR7 – Schematic Diagram



**QinetiQ Proprietary** 

# A.4.8 <u>NR8 – ATC Voice/Data Communications via Dedicated Wired Interface, TLM & TLC via Geostationary</u> Satellite Data link (NDW-GSD)

NR8 – Functional Diagram



NR8 – Schematic Diagram



**QinetiQ Proprietary** 

A.4.9 <u>NR9 – ATC Voice/Data Communications via Dedicated Wired Interface, TLM & TLC via Low Earth Orbit</u> Satellite Data link (NDW-LSD)

NR9 – Functional Diagram







#### **QinetiQ Proprietary**

### A.4.10 <u>NR10 – ATC Voice/Data Communications via Dedicated Wired Interface, TLM & TLC via High Altitude</u> Platform <u>Data link (NDW-HD)</u>

NR10 – Functional Diagram


QinetiQ Proprietary



**QinetiQ Proprietary** 

#### A.4.11 <u>NR11 – ATC Voice/Data Communications via Networked Wired Interface, TLM & TLC via Dedicated</u> <u>Terrestrial Data link (NNW-DTD)</u>

NR11 – Functional Diagram



**QinetiQ Proprietary** 



**QinetiQ Proprietary** 

#### A.4.12 <u>NR12 – ATC Voice/Data Communications via Networked Wired Interface, TLM & TLC via Networked</u> <u>Terrestrial Data link (NNW-NTD)</u>

NR12 – Functional Diagram





**QinetiQ Propriety** 

#### **QinetiQ Proprietary**

#### A.4.13 <u>NR13 – ATC Voice/Data Communications via Networked Wired Interface, TLM & TLC via Geostationary</u> Satellite Data link (NNW-GSD)

NR13 – Functional Diagram





#### **QinetiQ Proprietary**

# A.4.14 NR14 – ATC Voice/Data Communications via Networked Wired Interface, TLM & TLC via Low Earth Orbit Satellite Data link (NNW-LSD)

#### NR14 – Functional Diagram





A.4.15 <u>NR15 – ATC Voice/Data Communications via Networked Wired Interface, TLM & TLC via High Altitude</u> Platform Data link (NNW-HD)

NR15 – Functional Diagram





**B** Risk Analysis Scores This appendix provides details of the risk analysis scores, for each of the 20 architectures that were determined during the workshop.

#### **B.1AR1**

		No of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	tot	Mitigation	Comments
							ATC comms still	UAV would have to
	Loss of command and control						available to other	operate autonomously if
Total Loss	and ATC	6	4	3	3 12	72	a/c in the area	available.
				-				
	Loss of ATC voice/data						ATC procedures	
Doutiol Loop	comms	2	2	1		6	use of transponder	
Partial Loss			2	-	2	. 0	use of transportuer	
	Loss of OAV telecommand							
	data link	1	4	1	4	4	redundancy	
	Loss of UAV telemetry data							
	link	1	4	1	4	4		
	common to all							
	architectures,so not							
Error of Input/Output	considered.							
							Command &	
							control link certified	
	Control of wrong air vehicle -						and approved to	
Mindingstion of data	this prohitecture is reduct						high integrity	
Misdifection of data	this architecture is fobust				-		nign integrity	
In a subject of the state	ne herende ider (Cod				<u> </u>			
Inconsistent information	no hazards identified							
							Command &	
							control link certified	
							and approved to	assumed that errors are
Erroneous Updating	no hazards identified						high integrity	detected.
						1		
Failure to: start: stop: switch	no hazards identified				I			
, , , , , , , , , , , , , , , , , , , ,					1			
	This architecture is not				1			
Delayed/premature operation	vulnerable to latency							
Beingen premining operation	rainerable to lateriey							
Inadvertent operation	no hazards identified							
findevertent operation								
The second s	no homordo identified							
Intermittent or erratic operation	no nazaros identified							
	Corruption of ATC voice							
Misheard	comms	6	1	1	1	6	ATC read back	
Misunderstood	as misheard							
	UAV goes out of C&C							Lose all ATC comms &
Used beyond intent	coverage	1	4	4	16	16		control.
	UAV goes out of ATC sector						Still has voice	
	coverage	1	2	1	2	2	comms with ATC	
Out of time synchronisation	no hazards identified							
			l	Risk score	41	110		
			1		1			
	1		ł	1	1		1	1
Positive			1	1	1			
Connect to any ATC					1			
infractructure on only								
froquopov			Dick Summer		1			
Net many interferen			RISK SUMMARY					
not many menaces -			Llink		,			
simplistic form			High	C	,	<u> </u>		
no third party control issues			Medium	12	2			
			Low	10	)			
negative								
common mode of failure for								
ATC C&C								
Ground station has limited								
coverage					1			

## **B.2 AR2**

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	tot	Mitigation	Comments
							ATC comms still	UAV would have to operate autonomously if available. Number of elements is pessimistic as it does not take account of overlapping coverage
Total Loss	Loss of command and control			1		26	available to other	and movement of the UAV within range
I otal Loss	and ATC		4		4	30	a/c in the area	or other ground stations.
Partial Loss	Loss of ATC voice/data comms	3	2	1	2	6	ATC procedures, use of transponder	
	Loss of UAV telecommand	1		1	4	4	multiple redundancy	
	Loss of UAV telemetry data						redundancy	
	common to all	1	4	1	4	4		
Error of Input/Output	architectures,so not considered.							
							Command & control link certified and approved to	
Misdirection of data	Control of wrong air vehicle	1	5	1	5	5	high integrity	high integrity end to end authentication
Inconsistent information	no hazards identified							
Erroneous Updating	no hazards identified						Command & control link certified and approved to high integrity	assumed that errors are detected.
Failure to: start; stop; switch	no hazards identified							
Delayed/premature operation	Additional voice and data latency due to network management	1	2	1	2	2	ATC read back	time stamping of data may mitigate this.
Inadvertent operation	no hazards identified							
Intermittent or erratic operation	no hazard identified							
Misheard	Corruption of ATC voice comms	7	1	1	1	7	ATC read back	
Misunderstood	as misheard						-	
Misunderstood	ao mionodia							
Used beyond intent	UAV goes out of C&C coverage - this architecture is robust	1	4	1	3	3		Lose all comms & control
	UAV goes out of ATC sector coverage	1	2	1	2	2	Still has voice comms with ATC	
	a a harmada i dan (10° a d							
Out of time synchronisation	no nazárds identifiéd							
				Risk Score	27	69		
Positivo			l		<u> </u>			
Connect to any ATC								
infrastructure on any frequency			Risk Summary					
Increased coverage			High	0				
Some redundancy		1	Low	14				
Negative		1	1					
common mode of failure for ATC								
C&C More complex							ļ	
dependent upon third parties		1	1					

## **B.3 AR3**

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	tot	Mitigation	Comments
								UAV would have to
								operate autonomously if
								available. Number of
								alemente la possimistio
								elements is pessimistic
								as it does not take
								account of overlapping
								coverage and
							ATC comms still	movement of the UAV
							available to other	within range of other
Total Loss	Loss of command and control and ATC	11	4	. 2	8	88	a/c in the area	ground stations.
							ATC procedures.	
Partial Loss	Loss of ATC voice/data comms	3		1	3	9	use of transponder	
		-					multiple	
	Loss of LIAV telecommand data link	4		1	4	4	rodundancy	
			-		4	4	redundancy	
	Loss of UAV telemetry data link		4		4	4		
	and the second							
Error of Input/Output	common to all architectures, so not considered.							
								high integrity end to end
							Command &	authentication.
							control link certified	Likelihood is low as end
							and approved to	to end authentication is
Misdiraction of data	Control of wrong air vehicle	4		. 1	5	5	high integrity	the same as AP2
Wilsdifection of data	Control of wrong all venicle			, I			nign integrity	the same as ANZ.
Inconsistent information	no nazards identified							
-								
							Command &	
							control link certified	
							and approved to	assumed that errors are
Erroneous Undating	no hazards identified						high integrity	detected.
Enoncous opauting								
Failura to: start: stop: switch	no bazards identified							
randre to: start, stop, switch								
	Additional value and data latenay due to							
	Additional voice and data latency due to							
- · · ·	network management and propogation path							
Delayed/premature operation	to/from satellite	2	2	5	10	30	ATC read back	
Inadvertent operation	no hazards identified							
Intermittent or erratic operation	Intermittent loss of satellite communications	2	4	. 2	8	16		
Misheard	Corruption of ATC voice comms	g	1	1	1	9	ATC read back	
Misunderstood	as misheard							
								Lose all comms &
								control. Better coverage
	UAV goes out of C&C coverage - this							than AR2 (if emergency
Used beyond intent	architecture is robust	1	4	. 1	4	4		decent required)
					1		Still has voice	
1	UAV goes out of ATC sector coverage	1	2	2 1	2	2	comms with ATC	1
Out of time synchronisation	no hazards identified							
	1	İ	1	1	İ 👘		İ	İ
h	i	1		Risk Score	_⊿0	171		1
h	1	1	1				1	
H			ł	t	1	<b>—</b>		
Positivo					I			
FUSILIVE ATO					<u> </u>	<u> </u>		
Connect to any ATC	1	1			I	1		1
Intrastructure on any frequency		L	Risk Summary	L	L			
Increased coverage particularly at								
low level	1		High					
Some redundancy			Medium	20				
			Low	12		i i		
Negative		i	t	1	1	1	1	i
Significant latency issues								
Common mode of failure for ATC			+	1	I			
CONTINUE OF AILURE TOP ATC								
Mass seveles sectionized for the			ł	ł	I	I		
wore complex particularly for UA								
satellite tracking			ļ	L	I	I		
Dependent upon third parties		l					l	

