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

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Study Report

Final Report of the Preliminary Impact Assessment On the Safety of Communications for Unmanned Aircraft Systems (UAS) Volume 1

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0.1	26 Sep 2009	First draft
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Executive Summary

Introduction

This report constitutes the final formal deliverable of the Preliminary Impact Assessment (PIA) on the safety of communications architectures for UAS contract number EASA.2008.C20 (procedure OP.08). This final report contains a complete description of the preliminary impact assessment undertaken and the resulting analysis, conclusions and recommendations.

Objectives

Much debate has taken place within the industry (including standardisation groups such as EUROCAE WG-73 and RTCA SC-203) about the architecture of the communications systems that will support the operation of UAVs in non-segregated airspace. Although these groups have produced some useful technical work, their role is not to endorse or promote a particular architecture, and consequently there is no consensus on what the architecture should look like.

In creating this project, EASA has initiated a process that will lead to the implementation of regulatory policy to permit the use of UAS in non-segregated airspace. The objective of this study is to provide an initial input and guidance for the Regulatory Impact Assessment (RIA) process. This will be achieved through a Preliminary Impact Assessment on safety and other factors that will be affected by the architecture(s) used for UAS communication systems. In the end, the regulations, while protecting safety, should not over-constrain technical and business choices.

Scope of the Study

The scope of this impact assessment is limited to the following communications links:

- An air-ground link between the Ground Control Station (GCS) and the UAV for command and control;
- An air-ground link between ATS/C and the UAV for traffic surveillance (and/or communication) purposes, if assessed as necessary;
- Communication link(s) between the UAS crew and ATS/ATC.

Six impact topics have been defined by which the communications links are to be evaluated. These are:

- Safety - including taking into account the availability, integrity and latency of transmitted data
- Economy - including the cost and weight of avionics and of modifying ATC systems
- Social - including the speed of development of the market and its effect on jobs and market penetration
- Electromagnetic Spectrum - including the amount of spectrum required, candidate frequency bands and issues associated with protection of existing users (within the candidate bands)
- Global interoperability – the ability for UAS to be safely operated in different States, and to conduct flights that transit FIR boundaries from one State to another
- EU Regulation – the compatibility of architectures with SES regulations and future operating concepts and system architectures identified by SESAR.

Approach

The QinetiQ approach recognises the need to evaluate architectures that best satisfy the needs of the UAS industry at large, without compromising on safety performance. The architectures selected for evaluation contain all the elements that might be used by a remote pilot when communicating with the UAV and with ATC. The process adopted was as follows:

1. Identify (safe) bounded architectures
2. Assess the architectures against the remaining impact topics

3. Analyse the results and correlate the Group 1 and Group 2 stakeholder responses.

Identify Bounded Architectures

The first part identified 4 architectures from an initial list of 20 that were capable of meeting the supposed safety performance requirements. The filtering was achieved through a preliminary hazard identification and risk assessment process. Judgements were made to select four architectures that would be representative of all the key elements with the potential to exist in reality. Importantly, this does not invalidate the other architectures, nor does it mean that the 20 candidate architectures represent the only architectures that may be deployed.

Assess the Architectures

In the second part, engagement with a broad cross-section of UAS stakeholders took place to understand the importance of the impacts associated with the architectures identified. The stakeholder survey was performed in two ways. Firstly, organisations with regulatory responsibility (Group 1) were interviewed to understand the regulatory view of the architectures and the issues arising from the insertion of UAS into general air traffic. Secondly, the user community (Group 2) was surveyed using an on-line survey. Participation was sought throughout the EU and included selected countries outside the EU with active UAS programmes. The questionnaires were developed by performing an initial impact assessment using QinetiQ's in-house expertise. The questionnaires were agreed with EASA prior to the survey going live. An expert body of stakeholders comprising EASA, other regulators and ANSPs have provided input into determining the weightings to be applied to the stakeholder responses.

Analysis and Correlation

The final part analysed the results of the surveys. Group 1 and Group 2 responses were analysed and correlated using QinetiQ's expert judgement to produce a combined result from which conclusions and recommendations were determined. Finally, sensitivity analysis was performed to understand how sensitive the results were to each of the impact topics.

Identify Candidate Architectures

A range of architectures were developed that met a series of fundamental tenets, these were:

- Transparency to ATC communications and Surveillance
- Reliability and Continuity
- Spectrum Usage
- Geographical Coverage

The architectures that were developed included a wide range of typical features such as ATC relay, dedicated wired interface, C2 implementation using a dedicated terrestrial ground station, networked ground station (GS) and GEO and LEO satellites. These are represented in the tables below:

	Dedicated terrestrial GS	Networked Terrestrial GS	GEO satellite	LEO satellite	HAP
ATC Relay	AR1	AR2	AR3	AR4	AR5

Non ATC relay	Dedicated terrestrial GS	Networked Terrestrial GS	GEO satellite	LEO satellite	HAP
Terrestrial GS (Radio)	NR1	NR2	NR3	NR4	NR5
Dedicated Wired Interface	NR6	NR7	NR8	NR9	NR10
CSP Wired Interface	NR11	NR12	NR13	NR14	NR15

Functional Hazard Identification and Risk Assessment

A hazard identification and risk assessment workshop was convened with subject matter experts from QinetiQ's Air Traffic Management, Unmanned Aerial Systems and System Safety teams. The aim of the workshop was to identify and record the functional hazards arising from each of the 20 architectures, and a brainstorming approach was used to elicit this from the expert judgements.

The risk analysis was based on the EUROCONTROL Safety Assessment Methodology (SAM) Preliminary Hazard Assessment (PHA) process. This methodology uses a set of severity categories to quantify the risk to ATC.

The following table shows the results of the analysis.

		Risk Score			
Architecture	Description	Weighted	plain	Red Risks	Yellow
AR1	ATC relay: non-networked GS	110	41	1	
AR2	ATC relay: networked GS	69	27	0	
AR3	ATC relay: GEO satellite	171	49	0	1
AR4	ATC relay: LEO satellite	140	40	0	
AR5	ATC relay: HAP	142	44	0	
NR1	ATC via terrestrial GS + DL via non-networked GS	92	33	1	
NR2	ATC via terrestrial GS + DL via networked GS	129	31	0	
NR3	ATC via terrestrial GS + DL via GEO satellite	152	34	0	
NR4	ATC via terrestrial GS + DL via LEO satellite	154	32	0	
NR5	ATC via terrestrial GS + DL via HAP	153	36	0	
NR6	ATC via dedicated wired i/f + DL via non-networked GS	91	35	1	
NR7	ATC via dedicated wired i/f + DL via networked GS	126	40	0	1
NR8	ATC via dedicated wired i/f + DL via GEO satellite	146	38	0	
NR9	ATC via dedicated wired i/f + DL via LEO satellite	146	38	0	
NR10	ATC via dedicated wired i/f + DL via HAP	146	42	0	
NR11	ATC via CSP wired i/f + DL via non-networked GS	101	37	1	
NR12	ATC via CSP wired i/f + DL via networked GS	128	38	0	1
NR13	ATC via CSP wired i/f + DL via GEO satellite	161	38	0	
NR14	ATC via CSP wired i/f + DL via LEO satellite	161	38	0	
NR15	ATC via CSP wired i/f + DL via HAP	353	58	0	2

As a result of the risk analysis the following architectures were proposed to the EASA focal point Mr F Tomasello and representatives of the Project Steering Group (PSC). These were accepted as the bounded architectures to be used for the Preliminary Impact Assessment.

The architectures that best met or exceeded the tolerable safety level in all event categories were considered eligible. Out of these, 4 architectures were identified that contained attributes or system elements that are likely to have some impact on the UAS industry, ANSPs and safety regulatory authorities. These are referred to as bounded architectures. It should also be noted that in order to investigate all aspects of the architectures, those chosen did not necessarily have the best safety score.

AR2 - Networked terrestrial GS providing C2 and ATC Voice/Data Communications

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 data link.

NR1 – Non-networked terrestrial for C2 and ground-based ATC Voice/Data COM equipment

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).

It is important to stress that the bounded architectures are not intended to be de-facto solutions. They are simply architectures with particular attributes to allow stakeholders to consider what associated issues might exist, whether related to safety, performance, interoperability, spectrum, regulation or cost.

NR3 – C2 via GEO satellite and ATC Voice/Data via networked ground-based COM equipment

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 was 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 Voice/Data via CSP wired interface and C2 via networked terrestrial GS

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 was possible to explore issues associated with the use of a CSP managed wired interface to the ATC voice/data network.

Assessment of Impact Topics

The initial impact assessment identified the issues that were considered likely to be contentious or high risk, be it for UAV/S manufacturers, UAV/S operators, Air Navigation Service Providers (ANSP) or safety regulators. It covered a wide range of issues including:

- Investment Costs (to develop suitable avionics equipment and associated ground/space infrastructure)
- Practical limitations (size and weight of equipment)
- Operational Costs
- Operational Limitations.

To achieve this, the impact of each of the bounded architectures was assessed in detail in the following five areas:

- Economic (cost and weight of the avionics and/or cost of modifications to ATS/ATC systems)
- Social Impact (slower or faster development of EU UAS industry), with a benchmark prediction as to the size of the industry by 2020.
- Use of Electromagnetic Spectrum (estimated total requirement)
- Global Interoperability (ability to operate in different States, and to transit FIR boundaries)
- Impact on other existing EU rules (i.e. compatibility with SESAR regulations and ESARRs).

The purpose of the initial assessment process culminated in a list of topics to be investigated further through stakeholder engagement. Both positive and negative attributes associated with each topic were summarised. However, to ensure that only the issues likely to have significant impact were addressed, judgement was applied during this stage to ensure that issues of little impact were not included in the questions presented to stakeholders.

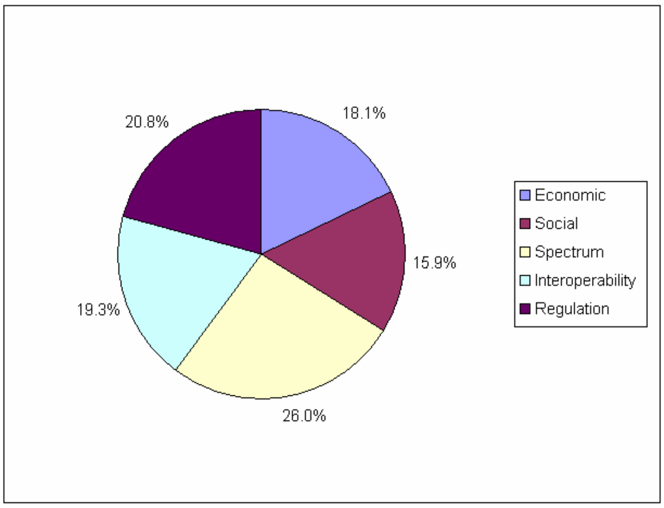
Group 1 Stakeholder Analysis

Group 1 stakeholders have two purposes, firstly, responses to the questions were analysed and scored. This was used to create an aggregate performance score for each of the impact topics, which was used as a weighting to multiply Group 2 scores and produce a compounded score for each of the bounded architectures. Secondly, through a qualitative analysis, common areas of importance were considered to derive observations (discussions on the consensus or divergence of views) and conclusions. These observations and conclusions were correlated with the Group 2 qualitative analysis to produce the final conclusions and recommendations.

Engagement with Group 1 stakeholders was in the form of face-to-face interviews that described the bounded architectures and the rationale for their selection. To allow the Group 1 stakeholders to prepare for the interview a briefing document was sent prior to the interview that described the background and architectures around which the questions were set. This is reproduced in Appendix C of volume 2 of this report. The questions for Group 1 were open questions to facilitate discussion and elicit a detailed rationale for the answers during the interview. All responses were reviewed and agreed with stakeholders to ensure that their opinions had been captured correctly.

Group 1 interviews were held with the following stakeholders:

- European Commission (DG-TREN)
- European Aviation Safety Agency (EASA)
- EUROCONTROL
- European Defence Agency (EDA)
- SESAR Joint Undertaking (SJU)
- French Civil Aviation Authority (DSNA)
- UK Civil Aviation Authority (CAA)
- ESA (ESTEC)



Group 1 Quantitative Analysis

The overall aggregate performance score against each of the impact topics is shown in the pie chart opposite.

The percentages represent the relative importance that Group 1 place on the impact topics. Sensitivity analysis was undertaken to test the sensitivity of these results and it was found that the results were consistent.

Group 1 Qualitative Analysis

The group 1 responses were also analysed according to the level of consensus against the questions. The following definitions were used in analysing the responses:

- Strong consensus: where the same response was given by nearly all stakeholders, and there were no opposing views
- General consensus: Where the same response was given by the majority of stakeholders
- Other responses: where issues were raised by one or two stakeholders. These responses may complement or oppose the general consensus.

The following table provides a summary by way of selected observations to the responses given.