#### **B.4 AR4**

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
								UAV would have to
								operate autonomously if
								elements is pessimistic
								as it does not take
								account of overlapping
								coverage and
							ATC comms still	movement of the UAV
							available to other	within range of other
Total Loss	Loss of command and control and ATC	10	4	. 2	8	80	a/c in the area	ground stations.
					0	0		
n							ATC procedures,	
Partial Loss	Loss of ATC voice/data comms	3	2	1	2	6	use of transponder	
	Loop of LIAV tologommand data link	1	4	1			multiple	
	Loss of UAV telecontriland data link	1	4	1	4	4	recurricancy	
	Loss of OAV telemetry data link	1	4	1	4	4		
Error of Input/Output	common to all architectures so not considered				0	0		
Error or input/Output	common to an architectures, so not considered.				0	0		
					0	0		
								high integrity end to end
							Command &	authentication.
							control link certified	Likelihood is low as end
							and approved to	to end authentication is
Misdirection of data	Control of wrong air vehicle	1	5	1	5	5	high integrity	the same as AR2.
					0	0		
Inconsistent information	no hazards identified				0	0		
					0	0		
							Command &	
							control link certified	
							and approved to	assumed that errors are
Erroneous Updating	no hazards identified				0	0	high integrity	detected.
					0	0		
Failure to: start; stop; switch	no nazards identified				0	0		
	Additional voice and data latency due to				0	0		
	network management and propogation path							Less proporation delay
Delayed/premature operation	to/from satellite	3	2		6	18	ATC read back	than AR3
Delayed premature operation	iomon satellite		2		0	10	ATO TCAG BACK	than / tro.
Inadvertent operation	no hazards identified				0	0		
					0	0		
								This architecture is
								slightly less prone to
Intermittent or erratic operation	Intermittent loss of satellite communications	2	4	. 1	4	8		intermittancy than AR3
					0	0		
Misheard	Corruption of ATC voice comms	9	1	1	1	9	ATC read back	
					0	0		
Misunderstood	as misheard				0	0		
					0	0		
								Lose all comms &
	LIAV goos out of C&C coverage - this							than AP2 (if omorgonay
Used beyond intent	architecture is repust	1	4	1	4	4		decent required)
esed beyond ment					-	-	Still has voice	decent required)
	LIAV goes out of ATC sector coverage	1	2	1	2	2	comms with ATC	
Out of time synchronisation	no hazards identified				0	0		
				Risk Score	40	140		
Positive								
Connect to any ATC		Risk						
infrastructure on any frequency		Summary						
Increased coverage than AR3			-	]	1	1		
particularly at low level		High	0		L	L		
Some redundancy		iviealurñ	1/					
Negativo	l	LUW	15					
INCYALIVE								
Reduced latency issues wet AP3				1	1	1		
Common mode of failure for ATC				1				
C&C								
More complex particularly for UA								
satellite tracking				1	1	1		
Dependent upon third parties				1			İ	

## **B.5 AR5**

		Number of				Risk		-
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
Total Loss	Loss of command and control and ATC	11	4	2	8	88	ATC comms still available to other a/c in the area	UAV would have to operate autonomously if available. Number of elements is pessimistic as it does not take account of overlapping coverage and movement of the UAV within range of other ground stations. HAP is more vulnerable to failure
					0	0		
Partial Loss	Loss of ATC voice/data comms	3	2	1	2	6	ATC procedures, use of transponder	
	Loss of UAV telecommand data link	1	4	1	4	4	redundancy	
	Loss of UAV telemetry data link	1	4	1	4	4	multiple redundancy	
Error of Input/Output	common to all architectures, so not considered.				0	0		
Misdirection of data	Control of wrong air vehicle	1	5	1	5	5	Command & control link certified and approved to high integrity	high integrity end to end authentication. Likelihood is low as end to end authentication is the same as AR2.
Inconsistent information	no hazards identified				0	0		
					0	0		
Erroneous Updating	no hazards identified				0	0	Command & control link certified and approved to high integrity	assumed that errors are detected.
Failure to: start; stop; switch	no hazards identified				0	0		
					0	0		
Delayed/premature operation	Additional voice and data latency due to network management.	1	2	3	6	6	ATC read back	Less propogation delay than AR3 & 4.
Inadvertent operation	no hazards identified				0	0		
					0	0		This architecture is slightly less prope
Intermittent or erratic operation	Intermittent loss of HAP communications	2	4	1	4	8		to intermittancy than AR3
Misheard	Corruption of ATC voice comms	11	1	1	1	11	ATC read back	
Misunderstood	as misheard				0	0		
Misunderstood	do mionodra				0	0		
Used beyond intent	UAV goes out of C&C coverage - this architecture is robust	1	4	2	8	8		Lose all comms & control. Better coverage than AR2 (if emergency decent required)
	UAV goes out of ATC sector coverage	1	2	1	2	2	Still has voice comms with ATC	
Out of time synchronisation	no hazards identified		-		0	0		
				Risk Score	44	1/2		
						1.12		
Positivo								
Connect to any ATC		Risk						
infrastructure on any frequency		Summary						
particularly at low level or if emergency decent is required		Hiah	0					
Some redundancy		Medium	17					
Negative		Low	15		<u> </u>			
Reduced latency issues wrt AR3 Common mode of failure for ATC								
More complex particularly for UA								
satellite tracking Dependent upon third parties					L	L		

## **B.6 NR1**

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
					0	0		
	Loss of ATC voice/data							
Partial Loss	comms	5	2	1	2	10	ATC read back	
	Loss of UAV telecommand						Multiple	
	data link	7	4	1	4	28	redundancv	
	Loss of UAV telemetry data						Multiple	
	link	7	4	1	4	28	redundancy	
					0	0	,	
	common to all							
	architectures,so not							
Error of Input/Output	considered.				0	0		
· ·					0	0		
	Control of wrong air vehicle -							
Misdirection of data	this architecture is robust				0	0		
					0	0		
Inconsistent information	no hazards identified				0	0		
					0	0		
Erroneous Updating	no hazards identified				0	0		
					0	0		
Failure to: start: stop: switch	no hazards identified				0	0		
					0	0		
Delayed/premature operation	no hazards identified				0	0		
					0	0		
Inadvertent operation	no hazards identified				0	0		
					0	0		
Intermittent or erratic operation	no hazards identified				0	0		
internation of ciratic operation					0	0		
	Corruption of ATC voice				0	0		
Mishaard	comms	1	1	1	1	4	ATC road back	
Misheard	commis	4	1	· · · · ·	0	4	ATC TEAU DACK	
Misunderstood	as misheard				0	0		
Wisunderstood	as mislicard				0	0		
						0	ATC comms still	
	LIAV does out of C&C						available to other	& ammon all comms
Used beyond intent	coverage	1	4	4	16	16	available to other	control
Osed beyond intent	coverage	1	4	4		10	a/c in the alea	
	LIAV does out of ATC sector						Still bas voice	not be with the right
	coverage	1	2	2	6	6	comme with ATC	controllor
	coverage	1	2	3	0	0	comms with ATC	controller.
Out of time synchronisation	no bazards identified				0	0		
Out of time synchronisation	no nazaros identined					0		
				Risk Score	33	92		
Positive	1					52		
Direct connection of pilot and								
ATC								
Not many interfaces -								
simplistic form								
no third party control issues								
Negative					<b> </b>			
Ground station has limited	1							
coverage constrained by								
location of ground station								
equipment.								
					<b> </b>			
			Risk Summarv					
			High	0				
			Medium	16				
			Low	10				
			1	10				