No.	Title	Observations	source
1	Applications	There is a large market for state sponsored applications such as border patrol, search and rescue etc. There is also a strong military requirement to traverse non segregated airspace for operational requirements and where this provides cost benefits. Commercial operations will be more cost benefit driven.	Q1
2	R&D cooperation	A number of organisations are providing R&D into aspects of UAS in GAT. It is important that regulators provide guidance on the performance standards that UAS must adhere to, to ensure consensus and integration focus for the research.	Q2/ Q4
3	Link to SESAR	R&D for UAS and subsequent exploitation must be compatible with SESAR concepts	Q2
4	Development of infrastructure	There is little or no visible activity to provide infrastructure and services to support UAS communications. Two reasons stand out. Firstly, it is difficult to provide a meaningful business plan when the traffic forecasts are uncertain and secondly there are neither safety rules nor guidelines nor performance requirements that can be used to develop the infrastructure. Requirements and performance standards need to be developed and a reliable forecast of realistic usage will be a pre-requisite to develop a business case. This is seen as particularly important for BLOS applications where the infrastructure is likely to be cost prohibitive for a single UAS manufacturer to provide alone.	Q3/ Q4/ Q5, Q7, Q9
5	Data link reliability	Standards need to be developed for data link reliability that take account of UAS autonomy	Q8
6	Voice communication with ATC	New architectures to support ground based ATC communication equipment might require new standards to be set (e.g. radios sited close to existing ATC transmitters).	Q10
7	Voice communication with ATC	Step-on was identified as a particular issue that might cause ATC issues due to excessive latency or through the use of Ground based radio	Q10
8	Wired ATC comms	Need to set safety and reliability standards and potential radio backup systems	Q11
9	Wired ATC comms	Wired infrastructures appear to be compatible with SESAR concepts.	Q11
10	Coupled C2 and ATC	Concern was expressed that standards need to be set to cover the system as well as individual constituents	Q11
11	Communications service providers	Need to set rules and standards for safety and reliability etc. including maintenance and SLAs. Security issues were raised in the context of the standards that are needed for a military UAS to operate through civil C2 bands. i.e. can a civil C2 link provide the necessary security for military aircraft.	Q13, Q29

No.	Title	Observations	source
12	Traffic forecasts	On going requirement to refine traffic forecasts - including civil/ military split	Q15, Q19
13	Spectrum requirements	Need to take into account security and reliability including back-up systems that are considered necessary	Q17,Q21,Q22
14	Spectrum requirements	A common spectrum allocation should be sought at WRC-11	Q18,Q20
15	Spectrum requirements	Can the Military bands be used for civil UAS?	Q19
16	Satellite Latency	Need to set standards for latency etc on all communications links, for all conditions	Q23,Q26
17	Voice party line	Need to determine what requirement exists now and in SESAR environment and set standards, also for relay to manned aircraft when wired interface is used	Q24,Q 27
18	Voice data comms	Need to set safety standards for planned limited ATC communications capability	Q25
19	UAS using IFR	Need to establish rules and minimum Sense and Avoid functionality	Q30
20	SES regulations	Need to review all extant regulations with regard to applicability to UAS and amend if necessary	Q31,Q32

Group 2 Stakeholder Analysis

It was recognised from the outset that it was essential to get responses from a large cross-section of stakeholders involved in all aspects of UAV/S and from as many member states of the EU as possible. It was also recognised that relevant stakeholders will not be limited to the European Union. It was clearly impractical to have face-to-face meetings with such a large number of stakeholders therefore the Group 2 stakeholders were consulted using an on-line survey.

The on line survey went live on 2 June 2009 when a number of groups/ organisations were contacted with a request to participate in the survey. This list is shown below:

- EASA Advisory Group of National Authorities (AGNA)
- EASA Safety Standards Consultative Committee (SSCC)
- SES Industry Consultation Body (ICB)
- CANSO (relevant WG's)
- UVS International membership
- AUVSI membership
- EUROCAE WG-73 membership
- RTCA SC-203 membership
- European Aviation Research Partnership Group
- UAVS
- SIGAT Project Consortium
- INNOUI Project Consortium
- SITA
- ARINC

- INMARSAT

Group 2 Response Statistics

In all 62 responses were received. Of these 10 were excluded from the analysis as they had not completed the questionnaire. Of the remaining 52 respondents most notable were the 29 responses from WG-73 members. In all 12 countries were represented from a wide range of organisations ranging from sole enterprises to large multinational corporations.

Overall our conclusion is that the Group 2 survey has been completed by a sufficiently wide representative sample of the UAS industry and that the results therefore reliably reflect the general opinion of the industry.

Multi Criteria Analysis

The Multi-Criteria Analysis (MCA) technique used in this study allows data to be analysed in various ways to ascertain user needs with respect to UAS communications infrastructure and architectures.

Firstly, a numerical analysis was performed on the data to determine the importance of each impact topic. This analysis identified user needs based on the range of applications to which the UAS community have indicated are of most importance both now and in the future. The user needs were compared to the four bounded architectures to determine an overall value to show how each of the architectures met those needs.

Secondly, a qualitative analysis was performed that summarises the results on a question-by-question basis. This is used to identify common themes and highlights consensus or disagreement amongst the user community.

Group 2 Qualitative Analysis

The following table summarises the results of the Group 2 qualitative analysis.

No.	Title	Observation	Source (Section)
1	UAS Applications	The UAS market can be loosely split into two categories; small lightweight UA used for short range (visual line-of-sight), and larger UA that are capable of operation beyond visual line-of-sight. The communication needs of these two categories are very different, and this is reflected in many of the answers to the Group 2 questions.	6.3.1
2	UAS Applications	Early introductions of UAS are expected to be state sponsored surveillance type applications. Post 2020 there is an anticipated increasing market for commercial applications.	6.3.1
3	Range and Height Requirements	80% of UAS will operate within 500NM of the GS and 60% below 10,000ft.	6.3.2
4	Communications Methods	No single architecture has been identified as meeting all needs. Single ground station/ network GS and satellite all very nearly get equal scores (29%, 38%, 33% respectively)	6.3.3
5	Constraints to Growth	Over 60% of respondents indicated that equipment costs, communications costs and latency are most likely to constrain the use of satellite communications for UAS	6.3.13
6	Timescales	Modal results indicate that single ground station solutions will be needed immediately (2010). Networked ground stations will be required by 2012, and satellite communications by 2014.	6.3.5
7	Interoperability	84% of UAS stakeholders said that they would make use of standardised and approved C2/C3 datalink equipment if it were available.	6.3.4
8	Funding	There is a majority expectation amongst all stakeholders	6.3.6

No.	Title	Observation	Source (Section)
		that the development of UAS communications networks should be publicly funded. However, there is significant expectation for privately funded networks, or a mix of solutions. Some small LOS manufacturers/operators have no interest in private or public investment for networked C2 infrastructure.	
9	Communications Method	Before 2020 relay via UA is the most popular method of communication with ATC, closely followed by ground based communications. Post 2020 the majority expect to use Communications Service Providers and wired infrastructures to communicate with ATC.	6.3.3, 6.3.7
10	Interoperability	A significant percentage of UAS manufacturers recognise need to have UA capable of VHF voice and SSR transponder carriage.	6.3.4
11	Interoperability	There is a significant number of small UA that are not expected to be large enough to support carriage of avionics equipment.	6.3.4
12	UAS Applications	Maritime Surveillance, Search and Rescue and Natural Hazard Monitoring are expected to be the most likely 'early' UAS applications to take place outside segregated airspace. The majority of these applications are expected to be in support of State activities.	6.3.1
13	UAS Applications	Cargo is expected to be the most popular UAS application after 2020. Other popular applications include traffic monitoring and communications relay. These represent a mix of State and private sector applications. It is notable that many of the initial (pre-2020) UAS applications become less popular.	6.3.1
14	Constraints to Growth	The biggest constraints to growth are perceived as regulation, global standards, Sense and Avoid, spectrum availability and safety.	6.3.13
15	Constraints to Growth	Latency and cost have been identified as major constraints of satellite usage.	6.3.13
16	Expected Growth of Industry	The number of people employed in the UAS industry is expected to grow steadily until 2018. This represents a significant new market for the European Aerospace Industry, and the potential for many jobs to be created exists if constraints to growth can be overcome.	6.3.12
17	UAS Applications	A significant percentage (60%) of UA/S industry stakeholders recognise the need to operate over remote or maritime areas, and this places a dependency on satellite communications at least for C2 elements.	6.3.1
18	Interoperability	95% of respondents stated that it was desirable or essential to have the capability to operate UAS in different countries, and to cross international boundaries. This places high importance on the need for standardised architectures that offer good interoperability. It is interesting to note that even those who intend to operate from a single ground station also recognise the need for global interoperability.	6.3.4
19	Spectrum Requirements	In terms of spectrum, a significant number of respondents expressed the view that sufficient spectrum should be sought to avoid UAS operations being constrained. However, an equal number recognised that operational limitations will occur, but will be overcome in time as the industry grows.	6.3.9
20	Spectrum	There was strong consensus that ad hoc or disparate	6.3.9

No.	Title	Observation	Source (Section)
	Requirements	solutions to spectrum are not acceptable, as they will not support the long-term growth of the industry.	
21	Interoperability	100% of responses indicated that it was desirable or essential to achieve a globally harmonised frequency allocation for UAS C2 datalink.	6.3.4
22	Data Throughput Requirements	Data throughput expectations are in line with other industry expectations of spectrum requirements.	6.3.8
23	Data Throughput Requirements	Use of wired or network architectures to communicate with ATC can save up to 40% of the spectrum requirement (compared with a relayed architecture)	6.3.8

Group 2 Quantitative Analysis

Quantitative analysis of the Group 2 results showed that different architectures have different appeal according to impact topic. There is no single architecture that consistently produces a high score regardless of impact topic.

Whilst there are economic incentives to opt for single ground station architectures such as NR1, such architectures provide little or no scope for interoperability. Similarly, architectures that provide good interoperability and high social impact will invariably require more spectrum and more economic investment. The results of combining the Group1 and group 2 results are shown in the following paragraphs.

Combined Quantitative Results

The weightings obtained from the Group 1 stakeholders in the form of the performance scores were applied to the Group 2 stakeholder importance scores to determine overall compound scores for each of the bounded architectures. Whilst the bounded architectures are not intended as solutions, they do highlight the attributes that are likely to be of most benefit to the development of the UAS industry.

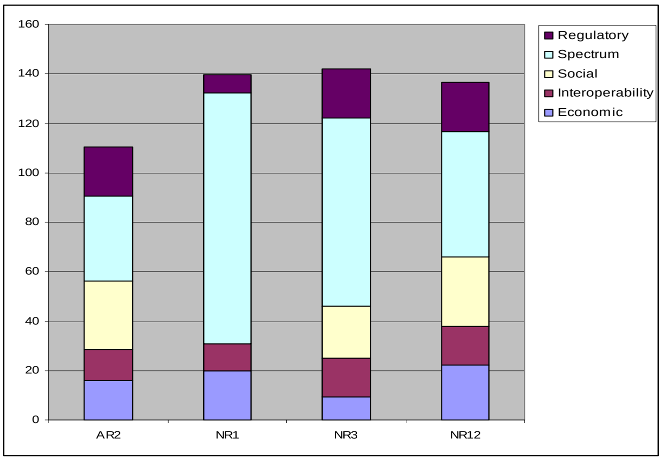
Finally a sensitivity analysis was conducted to determine how sensitive the overall score is to the impact category weightings.

Compound Score

This analysis indicates that NR3 (C2 via satellite and ground-based ATC voice/data COM) is overall the most beneficial architecture out of those considered, closely followed by NR1 (single ground station). AR2 (networked ground station) has the lowest compound score.

In order to fully understand this result, it is necessary to look at the constituent elements of each compound score.

It can be seen that spectrum is the most dominant factor for all architectures, as a result of it having the highest Group 1 performance score, and the highest mean importance Group 2 scores.



In the case of NR3, it is the combination of spectrum, regulation and interoperability that results in the highest overall compound score.

NR1 is even more dominated by the spectrum influence, and this is supported by a relatively high economic score. These figures overshadow the low values obtained for regulation, interoperability and social.

It is notable that interoperability and regulation have the smallest influence on the overall result, despite having respectable Group 1 performance scores. The dilution of these values is largely due to the split in the Group 2 stakeholders, with a significant proportion of industry stakeholders only interested in short range, line-of-sight operations. Such operations do not place a high importance on interoperability or the need for regulation.

Summary

The analysis consistently shows NR3 (networked architecture and COM service provider) and NR1 (single VHF ground station) as the most beneficial architectures, and this appears to complement user requirements and current views on market growth. Satellite-based architectures offer some unique and valuable attributes such as extensive coverage (particularly at low height), the ability to cross international boundaries and operate in areas devoid of terrestrial infrastructure. Furthermore, for many of the UAS applications identified, satellite communications is the only viable solution.

Similarly, NR1 meets the needs of the significant proportion of UAS operators that operate small UAS over a short range. As well as not being able to carry physically large or heavy communications equipment, this type of activity is likely to be highly sensitive to cost, and this makes the use of a single ground station very attractive.