## **B.7 NR2**

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
					0	0		
	Loss of ATC voice/data					-		
Partial Loss	comms	8	2	1	2	16	ATC read back	
I ultur Loss	Loss of LIAV telecommand					10	Multiple	
	data link	10	1	1	1	40	redundancy	
	Loss of LIAV tolomotry data	10	-	'		40	Multiplo	
	Loss of OAV teleffieldy data	10	4	4		40	rodundanav	
	IIIIK	10	4	· · ·	4	40	redundancy	
	as menors to all				0	0		
	common to all							
-	architectures, so not							
Error of Input/Output	considered.				0	0		
		-	_		0	0		
Misdirection of data	Control of wrong air vehicle	2	5	1	5	10		
					0	0		
Inconsistent information	no hazards identified				0	0		
					0	0		
Erroneous Updating	no hazards identified				0	0		
					0	0		
Failure to: start; stop; switch	no hazards identified				0	0		
					0	0		
	Additional voice and data							
	latency due to network							
Delayed/premature operation	management	2	2	. 1	2	4	ATC read back	
					0	0		
Inadvertent operation	no hazards identified				0	0		
					0	0		
Tetomeittent on omotio on ontion	no bazards identified				0	0		
Internitient or erratic operation	no nazaros identined				0	0		
	0				0	0		
	Corruption of ATC voice					_		
Misheard	comms	6	1	1	1	6	ATC read back	
					0	0		
Misunderstood	as misheard				0	0		
					0	0		
							ATC comms still	
	UAV goes out of C&C						available to other	Lose all comms &
Used beyond intent	coverage	1	3	3	9	9	a/c in the area	control
								The voice comms may
	UAV goes out of ATC sector						Still has voice	not be with the right
	coverage	1	2	2	4	4	comms with ATC	controller.
					0	0		
Out of time synchronisation	no hazards identified				0	0		
				Risk Score	31	129		
Positive								
Networked ground station				i –				
coverage								
Only 1 single point of failure								
Robust ATC comms								
architecture					ĺ			
				l				
Negativo	1			ł			ł	
Inegative					<u> </u>			
Ord parties to control								
Silu parties to control			Dials Commerce		<b>—</b>			
			KISK Summary		<u> </u>			
			High	0	L			
			Medium	16				
			Low	10				

## **B.8 NR3**

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
					0	0		
	Loss of ATC voice/data							
Partial Loss	comms	8	2	1	2	16	ATC read back	
	Loss of UAV telecommand						Multiple	
	data link	11	4	1	4	44	redundancy	
	Loss of UAV telemetry data						Multiple	
	link	11	4	1	4	44	redundancy	
					0	0		
	common to all							
	architectures, so not							
Error of input/Output	considered.				0	0		
Mindianation of data	Control of wrong air vohicle	2	5	1	5	10		
Misdirection of data	Control of wrong all vehicle	2		' '	0	10		
Tennesistant information	no hazards identified				0	0		
Inconsistent information	no nazaros identined				0	0		
Erroneous Undating	no hazards identified				0	0		
Erroneous opuaning	no nazaros identined				0	0		
Failure to: start: stop: switch	no hazards identified				0	0		
ranure to: start, stop, switch	no nazaros identined				0	0		
	Additional voice and data				Ŭ			
	latency due to network							
	management and satellite							
Delayed/premature operation	propogation delay	4	2	1	2	8	ATC read back	
	propaganen zena)				0	0		
Inadvertent operation	no hazards identified				0	0		
					0	0		
	Intermittent loss of satellite							
Intermittent or erratic operation	communications	2	4	2	8	16		
					0	0		
	Corruption of ATC voice							
Misheard	comms	6	1	1	1	6	ATC read back	
					0	0		
Misunderstood	as misheard				0	0		
					0	0		
							ATC comms still	
	UAV goes out of C&C						available to other	Lose all comms &
Used beyond intent	coverage	1	4	1	4	4	a/c in the area	control
								The voice comms may
	UAV goes out of ATC sector						Still has voice	not be with the right
	coverage	1	2	2	4	4	comms with ATC	controller.
					0	0		
Out of time synchronisation	no hazards identified				0	0		
				Dist. O		450		
D				Risk Score	34	152		
POSITIVE								
Networked ground station								
Only 1 single point of failure					—			
Driv I single point of failure								
architecture								
Increased C&C coverage				ł				
narticularly at low level				1				
Nogativo								
				l	<u> </u>			
Two 3rd parties to control				l				
Delay introduced on C&C by				1	┣			
satellite comms			Risk Summary	1				
			High	n -				
			Medium	16				
			Low	10				
L	1		2.511	10			1	

## **B.9 NR4**

		Number of				Risk		
Keyword	Hazard	elements	Consequence	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
					0	0		
Dominal Lana	Loss of ATC voice/data			1	2	16	ATC road book	
Paruai Loss	Loss of LIAV telecommand	0	2	· ·		10	Multiple	
	data link	12	4	1	4	48	redundancy	
	Loss of UAV telemetry data				· · ·		Multiple	
	link	12	4	1	4	48	redundancy	
					0	0		
	common to all							
	architectures,so not							
Error of Input/Output	considered.				0	0		
		-	_		0	0		
Misdirection of data	Control of wrong air vehicle	2	5	1	5	10		
	UAV communications with							
	wrong ATC controller	1	2	1	2	2		
Inconsistant information	no bazards identified				0	0		
inconsistent information	no nazaros identined				0	0		
Erroneous Updating	no hazards identified				0	0		
					n n	0		
Failure to: start; stop; switch	no hazards identified	i		i	Ō	0		
					0	0		
	Additional voice and data							
	latency due to network							
	management and satellite							
Delayed/premature operation	propogation delay	4	2	1	2	8	ATC read back	
					0	0		
Inadvertent operation	no hazards identified				0	0		
					0	0		
								-
								This architecture is
The second second second second second second second second second second second second second second second s	Intermittent loss of satellite			1	4			slightly less prone to
Intermittent or erratic operation	communications	2	4	<u>'</u>	4	0		Intermittancy than ARS
	Corruption of ATC voice				0	0		
Michaard	comms	6	1	1	1	6	ATC road back	
Wisheard	comms	0	1	· · ·	0	0	ATC TEAU DACK	
Misunderstood	as misheard				0	0		
Misunderstood					0	0		
							ATC comms still	
	UAV goes out of C&C						available to other	Lose all comms &
Used beyond intent	coverage	1	4	1	4	4	a/c in the area	control
								The voice comms may
	UAV goes out of ATC sector						Still has voice	not be with the right
	coverage	1	2	2	4	4	comms with ATC	controller.
0	an hammada 'dan (Cad				0	0		
Out of time synchronisation	no nazards identified				0	0		
				Pick Score	22	154		
Positive				NISK SCOLE	52	134		
Networked ground station	1							
coverage								
Only 1 single point of failure								
Robust ATC comms								
architecture								
Increased C&C coverage								
particularly at low level								
Negative								
	<b> </b>				L			
I wo 3rd parties to control					—	—		
peray introduced on C&C by	1		Diak Summers					
Satellite commis	ł		High					
	<u>†</u>		Medium	16				
	<u> </u>		Low	10			·	
				10				

## B.10 NR5

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
					0	0		
	Loss of ATC voice/data							
Partial Loss	comms	8	2	1	2	16	ATC read back	
	Loss of UAV telecommand						Multiple	
	data link	12	4	1	4	48	redundancy	
	Loss of UAV telemetry data						Multiple	
	link	12	4	1	4	48	redundancy	
					0	0		
	common to all							
	architectures,so not							
Error of Input/Output	considered.				0	0		
					0	0		
Misdirection of data	Control of wrong air vehicle	2	5	1	5	10		
	UAV communications with							
	wrong ATC controller	1	2	1	2	2		
					0	0		
Inconsistent information	no hazards identified				0	0		
					0	0		
Erroneous Updating	no hazards identified				0	0		
					0	0		
Failure to: start; stop; switch	no hazards identified				0	0		
					0	0		
	Additional voice and data							
	latency due to network							
	management and satellite							
Delayed/premature operation	propogation delay	2	2	1	2	4	ATC read back	
					0	0		
Inadvertent operation	no hazards identified				0	0		
					0	0		
								This architecture is
	Intermittent loss of satellite							slightly less prone to
Intermittent or erratic operation	communications	2	4	1	4	8		intermittancy than AR3
					0	0		,
	Corruption of ATC voice				-	-		
Misheard	comms	5	1	1	1	5	ATC read back	
initial de la companya de la	Commo			· · · · ·	0	0		
Misunderstood	as misheard				0	0		
misunderstööd					0	0		
							ATC comms still	
	LIAV goes out of C&C						available to other	Lose all comms &
Used beyond intent	coverage	1	4	2	8	8	a/c in the area	control
esea beyona mient	corolago							The voice comms may
	LIAV does out of ATC sector						Still has voice	not be with the right
	coverage	1	2	2	4	4	comms with ATC	controller
	corolago		-		0	0		
Out of time synchronisation	no hazards identified	1			n n	0		
out of time synchronisation	no nazardo laonanoa							
				Risk Score	36	153		
Positive		1				100		
Networked ground station								
coverage								
Only 1 single point of failure								
Robust ATC comms								
architecture								
Increased C&C coverage	1							
particularly at low level								
Negative								
110gauve	+				<b>—</b>			
Two 3rd parties to control	1							
Two ord parties to control	+		Rick Summony					
			High		┣───			
	1		Modium	16				
	1			10				
L	l		LUW	10				1