Throughout the sensitivity testing, the wired architecture (NR12) has a consistently high compound score. This architecture has a lot of potential benefits, such as reduced need for spectrum, high reliability, low latency and low operating costs. It is possible that some of these benefits have not been fully reflected in this analysis, and this may be suppressing the true compound score value to a degree.

Perhaps the biggest surprise is the consistently low score achieved by AR2, (ATC relay and the use of networked terrestrial ground stations). This can be explained by the combination of high infrastructure costs, high spectrum requirements and inferior interoperability performance (in terms of coverage at low heights and over remote/maritime regions).

Conclusions and Recommendations

In this section the various observations and conclusions from the different analysis of Group 1 and Group 2 stakeholders are dawn together and recommendations made.

Impact Categories

Economic

Market Forecasting:

Although there is some degree of consensus of the UAS applications that will exist in the short term, there is no accurate market forecast data available. This lack of accurate market forecast data hinders investment in high value enabling infrastructure (such as satellite or ground based communication networks) that will be required for operation beyond visual line of sight.

There is a strong consensus that state surveillance applications will be the early adopters of UAS missions, although there is a strong view that infrastructure applications (utility surveillance) may also be an early adopter. Post 2020 commercial applications (cargo transport) are expected to dominate the UAS applications.

There is also no reliable data concerning the military requirement to fly through non segregated airspace, even though this is a goal of the military for operational and cost benefit reasons.

Market Segmentation:

There is a strong consensus that the market is essentially split between small lightweight UA used for short range (VLOS) and larger UA that are capable of BLOS operations. The survey found that the infrastructure needs of these two camps are very different in many respects, but share some concerns (see global reach below for example).

Timescales:

Group 2 stakeholders have expressed a view that UAS operations, using a single ground station, are required from 2010, followed by network ground stations in 2012 and satellites by 2014. This may be aspirational rather than a realistic belief that these infrastructures will be in place by these timescales. However, it does highlight that there is a developing need and that the infrastructure is required as soon as possible. However, this aspiration appears inconsistent with constraints that have been identified (e.g. Sense and Avoid) that will not be overcome in this timeframe.

Investment:

There is little or no visible activity to provide infrastructure and services to support UAS communications. A significant percentage of Group 1 stakeholders (46%) expressed the view that the communications infrastructure should be publicly funded. The majority of Group 2 stakeholders (54%) recognised the need for private investment, but only 20% have any expectation in providing any in-house investment. Group 1 stakeholders are investing in R&D type activities, but this is the limit of their investment plans.

Operating Costs:

Both groups recognise the need for minimising the cost impact, whether due to the use of infrastructure, equipage of onboard systems, or the amount of spectrum required. Any negative cost differential from manned aviation will have a detrimental impact on the UAS industry.

Social

Jobs:

There is consensus amongst all stakeholders that the UAS sector will continue to grow, and that this will lead to an increase in the number of people employed in the industry.

Constraints to Growth:

Both groups see lack of global standards, spectrum availability, regulation and Sense and Avoid as the major constraints to UAS market growth. Latency and cost for Satellite communications was also cited as a constraint and possible issue by both groups.

Standardised Service Provision:

The vast majority (84%) of Group 2 respondents said that they would make use of standardised and approved C2/C3 data link equipment if it was available. All agreed that it was either essential or desirable to have a standardised and interoperable set of standards for C2 datalink communications. Consideration will need to be given to the level of autonomy of the UA when setting these standards.

The use of safety regulated and standardised service provision is driven in part by cost considerations for both development and operational costs. Users expect that satellite costs (both equipment and operating costs) were likely to be more expensive than terrestrial ground stations.

Concern was raised over the security of using standardised data links for controlling UAs.

Spectrum

Spectrum Availability:

All stakeholders recognise spectrum availability as a major constraint to the development of the industry. The initial predominance of state surveillance applications for UAS would lend credibility to the Group 1 view that the military frequency bands might be used, at least initially, to kick start the UAS market.

The use of wired architectures might save up to 40% of the spectrum requirement when compared with relayed architectures.

Spectrum Cost:

Many stakeholders recognise the value of spectrum, particularly frequencies suitable for mobile communications for which there is a high demand.

Harmonised Frequency Allocations:

All stakeholders expressed the view that a global or regional spectrum allocation is essential to the cost efficient use of UAS and for global interoperability. The data throughput requirements are in line with other spectrum requirement estimates.

Interoperability

Latency:

Latency in ATC communications is recognised as a significant issue, particularly for satellite communications.

Infrastructure architectures:

No single architecture (or architecture element) stands out as the predominant method of communications. There is no clear preference for a single ground station, networked ground station or satellite for C2 communications (29%, 38% and 33% respectively). It is likely that many UAS applications will utilise a combination of communication methods during the course of a single mission.

Global Reach:

There was near unanimity by both groups that global interoperability was an essential aspect to make UAS operations a reality. A significant proportion (60%) of respondents thought that there was a need to fly over remote or maritime areas where it would be impractical to operate ground stations. It was also recognised as important that UAs were able to cross state boundaries. This indicates that although many of the early missions are of a local nature (search and rescue for instance) they have global application and therefore to ensure cost effectiveness of development and deployment the same infrastructure requirements are needed globally. This must apply to all aspects of the communications infrastructure, such as spectrum allocation, communications protocols etc. Also, this must extend to the seamless use of ground station and/ or satellite usage. To go further there may be a requirement that UAS should be able to seamlessly and safely switch between ground station and satellite operation. There are clear economic benefits to having global standardised infrastructure available to all UAS operators through the mass production of avionics and avoidance of multiple system equipage.

ATC Communications:

In the short term (before 2020) there is a general expectation that remote pilot communication with ATC will be relayed through the UA. Post 2020 the majority expect to be using a communications service provider or a wired interface.

Step-on was identified as a potential issue to ATC in high traffic periods due to excessive latency.

The carriage of VHF voice and SSR transponders is recognised by stakeholders but there is a significant number of small UA that are not expected to be large enough to support carriage of avionics equipment.

Regulation

Guidance and Technical Standards:

Both groups recognise the need for regulation, and the important role it plays in enabling development of the industry. There is a clear need for regulatory guidance and technical standards for UAS communications infrastructure to be developed that will cover all aspects both individually and systemically. For example:

- Proper safety regulation and oversight of the communication service providers
- Maximum latency for ATC communications will need to be established
- The protocols and specifications of switching C2 between ground station and satellite links will need to be determined (assuming there is a need for this requirement). By extension, the seamless switching between satellites will also be necessary.
- Backup communications requirements may need to be established to ensure that the remote pilot can always communicate with ATC.

There was consensus among the Group 1 stakeholders that the applicability of the current ICAO Standards and Recommended Practices (SaRPs) to support UAS operation needs to be established and if necessary amended.