## B.11 NR6

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
					0	0		
	Loss of ATC voice/data							
Partial Loss	comms	4	2	1	2	8	read back	
	Loss of UAV telecommand						Multiple	
	data link	7	4	1	4	28	redundancy	
	Loss of UAV telemetry data							
	link	7	4	1	4	28		
					0	0		
	common to all							
	architectures,so not							
Error of Input/Output	considered.				0	0		
					0	0		
	Control of wrong air vehicle -							
Misdirection of data	this architecture is robust				0	0		
					0	0		
Inconsistent information	no hazards identified				0	0		
					0	0		
Erroneous Updating	no hazards identified				0	0		
					0	0		
Failure to: start; stop; switch	no hazards identified				0	0		
					0	0		
Delayed/premature operation	no hazards identified				0	0		
					0	0		
Inadvertent operation	no hazards identified				0	0		
					0	0		
Intermittent or erratic operation	no hazards identified				0	0		
					0	0		
	Corruption of ATC voice							
Misheard	comms	3	1	1	1	3	ATC read back	
					0	0		
Misunderstood	as misheard				0	0		
					0	0		
	UAV goes out of C&C							Lose all comms &
Used beyond intent	coverage	1	4	4	16	16		control
	UAV goes out of ATC sector						Still has voice	
	coverage	1	2	3	6	6	comms with ATC	
					0	0		
	Loss of synchronisation							
	between the UAV network							
	and the ATC network. Loss of							
Out of time synchronisation	ATC voice comms	1	2	1	2	2		
				Risk Score	35	91		
Positive								
Direct connection of pilot and		Dials Commence						
ATC Net means interference		KISK SUMMARY				<u> </u>		
Not many interfaces -		Llink	_					
simplistic form		riign Maaliissee	0					
Retter connectivity between		wealum	16					
Better connectivity between		1	10					
	l	LUW	10					
	1							
Nogativo	1							
Ground station has limited								
coverage constrained by	1							
location of ground station								
equipment	1							
Need one dedicated GCS								
interface for each LIAV CCS	1							
Could make ATC	1							
infrastructure complay	1							
Can't communicate with ATC	}							
I I I I I I I I I I I I I I I I I I I								

## B.12 NR7

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
Tetal Lana	Loss of command and control					0		
l otal Loss	and ATC				0	0		
	Loss of ATC voice/data				-	Ů		
Partial Loss	comms	4	2	1	2	8	ATC read back	
	Loss of UAV telecommand						Multiple	
	data link	10	4	1	4	40	redundancy	
	Loss of UAV telemetry data						Multiple	
	link	10	4	1	4	40	redundancy	
	common to all				0	0		
	architectures.so not							
Error of Input/Output	considered.				0	0		
· ·					0	0		
Misdirection of data	Control of wrong air vehicle	1	5	1	5	5		
	UAV communications with							
	wrong ATC controller	1	2	1	2	2		
Inconsistant information	no bazards identified				0	0		
inconsistent information	no nazaros identined				0	0		
Erroneous Updating	no hazards identified				0	0		
					0	0		
Failure to: start; stop; switch	no hazards identified				0	0		
					0	0		
	Additional voice and data							
Dalana d/amagetana ana anti-an	latency due to network	4					ATC road book	
Delayed/premature operation	management	4	2	1	2	8	ATC read back	
Inadvertent operation	no hazards identified				0	0		
					0	0		
Intermittent or erratic operation	no hazards identified				0	0		
					0	0		
	Corruption of ATC voice	2						
Misheard	comms	3	1	1	1	3	ATC read back	
Misunderstood	as misheard				0	0		
Misulderstood	ao monoara				0	0		
	UAV goes out of C&C							
Used beyond intent	coverage	1	4	3	12	12		
								The voice comms may
								not be with the right
	LIAV goos out of ATC soctor						Still bac voice	controller. Not as bad
	coverage	1	2		6	6	comms with ATC	architecture (NR2)
	ooverage		-		0	0		
	Loss of synchronisation							
	between the UAV network							
	and the ATC network. Loss of							
Out of time synchronisation	ATC voice comms	1	2	1	2	2		
				Risk Score	40	126		
Positive					-10	120		
Direct connection of pilot and								
ATC		Risk Summary						
Not many interfaces for ATC								
comms path - simplistic form		High	0					
Better connectivity betwoon		weatum	16					
pilot and ATC		Low	10					
		2011	10					
Negative								
Need one dedicated GCS								
interface for each UAV GCS.								
Louid make ATC								
Can't communicate with ATC.								
	1							

## B.13 NR8

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
					0	0		
	Loss of ATC voice/data				_			
Partial Loss	comms	4	2	1	2	8	ATC read back	
	Loss of UAV telecommand						Multiple	
	data link	12	4	1	4	48	redundancy	
	Loss of UAV telemetry data						Multiple	
	link	12	4	1	4	48	redundancy	
					0	0		
	common to all							
F (1 ) (0 )	architectures, so not							
Error of Input/Output	considered.				0	0		
Minding sting of data	Control of urong oir vehicle	1	E	1	0	5		
Misurection of data	Control of wrong all vehicle	1	5	1	5	5		
In an a stand in fammation	no hazards identified				0			
Inconsistent information	no nazaros identineo				0			
Erronaous Undating	no bazards identified				0			
Enoneous Opdating	no nazaros identined				0			
Failure to: start: stop: switch	no hazards identified				0			
Failure to: start, stop, switch	no nazaros identined				0			
	Additional voice and data					l – ĭ		
	latency due to network							
Delayed/premature operation	management	3	2	1	2	6	ATC read back	
Delayed/premature operation	management		2		0	0	ATO TEAU DACK	
Inadvertent operation	no hazards identified				0			
inadvertent operation					0	0		
	Intermittent loss of satellite					ľ		
Intermittent or erratic operation	communications	2	4	2	8	16		
Internation of endue operation	Communications	-			0	0		
	Corruption of ATC voice					ľ		
Misheard	comms	3	1	1	1	3	ATC read back	
		-			0	0		
Misunderstood	as misheard				0	0		
					0	0		
	UAV goes out of C&C							
Used beyond intent	coverage	1	4	1	4	4		
								The voice comms may
								not be with the right
								controller. Not as bad
	UAV goes out of ATC sector						Still has voice	as a fixed frequency
	coverage	1	2	3	6	6	comms with ATC	architecture (NR2)
					0	0		
	Loss of synchronisation							
	between the UAV network							
	and the ATC network. Loss of							
Out of time synchronisation	ATC voice comms	1	2	1	2	2		
				<b>D</b> : 1 0				
Desitive				KISK Score	- 38	146		
Positive								
Direct connection of pilot and		Dials Commence						
ATC		Risk Summary						
comme path simplistic form		High	0					
Increased C&C coverage		riign	0					
particularly at low level		Medium	16					
Better connectivity between		moulant	10					
pilot and ATC		Low	10					
		2011	10					
Negative			1					
			1					
Need one dedicated GCS			1					
interface for each UAV GCS								
Could make ATC								
infrastructure complex								
Can't communicate with ATC	-	i		i		i		1
h in the				1		1		

## B.14 NR9

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
					0	0		
	Loss of ATC voice/data							
Partial Loss	comms	4	2	1	2	8	ATC read back	
	Loss of UAV telecommand						Multiple	
	data link	12	4	1	4	48	redundancy	
	Loss of UAV telemetry data						Multiple	
	link	12	4	1	4	48	redundancy	
						0	roddinddinoy	
	common to all					ľ		
	architectures so not							
Error of Input/Output	considered					<u>ہ</u>		
	considered.				0	0		
Mindianation of data	Control of wrong oir vehicle	1	E	4	0	0 5		
Misdirection of data	Control of wrong all vehicle	1	5	1	5	5		
	and the second of the second second				0	0		
Inconsistent information	no nazards identified				0	0		
					0	0		
Erroneous Updating	no hazards identified				0	0		
					0	0		
Failure to: start; stop; switch	no hazards identified				0	0		
					0	0		
	Additional voice and data							
	latency due to network							
Delayed/premature operation	management	3	2	1	2	6	ATC read back	
					0	0		
Inadvertent operation	no hazards identified				0	0		
					0	0		
	Intermittent loss of satellite				-			
Intermittent or erratic operation	communications	2	4	2	8	16		
internation of endue operation	Communications	-	•	_	0	.0		
	Corruption of ATC voice					- v		
Mishoord	commo	2	1	1	1	2	ATC road back	
Misieard	comms	5	1		1	3	ATC TEAU DACK	
Minundantaad	as michoard				0			
Misunderstood	as misneard				0	0		
					0	U U		
	DAV goes out of C&C	4		4				
Used beyond intent	coverage	1	4	1	4	4		<b>T</b> I
								The voice comms may
								not be with the right
							o	controller. Not as bad
	UAV goes out of ATC sector						Still has voice	as a fixed frequency
	coverage	1	2	3	6	6	comms with ATC	architecture (NR2)
					0	0		
	Loss of synchronisation							
	between the UAV network							
	and the ATC network. Loss of							
Out of time synchronisation	ATC voice comms	1	2	1	2	2		
				Risk Score	38	146		
Positive								
Direct connection of pilot and								
ATC		Risk Summary						
Not many interfaces for ATC								
comms path - simplistic form		High	0					
Increased C&C coverage								
particularly at low level		Medium	16					
Better connectivity between								
pilot and ATC		Low	10			1		
		1	10	1	1	1		
Negative					i –	1		
- toganto								
Need one dedicated GCS								
interface for each UAV CCS						1		
Could make ATC								
infrastructure complex						1		
Cap't communicate with								
I Communicate with ATC	1							
P	1	1	1	1	1			1

## B.15 NR10

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
	Loop of ATC vision/data				0	0		
Partial Loss	comms	1	2	1	2	8	ATC read back	
l altiai Loss	Loss of LIAV telecommand		2		~ ~		Multiple	
	data link	12	4	1	4	48	redundancy	
	Loss of UAV telemetry data						Multiple	
	link	12	4	1	4	48	redundancy	
					0	0		
	common to all							
	architectures, so not							
Error of Input/Output	considered.				0	0		
Misdirection of data	Control of wrong air vehicle	1	5	1	5	5		
ivisureedon of data	Control of wrong an vehicle				0	0		
Inconsistent information	no hazards identified				0	0		
					0	0		
Erroneous Updating	no hazards identified				0	0		
					0	0		
Failure to: start; stop; switch	no hazards identified				0	0		
					0	0		
	Additional voice and data							
Deleved/prometure operation	management	1	2	1	2	2	ATC road back	
Delayed/premature operation	management	1	2	1	2	2	ATC TEAU DACK	
Inadvertent operation	no hazards identified				0	0		
indevertent operation	no hazardo laonanod				0	0		
	Intermittent loss of satellite							
Intermittent or erratic operation	communications	2	4	2	8	16		
					0	0		
	Corruption of ATC voice							
Misheard	comms	3	1	1	1	3	ATC read back	
	as mishoard				0	0		
Misunderstood	as misneard				0	0		
	UAV goes out of C&C				0	0		
Used beyond intent	coverage	1	4	2	8	8		
								The voice comms may
								not be with the right
								controller. Not as bad
	UAV goes out of ATC sector						Still has voice	as a fixed frequency
	coverage	1	2	3	6	6	comms with ATC	architecture (NR2)
	Loss of synchronisation				0	0		
	between the UAV network							
	and the ATC network. Loss of							
Out of time synchronisation	ATC voice comms	1	2	1	2	2		
				Risk Score	42	146		
Positive								
Direct connection of pilot and		Diel: Comment						
ATC		RISK SUITITIALY						
Not many interfaces for ATC								
comms path - simplistic form		High	0					
Increased C&C coverage								
particularly at low level		Medium	16					
Better connectivity between								
pilot and ATC		Low	10					
Nanativa					<u> </u>			
Negative								
Need one dedicated GCS								
interface for each LIAV GCS								
Could make ATC								
infrastructure complex								
Can't communicate with ATC	-							
1								
Dependent upon third parties				1	I		1	

## B.16 NR11

		Number of				Bick		
Keyword	Hazard	elements	Consequence	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
	Loss of ATC voice/data				0	0	road back and data	
Partial Loss	comms	7	2	1	2	14	expiry times	
r artiar 2035	Loss of UAV telecommand	,		· · ·			Multiple	
	data link	7	4	1	4	28	redundancy	
	Loss of UAV telemetry data							
	link	7	4	1	4	28		
					0	0		
	common to all							
Emon of Innut/Output	architectures, so not				0	0		
Error of Input/Output	considered.				0	0		
	Control of wrong air vehicle -					Ŭ		
Misdirection of data	this architecture is robust				0	0		
	UAV communications with							
	wrong ATC controller	1	2	1	2	2		
					0	0		
Inconsistent information	no hazards identified				0	0		
Erroneous Undating	no bazards identified				0	0		
Enoncous Opuaning	no nazarus iucritineu				0	0		
Failure to: start; stop: switch	no hazards identified				0	0		
,, ,					0	0		
	Additional ATC voice and							
	data latency due to network							
Delayed/premature operation	management	1	2	1	2	2	ATC read back	
<b>X 1</b>	no homordo identified				0	0		
Inadvertent operation	no nazards identified				0	0		
Intermittant or arretic operation	no bazards identified				0	0		
Internation of erratic operation	no nazarus identined				0	0		
	Corruption of ATC voice				0	0		
Misheard	comms	5	1	1	1	5	ATC read back	
					0	0		
Misunderstood	as misheard				0	0		
					0	0		
	UAV goes out of C&C							Lose all comms &
Used beyond intent	coverage	1	4	4	16	16	Offit has such as	control
	Coverage	1	2	2	4	4	comms with ATC	
	coverage		Z	2	0	0		
-	Loss of synchronisation				-	-		
	between the UAV network							
	and the ATC network. Loss of							
Out of time synchronisation	ATC voice comms	1	2	1	2	2		
				Diale O a sea	07	404		
Positive				RISK Score	31	101		
Direct connection of pilot and								
ATC								
Not many interfaces -								
simplistic form								
-								
better connectivity between								
Single interface and safety								
case for ATC and data								
comms.								
Negative								
C&C Ground station has								
limited coverage constrained								
by location of ground station								
oquipmont.								
UAV reliance on third party for								
ATC comms.								
No ability to communicate								
with ATC-I.								

## B.17 NR12

		Number of				Rick		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
					0	0	and the state of data	
Partial Loss	LOSS OF A I C VOICE/data	7		1	2	1/	read back and data	
Partial Loss	Loss of UAV telecommand	,	2	· · · · ·	2	14	Multiple	
	data link	10	4	1	4	40	redundancy	
	Loss of UAV telemetry data							
	link	10	4	1	4	40		
			-		0	0		
	common to all							
Error of Input/Output	architectures, so not				0	0		
	considered.				0	0		
Misdirection of data	Control of wrong air vehicle	1	5	1	5	5		
	UAV communications with							
	wrong ATC controller	1	2	1	2	2		
					0	0		
Inconsistent information	no hazards identified				0	0		
Erronoous Undefing	no bazards identified				0			
Enoneous Opdatting	no nazarus identined				0	0		
Failure to: start; stop; switch	no hazards identified				0	0		
					0	0		
	Additional voice and data							
	latency due to network		_		_			
Delayed/premature operation	management	2	2	1	2	4	ATC read back	
Inadvertent operation	no bazards identified				0			
madvertent operation	no nazarus identined				0	0		
Intermittent or erratic operation	no hazards identified				0	0		
					0	0		
	Corruption of ATC voice							
Misheard	comms	5	1	1	1	5	ATC read back	
					0	0		
Misunderstood	as misheard				0	0		
	LIAV goes out of C&C				0	0		Lose all comms &
Used beyond intent	coverage	1	4	3	12	12		control
cood obyona mon	UAV goes out of ATC sector	-		-			Still has voice	
	coverage	1	2	2	4	4	comms with ATC	
					0	0		
	Loss of synchronisation							
	between the UAV network							
Out of time synchronisation	ATC voice comms	1	2	1	2	2		
out of time synchronisation					_	-		
				Risk Score	38	128		
Positive								
Direct connection of pilot and ATC								
Not many interfaces - simplistic form								
•								
Better connectivity between								
Single interface and safety								
case for ATC and data								
comms.								
Negative								
UAV reliance on third party for								
U&U.								
with ATC-I								
			1				1	