UAs will exhibit different levels of autonomy and this must be taken into account when setting the standards of operation and performance requirements of the communications infrastructure.

SESAR

Group 2 stakeholders were not specifically questioned on SESAR but there is a fundamental requirement that any C3 infrastructure should be compatible with SESAR concepts such as SWIM and compatible networks such as the NEWSKY air-to-ground architecture.

Group 1 stakeholders questioned the continued requirement for a voice party line in the SESAR environment and whether there is a requirement for a relay to manned aircraft when a wired interface is used.

Architectural Considerations

The following discussion highlights the applicability or otherwise of the conclusions to the various methods of communication described in the bounded architectures.

ATC relay

A radio relay through the UA is seen by most as the initial method of communicating with ATC but there is a strong motivation to replace this with a ground or wired interface in the future. The bounded architecture that included ATC relay scored constantly low in the quantitative analysis, in part because of the increased spectrum requirement.

It is recognised that many smaller UAs cannot carry the avionics to support ATC relay communication and therefore this could constrain market growth.

The use of airborne VHF radio (in architecture AR2) had the lowest compound score due to its high economic cost and need for spectrum.

Wired ATC communications

This has the benefit of saving considerable spectrum requirements (estimated up to 40% over relay architectures) and will save weight and cost of equipping the UA with VHF/ UHF radio equipment. It is recognised that although this is a novel architecture it has many potential benefits. However, concern was expressed that there may be safety and interoperability issues.

This approach is seen as compatible with SESAR concepts.

Ground Based ATC Radio Communications

Like the Wired ATC communications method this has the benefit of saving considerable spectrum requirements (estimated up to 40% over relay architectures) and will save weight and cost of equipping the UA with VHF/ UHF radio equipment.

This approach is seen as particularly beneficial in the pre-2020 timeframe.

Single Ground station

This is seen as the initial configuration of ground stations and represents the current state of the art. For many small, short range applications this represents the optimum architecture as a result of its low cost, mobility and low spectrum requirement.

As well as being constrained on operating range and height there are likely to be geographical limitations where the Ground Station can be located.

Network Ground Stations

Network ground stations are likely to be static and operated by a communication service provider (rather than an individual air operator). The majority of users indicated they would use a COM service provider if available. The advantages of a service provider are that benefits of scale will materialise both for the development of the infrastructure and for the operational cost to the user.

There will be the added benefit of standardised communication across all UAs. Safety and security issues were raised as some form of licensing may be required in order for UAS operators to be able to prove airworthiness of the infrastructure.

In the case of NR3, it is the combination of spectrum, regulation and interoperability that results in the highest overall compound score.

Satellite

Satellite was seen as the most expensive option for C3 communications but also the most flexible given its global reach. Other issues highlighted are the latency, particularly for ATC voice communications. However, satellite communications has been identified as the only viable solution for many UAS applications.

Recommendations

The following recommendations are made for EASA's consideration:

Title	Description
Action plan and industry co-ordination	To develop an action plan in coordination with industry. A key element of this is to gain a more robust forecast of industry expectations of timescales for UAS operations and priorities.
Certification	To investigate the issues surrounding the potential safety certification of communication service providers to operate UAS communications infrastructure.
Performance Standards	To set the minimum performance standards that all UAS communication infrastructures must meet to be certified as airworthy.
Security Requirements	To define the security requirements to enable secure operation of C2 datalinks in the context of networked stations and the ability to transit international boundaries.
Generic safety Case	To develop guidelines and a standardised framework by which potential UAS communications systems manufacturers and service providers can make a safety case for their systems to be demonstrated as safe.
Latency	Investigate the effects of latency on the efficient operation of ATC voice communications in different traffic density environments.
ATC simulation studies	A range of simulation studies to assess the operational impact that novel architectures will have on ATC work load and performance.
Regulation	Continuing engagement with stakeholders in order to identify where ICAO annexes and EC regulations require updating.
Spectrum	Investigate and quantify the potential spectrum savings that could be made in the European region through the use of novel architectures.
Spectrum	Continue to support the requirement for a common globally harmonised spectrum allocation for C2 communications for UAS at WRC-11.
Global Interoperability	To liaise with counterparts in other regions of the world to ensure global interoperability.

Contents

1 Introduction

This report constitutes the final formal deliverable of the Preliminary Impact Assessment (PIA) on the Safety of communications architectures for UAS contract number EASA.2008.C20 (procedure OP.08). This final report contains a complete description of the preliminary impact assessment undertaken and the resulting analysis, conclusions and recommendations.

1.1 Background

In recent years considerable interest and effort has been expended world-wide into the development of technologies, procedures and standards that will allow Unmanned Aircraft Systems (UAS) to become fully integrated into the Air Traffic Management (ATM) environment. This work is essential to satisfy the safety criteria required for UAS to be operated in non-segregated airspace.

The mission of the European Aviation Safety Agency (EASA) is to promote and maintain the highest common standards of safety and environmental protection for civil aviation in Europe and world-wide. In the near future the Agency will also be responsible for safety regulation of airports and air traffic management systems.

The Agency needs to prepare itself to progressively develop implementing rules, certification specifications (CS), acceptable means of compliance (AMC) and guidance material (GM) as appropriate, for the UAS, their crews and their operations, including their interaction with aerodromes, other airspace users and the Air Traffic Management (ATM)/Air Navigation Services (ANS) infrastructure that exists both now and in the future.

The communications architectures required to operate UAS will form the foundation upon which many technologies, systems and operational procedures will be based. There are many architecture options available and no single, obvious solution. It is essential that these options are properly assessed and refined to enable the pace of development to be maintained.

1.2 Objectives

Much debate has taken place within the industry (including standardisation groups such as EUROCAE WG-73 and RTCA SC-203) about the architecture of the communications systems that will support the operation of UAS in non-segregated airspace. Although these groups have produced some useful technical work, their role is not to endorse or promote a particular architecture, and consequently there is no consensus on what the architecture should look like.

1.2.1 EASA Purpose

In creating this project, EASA has initiated a process that will lead to the implementation of a regulatory policy to permit the use of UAS in non-segregated airspace. The objective of this study is to provide an initial input and guidance for the Regulatory Impact Assessment (RIA) process. This will be achieved through a Preliminary Impact Assessment on the safety and other factors that will be affected by the architecture(s) used for UAS communication systems.

The purpose is not to define, endorse or mandate any particular architecture, but to provide a platform for investigation and discussion of the issues and impacts that various architectural features will have on the impact topics being investigated in this study.