## B.18 NR13

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control							
Total Loss	and ATC				0	0		
					0	0		
	Loss of ATC voice/data							
Partial Loss	comms	7	2	1	2	14	ATC read back	
	Loss of UAV telecommand						Multiple	
	data link	12	4	1	4	48	redundancy	
	Loss of UAV telemetry data						Multiple	
	link	12	4	1	4	48	redundancy	
					0	0		
	common to all							
	architectures.so not							
Error of Input/Output	considered.				0	0		
					0	0		
Misdirection of data	Control of wrong air vehicle	2	5	1	5	10		
	UAV communications with							
	wrong ATC controller	1	2	1	2	2		
Inconsistent information	no hazards identified				0	0		
Inconsistent information					0	0		
Erroneous Undating	no hazards identified				0	0		
Enoleous optiating	no nazarao idonanod				0	0		
Failure to: start: stop: switch	no hazards identified				0	0		
ranuie to: start, stop, switch	no nazaros identined				0	0		
	Additional voice and data				0	- ·		
	latanay due to notwork							
	management and							
D-law d/manufactors and setting	management and	4	2	1			ATC road book	
Delayed/premature operation	propogation delay	4	2	1	2	0	ATC TEAU DACK	
<b>X</b> 1 4 4	a a la seconda i de stifica d				0	0		
Inadvertent operation	no nazards identilied				0	0		
	Internetitient lease of establish				0	0		
• · · · · · ·	Intermittent loss of satellite					10		
Intermittent or erratic operation	communications	2	4	2	8	16		
	O TATO				0	0		
	Corruption of ATC voice	-						
Misheard	comms	5	1	1	1	5	ATC read back	
					0	0		
Misunderstood	as misheard				0	0		
					0	0		
	UAV goes out of C&C							
Used beyond intent	coverage	1	4	1	4	4		
								The voice comms may
								not be with the right
							<b>.</b>	controller. Not as bad
	UAV goes out of ATC sector						Still has voice	as a fixed frequency
	coverage	1	2	2	4	4	comms with ATC	architecture (NR2)
					0	0		
1	Loss of synchronisation					1		
1	between the UAV network							
	and the ATC network. Loss of							
Out of time synchronisation	ATC voice comms	1	2	1	2	2		
				Risk Score	38	161		
Positive								
Direct connection of pilot and								
ATC		Risk Summary						
Not many interfaces for ATC								
comms path - simplistic form		High	0					
Increased C&C coverage								
particularly at low level		Medium	16					
Better connectivity between								
pilot and ATC		Low	10					
Negative								
Can't communicate with ATC-	-							
1								

## B.19 NR14

		Number of				Risk		
Keyword	Hazard	elements	Severity	Likelihood	Risk	Tot	Mitigation	Comments
	Loss of command and control				_			
Total Loss	and ATC				0	0		
					0	0		
D. C.I.T.	Loss of ATC Voice/data	7	0					
Paruai Loss	Loss of LIAV tolocommand	1	2	1	2	14	ATC TEAU DACK	
	data link	12	1	1	1	48	redundancy	
	Loss of LIAV telemetry data	12	7		-	40	Multinle	
	link	12	4	1	4	48	redundancy	
					0	.0	rodundanoj	
	common to all				-			
	architectures,so not							
Error of Input/Output	considered.				0	0		
					0	0		
Misdirection of data	Control of wrong air vehicle	2	5	1	5	10		
	UAV communications with				_			
	wrong ATC controller	1	2	1	2	2		
	as because identified				0	0		
Inconsistent information	no nazards identified				0	0		
Erronaous Undating	no bazards identified				0	0		
Erroneous Opdaung	no nazaros identined				0	0		
Failure to: start: stop: switch	no hazards identified				0	0		
r unure to: start, stop, switch					0	0		
	Additional voice and data							
	latency due to network							
	management and							
Delayed/premature operation	propogation delay	4	2	1	2	8	ATC read back	
					0	0		
Inadvertent operation	no hazards identified				0	0		
					0	0		
	Intermittent loss of satellite							
Intermittent or erratic operation	communications	2	4	2	8	16		
	Corruption of ATC vision				0	0		
Mishaard	comms	5	1	1	1	5	ATC road back	
Misneard	commis	5	1	1	0	0	ATC TEAU DACK	
Misunderstood	as misheard				0	0		
Misunder stood					0	0		
	UAV goes out of C&C							
Used beyond intent	coverage	1	4	1	4	4		
								The voice comms may
								not be with the right
								controller. Not as bad
	UAV goes out of ATC sector						Still has voice	as a fixed frequency
	coverage	1	2	2	4	4	comms with ATC	architecture (NR2)
	Loss of synchronisation				0	0		
	between the LIAV network							
	and the ATC network. Loss of							
Out of time synchronisation	ATC voice comms	1	2	1	2	2		
				Risk Score	38	161		
Positive								
Direct connection of pilot and								
ATC		Risk Summary						
Not many interfaces for ATC								
comms path - simplistic form		High	0					
Increased C&C coverage		riigii	0					
particularly at low level		Medium	16					
Better connectivity between								
pilot and ATC		Low	10					
Single interface and safety								
case for ATC and data								
comms.								
					ļ	L		
Negative								
Cap't communicate with ATC								
I Carri communicate with ATC-	]							
P								

## B.20 NR15

Konword	Hazard	Number of	Soverity	Likalihaad	Biok	Risk	Mitigation	Commonto
Keyword	Loss of command and control	elements	Severity	Likelinood	RISK	TOT	Mitigation	Comments
Total Loss	and ATC				0	0		
					0	0	read basis and data	
Partial Loss	comms	7	2	1	2	14	expirv times	
	Loss of UAV telecommand							
	data link	12	4	3	12	144	Limited redundancy	
	link	12	4	3	12	144		
					0	0		
	common to all							
Error of Input/Output	considered.				0	0		
					0	0		
							Command & control link certified	high integrity and to and
Misdirection of data	Control of wrong air vehicle	2	5	1	5	10	high integrity	authentication
	UAV communications with		_					
	wrong ATC controller	1	2	1	2	2		
Inconsistent information	no hazards identified				0	0		
					0	0		
Erroneous Updating	no hazards identified				0	0		
Failure to: start; stop; switch	no hazards identified				0	0		
					0	0		
	Additional voice and data latency due to network management and							
Delayed/premature operation	propogation delay	2	2	1	2	4	ATC read back	
Inadvertent operation	no hazards identified				0	0		
					0	0		
Intermittent or erratic operation	Intermittent loss of satellite	2	А	2	8	16		
Intermittent of errate operation	Communications				0	0		
	Corruption of ATC voice							
Misheard	comms	5	1	1	1	5	ATC read back	
Misunderstood	as misheard				0	0		
					0	0		
Used beyond intent	UAV goes out of C&C	1	А	2	8	8		Lose all comms &
Osed beyond ment	UAV goes out of ATC sector				Ē	Ē	Still has voice	Control
	coverage	1	2	2	4	4	comms with ATC	
Out of time synchronisation	Loss of synchronisation between the UAV network and the ATC network. Loss of ATC voice comms	1	2	1	2	2		
Positive				Risk Score	58	353		
Direct connection of pilot and ATC								
pilot and ATC								
Single interface and safety								
case for ATC and data								
Improved coverage over								
terrestial								
Nogativo								
Ground station has limited								
coverage constrained by								
location of ground station								
Number and complexity of								
comms interfaces between								
dedicated wired ATC								
UAV reliance on third party for								
ATC comms.								
No ability to communicate with other ATC.								
HAP is mobile and vulnerable.								
Third party dependence					i – – – – – – – – – – – – – – – – – – –	i – –		

## C Bounded Architectures

The following architectures were selected and agreed at the project kick off meeting as the 4 bounded architectures to take forward to assess the remaining impact topics.

#### AR2 - ATC relay using a networked ground station

This had the lowest overall risk score, required no modification to present day ATC infrastructure and was seen as a logical solution as long as sufficient spectrum was available to permit ATC voice/data to be carried over the C2 datalink.

#### NR1 - ATC via terrestrial ground station and datalink via non-networked ground station

This had the lowest risk score of the non-ATC relay architectures, and was seen as being a practical and cost effective solution for small UAS operating within a confined geographical area (e.g. radio line of sight).

#### NR3 - ATC via terrestrial Ground Station and datalink via geostationary satellite

This is the lowest scoring architecture with a satellite communications element and is seen as being cost effective and practical for medium/large UAS that need to operate over longer distances, or where there is no terrestrial C2 ground station coverage. By studying this architecture in more detail it will be possible to explore issues to do with the use of Satellite communications for C2, and the use of a Communication Service provider (CSP) to provide voice/data communications with ATC using ground-based radio equipment.

#### NR12 - ATC via CSP wired interface and datalink via networked ground station

Although this architecture does not have a particularly low score, it is considered to be a practical solution in the context of the SESAR 2020 timeframe. By studying this architecture in more detail it will be possible to explore issues associated with the use of a CSP managed wired interface to the ATC voice/data network.