It should be remembered that this is a preliminary assessment and therefore the investigations and analysis undertaken are not a thorough in-depth investigation into every topic or issue identified. It is sufficient to highlight pointers where further study is needed.

However, the regulations, while protecting safety, should not over-constrain technical and business choices.

1.2.2 Architectures and Safety

There is no single, obvious architecture for UAS communications that satisfies the underlying needs for equivalence, interoperability and safety. In this age of wideband communications and high speed data networks, many existing technologies and established communications networks have the potential to support UAS communications, to a greater or lesser extent. Using such technologies and systems, any number of architectures could be designed to meet the requirement.

However, not all architectures will be capable of meeting the exacting safety requirements for command and control, ATC communications and surveillance, where there is a need for data to be transferred with high availability, high integrity and low latency. Conversely, for some of the architectures that are capable of meeting the safety performance requirements, cost or complexity may be an issue. For example, the cost of required infrastructure may act as a constraint to UAS industry growth, or complexity may mean that the cost of equipment is beyond the reach of most UA operators.

There are two key objectives. The first is to determine which of the many postulated architectures are capable of satisfying the safety requirements for ATC communications and surveillance. The second is to objectively quantify the merits of the architectures selected in other key areas (economic, social impact, global interoperability etc). Analysis will then be applied to numerically score the architectures, and rank each in terms of their ability to satisfy regulatory requirements and meet stakeholder expectation.

1.3 Scope

The scope of this preliminary impact assessment is limited to the following communications links:

- An air-ground link between the Ground Control Station (GCS) and the UAV for command and control
- An air-ground link between ATS/ ATC and the UAV for traffic surveillance (and/or communication) purposes, if assessed as necessary
- Communication link(s) between the UAS crew and ATS/ ATC

The way these links are implemented may have a considerable impact on safety and other aspects of the UAS marketplace. This study will therefore assess the impact of various communications architectures on the following topics:

- Safety - including taking into account the availability, integrity and latency of transmitted data
- Economy - including the cost and weight of avionics and of modifying ATC systems
- Social - including the speed of development of the market and its effect on jobs and market penetration
- Electromagnetic Spectrum - including the amount of spectrum required, candidate frequency bands and issues associated with protection of existing users (within the candidate bands)
- Global interoperability – the ability for UAS to be safely operated in different States and to conduct flights that transit FIR boundaries from one State to another
- EU Regulation – the compatibility of architectures with SES regulations, future operating concepts and system architectures identified by SESAR

A requirement of the impact assessment is to cover adequately all 27 countries in the EU and to provide possible international comparisons. QinetiQ conducted the main stakeholder engagement primarily through the use of an on-line survey tool. This was made available to a world-wide stakeholder group to ensure that the international input as well as the EU input is as comprehensive as possible.

This report contains a detailed step by step exposition of the PIA process undertaken and of the results and potential issues identified.

1.4 Structure of the Report

1.4.1 Volume 1

Section 1 – Introduction to the Requirement provides a statement of the customer need and objectives.

Section 2 – Describes approach and methodology adopted in the Study

Section 3 – Describes the process to identify the bounded architectures

Section 4 – Describes the assessment of the Impact topics and stakeholder engagement

Section 5 – Describes the responses of the Group 1 stakeholder interviews

Section 6 – Describes the Group 2 stakeholder survey and analysis

Section 7 – Describes the combined results where the Group 1 performance scores are applied to the Group 2 importance scores

Section 8 – Presents the conclusions and recommendations

1.4.2 Volume 2

Appendix A - Candidate architecture diagrams

Appendix B – Risk Analysis scores

Appendix C - Group 1 Briefing Document

Appendix D - Description of the bounded architectures

Appendix E - Provides the Group 2 stakeholders questionnaire

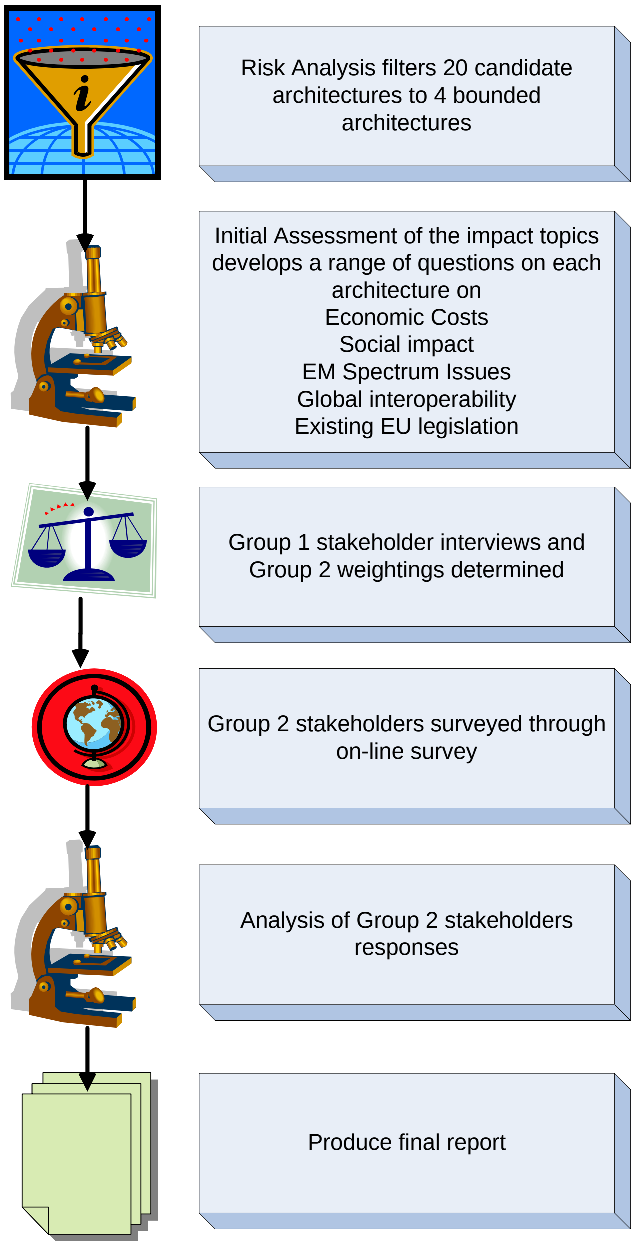
2 Approach

This section provides a detailed exposition of the approach taken in the project.

2.1 Study Methodology

The QinetiQ approach recognises the need to evaluate architectures that best satisfy the needs of the UAS industry at large, without compromising on safety performance. The architectures selected for evaluation contain all the elements that might be used by a remote pilot when communicating with the UAV and with ATC. The process adopted was essentially a 6 step process as shown in the diagram opposite that can be described as a 3 part approach.