#### C.1 Candidate architectures Diagrams

The following diagrams represent the 20 candidate architectures and their equivalent schematic diagrams

#### C.2 Definitions

The following definitions are used in the functional and schematic diagrams.

UA	Unmanned Aircraft
UAS	Unmanned Aircraft System (comprises the UA the GCS and the radio link for command and control between the two).
ATC Relay	An architecture where the ATC voice and/or data communications path is relayed via the UA.
Non-ATC Relay	An architecture where the ATC voice and/or data communications path is not relayed via the UA.
DL	Data link (used for either ATC voice/data, and/or UA command and control)
GS	(radio) Ground Station (facility used to support either ATC voice/data, and/or UA command and control communications equipment)
GCS	Ground Control Station (from where the UAS pilot governs the flight of the UAV) and associated UAV monitoring/control systems
CSP	Communications Service Provider (used to provide voice/data communications between two specified points – independent of national ATC system).

DLSP	Data link Service Provider (used to provide aeronautical data communications between ATC and aircraft)
SCSP	Satellite Communications Service Provider. This includes routing signals to/from satellite earth stations, along satellite feeder links and transmission/reception of signals by satellites.
Direct Communications	Where there is a direct communications path between the UA or GCS with ATC (i.e. not routed via a third party voice or data communications network).
Non-Direct Communications	Where the communications path between the UA or GCS with ATC is routed via third party voice or data communications network.
ATC-N	Air Traffic Control – part of a national networked ATC system.
ATC-I	Air Traffic Control – independent service provider without connection to the national networked ATC system.

#### **C.3 Conventions**

The following conventions apply to all candidate architectures in this paper:

Colour coding on functional diagrams

- RF links are denoted by dashed lines
- Wired links are denoted by solid lines
- Single line = half duplex channel
- Parallel line = full duplex channel
- Colour shading (on schematic diagrams):
- Light blue denotes systems physically installed on the unmanned aircraft
- Orange shapes are current and future ATC systems
- Magenta lines represent ATC voice/data
- Blue lines represent telecommand links
- Green lines represent telemetry links
- Black lines represent a combined ATC communications, telecommand and telemetry

A mnemonic is used to reference each of the architectures.

- The first letter categorises the architecture in terms of having ATC relay (R) or non-ATC relay (N).
- The second letter defines whether the architecture has a dedicated (D) or networked (N) communications path to ATC.
- The third letter defines whether the architecture has radio (R) or wired (W) connection to ATC.
- Where there is more than one path in the architecture, a second mnemonic block is used.

#### C.4 Functional Diagram

The purpose of the functional diagram is to show the signal path(s) for ATC voice/data, telecommand and telemetry components, which constitute the command and control or C2 link. To aid clarity, the functional diagram does not show other aircraft or UAS. Similarly, it does not show the system elements or institutional aspects of each architecture.

## C.5 Schematic Diagram

The schematic diagram provides a more detailed breakdown of the communications paths used for ATC voice/data, telecommand and telemetry. It identifies the systems used, the means of connectivity between systems, and in broad terms, who has responsibility for each system element.

To maintain clarity and to enable maximum flexibility in the functional risk analysis process, the attributes of each system (i.e. availability, integrity, likelihood of failure etc) are not specified.

Key to Schematic diagram

- T Potential to result in total failure of UAS communications
- M Potential for a fault to result in communications being misheard by ATC or the UAV pilot
- P Potential to result in a partial failure of UAS communications
- D Potential for communications to be misdirected (to the wrong aircraft, ground station or ATC unit)
- L Potential for system element to introduce significant latency
- I Potential for system element to be intermittent
- S Potential for system element to fail through loss of synchronisation with other system elements

## C.5.1 <u>AR2 – ATC Voice/Data Communications, TLM & TCM via Networked Terrestrial Radio (ANTR)</u>

AR2 – Functional Diagram



AR2 – Schematic Diagram


C.5.2 NR1 – ATC Voice/Data Communications via Dedicated Ground-based ATC Radio, TCM & TLM via Dedicated Terrestrial Data link (NDGR-DTD)

NR1 – Functional Diagram





### C.5.3 NR3 – ATC Voice/Data Communications via <u>N</u>etworked <u>G</u>round-based ATC <u>R</u>adio, TLM & TLC via <u>G</u>eostationary <u>S</u>atellite <u>D</u>ata link (NNGR-GSD)

NR3 – Functional Diagram





74

C.5.4 NR12 – ATC Voice/Data Communications via <u>N</u>etworked <u>W</u>ired Interface, TLM & TLC via <u>N</u>etworked <u>T</u>errestrial <u>D</u>ata link (NNW-NTD)

NR12 – Functional Diagram





<sup>76</sup> 

### D Group 2 Stakeholder Questionnaire

#### Page 1: Information for Respondents

The purpose of this questionnaire is to gain a wide cross section of stakeholder opinion on communication infrastructures for Unmanned Aircraft Systems (UAS). The aim is to gain general opinion in the areas of UAS development, regulation and operation. Collection of the results is being performed by QinetiQ Ltd\* in the UK on behalf of EASA.

The results of this questionnaire will not be publicly attributable to any individual and/or organisation and any such information is treated with strictest confidence. Information obtained will not be used for any other purpose or passed to any other organisation. An analysis of results will be included within the final EASA report for the project 'Preliminary Impact Assessment for UAS communication systems.' Your opinions are vital to the development of civil UAS and inclusion within the preliminary impact assessment; this is an important initial input to the Regulatory Impact Assessment (RIA) process.

Note: You may answer the questionnaire multiple times to reflect the needs of different UAS roles or applications.

In order to progress through this survey, please use the following navigation links:

- Click the Next >> button to continue to the next page.
- Click the Previous >> button to return to the previous page.
- Click the Submit >> button to submit your survey.

NOTE: If you do not have an opinion/answer on a particular question please leave the question blank.

\*QinetiQ strictly adheres to a Third Party Information Policy which mandates the storage and management of data in accordance with the UK Data Protection Act 1998.

#### Page 2: Contact Information

What is your role within the Unmanned Aerial System (UAS) industry?

UA/S Manufacturer UA/S Operator Systems/Avionics manufacturer/supplier Communication Service Provider ANSP Regulator Support services – e.g. airport/ maintenance/ training – please specify Other – please specify

Please fill in general information below:

Name Company Size of organisation (approximate no. of people employed) Country Email Address Phone Number

Are you willing to be contacted by QinetiQ for clarification of answers if required? Yes No

Enter security code (from the invitation email)

#### **PAGE 3: General Applications**

In general it is recognised that UAS may require different communication links, such as:

- A command and control data link (C2) between the remote control station and the Unmanned Aircraft (UA);
- Voice/data communications (and the exchange of surveillance data) with Air Traffic Control (ATC) service providers;
- "Sense and avoid" in relation to neighbouring air traffic, severe weather, terrain;
- "Payload" data link (e.g. to downlink video images);
- C3 link which is defined as C2 and ATC communications relayed through the UA.

The primary aim of the following questions is to acquire stakeholders' opinions on the first two communication links listed above. The way in which the data links are implemented may have a considerable impact on aspects of the UAS marketplace including: economy, social, spectrum, global interoperability and EU regulation. Hence it is necessary as a first step to explore the various topics associated with UAS communications to see their importance to industry.

The aim of this section is to identify applications of relevance for civil UAS operations and identification of potential areas that you forsee future requirements of operation.

### Q1. When do you foresee the following UAS applications commencing outside segregated airspace (answer all that you think are applicable)?

Before 2020 After 2020

Aerial Imaging and Mapping Agricultural Applications Airborne Pollution Observation & Tracking Atmospheric Research Border Patrol Cargo Chemical & Petroleum Spill Monitoring **Communications Relay** Drug Surveillance and Interdiction Humanitarian Aid Law Enforcement Maritime Surveillance Natural Hazard Monitoring Other Port Security Search and Rescue **Traffic Monitoring Utility Inspections** Other please specify:

Page 4: UAV Operational Context

It is important that this questionnaire is answered with only one application in mind, various applications may have different communication requirements from a UAS. This section considers where the UAS may operate

- Q2. Please specify the chosen application against which these questions will be answered.
- Q3. For the application selected please specify the area of operation (from the ground station) Operating altitude (drop down box within the following range- below 400 ft to up to 40000ft)

Maximum operating range (drop down box within the range less than 24NM to beyond 500 NM)

Q4. For the altitude and range selected above what is your preferred C2/C3 data link communications method (tick all that apply)

Satellite Single ground station

Networked ground stations

N/A

- Q5. Do you foresee any requirement to operate UAS over remote, maritime or polar regions devoid of infrastructure required for terrestrial based data link ground stations?
  - a) Yes
  - b) No
- Q6. How important is it to have the capability to operate UAS in different countries, and to cross international boundaries?
  - a) Not important
  - b) Desirable
  - c) Essential

#### Page 5: Infrastructure

Infrastructure on both the UAS and ground systems has an implication on the practicalities of operating a UAS in non-segregated airspace. The questions below aim to find out what sort of infrastructure you think is necessary to support the UAS application you foresee.

- Q7. If globally standardised and approved C2/C3 data link equipment were available, would you make use of it?
  - a) Yes
  - b) No
  - C) n/a or don't know

If No please explain:

- Q8. What percentage of UAS operations do you expect to use the following C2/C3 communication infrastructures?
  - Single ground station

Networked ground stations

Satellite

Combination ground/ satellite

- a) 0% to 20%
- b) 21% to 40%
- c) 41% to 60%
- d) 61% to 80%
- e) 81% to 100%

### Q9. When do you require the following types of C2/C3 communications infrastructure to be available to support your business need?

Single ground station Networked ground stations Satellite

Combination ground/ satellite

- a) 2010
- b) 2012
- c) 2014
- d) 2016
- e) 2018
- f) 2020
- g) n/a

#### Q10. How would you see the above infrastructure being provided?

In-house development of proprietary networks Privately funded development of standardised networks Publicly funded development of standardised networks

#### Q11. How do you intend to communicate with ATC?

Before 2020 After 2020

Relay through UA using onboard COM equipment Ground based COM equipment Wired connection with ATC Via a Communications Service Provider

# Q12. What percentage of UAS platforms produced or operated by your organisation and intended for operation inside a controlled/known airspace environment will be capable of transponder <u>and</u> VHF (voice) transceiver carriage?

a) 0-20%

- b) 21-40%
- c) 41-60%
- d) 61-80%
- e) 81-100%

Q13. What percentage of UAS platforms produced or operated by your organisation and intended for operation inside a controlled/known airspace environment will be capable of transponder <u>and</u> VHF (voice) <u>and</u> VHF (data) transceiver carriage?

- a) 0-20%
- b) 21-40%
- c) 41-60%
- d) 61-80%
- e) 81-100%

#### Page 6: Cost

Cost is a factor that is important to the development of the UAS industry. The questions below aim to capture the approximate range of cost and data requirements you would expect when operating an UAS.

### Q14. What do you expect the cost per UA will be for the following communications standardised equipment (not including installation costs);

Terrestrial C2/C3 data link

Satellite C2/3 data link

- a) Less than €10k
- b) €10k to €49k
- C) €50k to €99k
- d) €100k to €250k
- e) More than €250k

#### Q15. What are your expected data throughput requirements per UA?

Command and Control (C2)

Downlink of sense and avoid data

- ATC voice communications
- ATC data communications
- a) 0 to 20kbps
- b) 21 to 40
- c) 41 to 60
- d) 61 to 80
- e) More than 80

# Q16. Where communications are provided by a service provider, what costs would you expect per UA (€per kbps)?

Command and Control (C2)

Downlink of sense and avoid data

ATC voice communications

ATC data communications

- a) 0.1 to 0.5
- b) 0.6 to 1.0
- c) 1.1 to 2.0
- d) 2.1 to 4.0
- e) 4.1 to 6.0
- f) More than 6.1

#### Page 7: Equipment

This section aims to gather information on the general equipage requirements for a UAS operating in non-segregated airspace.

## Q17. What is an acceptable weight, power consumption, size and antenna gain of satellite communications equipment that a UA can support?

#### **Supply Power Requirements (Watts)**

1-49 Watts 50 to 99 100 to 199 200 to 299 300 to 499 Above 500 Weight (kg) 1-4 5 to 9 10 to 14 15 to 19 20 to 24 Above 25 Size (Number of MCUs) 1 to 2 3 to 4 5 to 6 7 to 8 Above 8 Antenna Diameter (m) Less than 0.5m Less than 1m Less than 2m 2m or more

Q18. What is an acceptable weight of terrestrial communications equipment that a UA can support?

- Weight
- 1-4 kgs
- 5 to 9
- 10 to 14
- 15 to 19
- 20 to 24
- Above 25
- Q19. The European Space Agency (ESA) is developing a new satellite system (i.e. Iris) to support airground communications for Air Traffic Management in the framework of SESAR. Iris should allow lighter avionics, smaller antennas on-board and cheaper service, when compared with today's technology. Do you think it would be worthwhile to explore the possibility of applying the Iris approach also to C2 datalink for UAS?
  - d) Yes
  - e) No

#### Page 8: Realization

This section aims to gain understanding of areas of importance for the realization of a UAS operating in non-segregated airspace. Understanding what areas you view as having a significant impact for advancement of the UAS industry.

### Q20. On a scale of 1 to 5, (where 1=Not important and 5=Critical) how do you perceive the following areas to be constraining the development of the UAS industry in Europe?

- Regulation
- Global Standards
- Sense and Avoid
- Spectrum Availability
- Communications Infrastructure
- Environmental
- Social Acceptability
- Safety
- Availability of Trained Personnel (including internationally agreed competence requirements for them)
- Any other area to consider (if yes, please specify)

Other please specify:

### Q21. Which of the following views do you most agree with on a scale of 1 (strongly disagree) to 5 (strongly agree)?

a) Sufficient spectrum should be sought to avoid UAS operations being constrained in any area, whatever the cost implications.

Available Spectrum

- b) Operational limitations due to insufficient spectrum are inevitable, but will be overcome in time as the UAS industry grows.
- c) It is acceptable to continue with the practice of seeking spectrum on a case-by-case basis, accepting that this could constrain the growth of UAS in many areas.

### Q22. What are the constraining factors in using satellite communications for C2 and ATC (tick all that apply)

Communication cost Equipment cost Equipment Weight Latency (signal delay) Use of third party provider(s) for communication services Reliability Availability (service level/system coverage) Security

- Q23. The emerging Single European Sky (SES) Implementing Rule (IR) on Surveillance Performance and Interoperability (SPI), will require transponder carriage by UAVs operating in a controlled/known airspace environment. What percentage of UAS platforms produced or operated by your organisation and intended for operation inside a controlled/known airspace environment will be capable of transponder carriage?
  - a) 0-20%
  - b) 21-40%
  - c) 41-60%
  - d) 61-80%
  - e) 81-100%

#### Page 9: Standardisation

This section aims to find out your view on the importance of standardisation for the UAS industry.

### Q24. How important is it for the UAS industry to have a standardised and interoperable set of standards for networked C2 datalink communications?

- a. Not important
- b. Desirable
- c. Essential

## Q25. How important is the need to achieve globally harmonised frequency allocation for UAS C2 datalink?

- a. Not important
- b. Desirable
- c. Essential

#### Page 10 General

In general what will the impact be on your organisation over the coming years and is there any other important topics that have not been discussed within previous sections.

## Q26. With the expansion UAS market what increase in manpower dedicated to UAS activity do you foresee over the following years

2010

2012

2014

2016

2018

2020

Beyond 2020

- a) 0%
- b) 1% to 20%
- c) 21% to 40%
- d) 41% to 60%
- e) 61% to 80%
- f) 81% to 100%
- g) More than 100%
- Q27. Do you see any other important issues to be considered in order to allow UAS operations in non-segregated airspace?

### E Glossary

ACAS	Airborne Collision Avoidance System
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
ASAS	Airborne Separation Assistance System
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
BLOS	Beyond Line of Sight
C2	Command and Control
C3	Command, Control and Communications
CATS	Combined Aerial Targets Service
CNS	Communication, Navigation and Surveillance
CS	Certification Specifications
CSP	Communications Service Provider
DL	Datalink
DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency
EU	European Union
FANS	Future Air Navigation System
FOM	Figure of Merit
FIR	Flight Information Region
GAT	General Air Traffic
GCS	Ground Control Station
GS	(radio) Ground Station
HALE	High Altitude Long Endurance
ІТТ	Invitation to Tender
MCA	Multi Criteria Analysis
NCO	Network Centric Operation
NEC	Network Enabled Capability
PMP	Project Management Plan
SESAR	Single European Sky ATM Research Programme
SMART	Specific, Measurable, Achievable, Relevant, Timely
SSR	Secondary Surveillance Radar
SWIM	System Wide Information Management
UAS	Unmanned Aircraft System
UA (or UAV)	Unmanned Aircraft (Vehicle)
VHF	Very High Frequency

Intentionally left blank



European Aviation Safety Agency Ottoplatz, 1 D-50679 Cologne, Germany

easa.europa.eu