1. Identify Bounded (safe) architectures
2. Assess the architectures against the impact topics
3. Analyse the results and correlate the Group 1 and Group 2 responses



2.1.1 Identify Bounded Architectures

The first part identified 4 architectures from an initial list of 20 that were capable of meeting the supposed safety performance requirements. The filtering was achieved through a preliminary hazard identification and risk assessment process. Judgements were made to select four architectures that would be representative of all the key elements that will exist in reality. This does not invalidate the other architectures, nor do the 20 candidate architectures represent the only architectures that may be deployed.

2.1.2 Assess the Architectures

In the second part, engagement with a broad cross-section of UAS stakeholders took place to understand the importance of the impacts associated with the architectures identified. The stakeholder survey was performed in two ways. Firstly, organisations with regulatory responsibility were interviewed to understand the regulatory view of the architectures and the issues arising from the insertion of UAS into general air traffic. Secondly, the user community was surveyed using an on-line survey. Participation was sought throughout the EU and world-wide from selected countries with active UAS programmes. The questionnaires were developed by performing an initial impact assessment using QinetiQ's in house expertise. The questionnaires were agreed with EASA prior to the survey going live. An expert body of stakeholders comprising EASA, other regulators and ANSPs have provided input into determining the weightings to be applied to the stakeholder responses.

2.1.3 Analysis and Correlation

The final part was to analyse the results of the surveys. Group 1 and Group 2 responses were analysed and correlated using QinetiQ's expert judgement to produce a combined result from which conclusions and recommendations were determined. Finally a sensitivity analysis was performed to gauge the variation in impact against the weighting applied.

2.1.4 Project Steering Group

To support the study EASA invited selected organisations to oversee the work and to provide a further level of expert advice. The steering group were invited to participate in the formal progress review meetings and results presentations and to provide comments on the reports.

The steering committee consisted of the following representatives at various times during the course of the project:

Name	Title/Role	Organisation
Filippo Tomasello (FT)	Project Sponsor, Rulemaking Directorate	EASA (Customer)
Werner Kleine-Beek (WK)	Research Project Manager	EASA
Dr Kai Bauer (KB)	Economic Analysis Officer	EASA
Marcel Staicu (MS)	Project Officer, NEC	EDA
Rodolphe Paris (RP)	CIS Project Officer	EDA
Giles Fartek (GF)	DG TREN	EU
Marc Dalichampt (MD)	Airspace Research Project Leader	EUROCONTROL
Christian Pelmoine (CP)	Spectrum Defence Service Manager	EUROCONTROL
Holger Matthiesen (HM)	Air Traffic Management Procedures	EUROCONTROL
Frederico Corona (FC)	Air Traffic Management Procedures	EUROCONTROL

The meetings consisted of the kick-off meeting, interim review and final results presentation. There were three reports associated with the meeting, the Inception Report, Interim Report and Final Report (this document). All reports are available on the EASA website. This final report intentionally includes all the material from the inception and interim report, so that it may be read in isolation.

The steps are explained in more detail in the following paragraphs:

2.2 Identify Candidate Architectures

For any architecture to be eligible for consideration it must satisfy certain core tenets to ensure transparency, equivalence and interoperability. Those taken into account are:

- ATC communications with a UAV pilot should be no different to that for pilots of manned aviation. Fundamentally, voice channels should have good intelligibility, low latency and high reliability.
- Controller-Pilot communications should be available at all times, from the time the aircraft starts moving to the time it comes to a halt at the end of the flight. Even if the UAV/S is fully autonomous, there is a requirement for the UAV pilot to monitor ATC frequencies, and comply with any ATC instructions that are issued whenever operating inside controlled airspace, or accepting a separation service from ATC in other airspace.
- There is a need for accurate UAV position information to be available via the air-ground surveillance link at all times. Furthermore, surveillance systems on the UAV should be standardised to ensure interoperability with other systems (e.g. ATC surveillance and airborne collision avoidance systems).
- Similarly, the UAV pilot is legally responsible for the UAV. There is a requirement to monitor the position and status of the UAV at all times, as there is a duty to comply with aviation law and avoid harm or injury to people, air vehicles or structures through negligence or in the event of a system failure/emergency.

Up to 20 architectures capable of satisfying these core tenets were identified. A review of WG-73 and SC-203 was conducted to ensure that architectures being considered by these expert groups were included. These architectures are shown in Appendix A - Candidate architectures.

2.3 Functional Hazard Identification

It is essential that only architectures that are capable of meeting safety requirements for ATC communications and surveillance should be considered for more detailed impact assessment. QinetiQ organised an internal workshop with communication systems architects and operational experts who performed a Functional Hazard Identification and Risk Assessment on all the 20 architectures.

Whilst a failure or interruption of any element of the architecture may not constitute a direct safety hazard, such problems can contribute to an operational incident (the so called "chain of events"). For example, loss of voice communications with a UAV pilot could increase ATC workload, which could lead to a more serious incident (i.e. loss of separation).

When considering the generic safety performance of candidate architectures the following events were considered to be hazardous:

- Loss of voice communications between UAV/S pilot and ATC
- Interruptions to voice communications between UAV pilot and ATC
- Intelligibility and latency of voice communications between UAV pilot and ATC
- Loss of command and control link between UAV and GCS
- Interruption of command and control link between UAV and ATC (due to system reliability or coverage)
- Loss of surveillance information feed to ATC
- Interruption of surveillance information feed to ATC (due to system reliability or coverage)
- Loss of surveillance information to other airspace users
- Interruption of surveillance information to other airspace users (due to system reliability or coverage).

For each of the above categories, a tolerable safety level was proposed. Once the tolerable levels were agreed, a risk assessment was conducted on each of the proposed architectures. It should be remembered that this is a preliminary study and therefore the rigour of a full hazard analysis and risk assessment did not take place. The process performed a qualitative analysis and given that there were 20 architectures to evaluate a degree of comparison took place to rank the safety of the architectures.

It is important to stress that the bounded architectures are not intended to be de-facto solutions. They are simply architectures with particular attributes to allow stakeholders to consider what associated issues might exist, whether related to safety, performance, interoperability, spectrum, regulation or cost.

The architectures that best met or exceeded the tolerable safety level in all event categories were considered eligible. Out of these, 4 architectures were identified that contained attributes or system elements that are likely to have some impact on the UAS industry, ANSPs and safety regulatory authorities. These are referred to as bounded architectures. It should also be noted that in order to investigate all aspects of the architectures, those chosen did not necessarily have the best safety score.

The preliminary set of 4 bounded (safe) architectures were identified for detailed impact assessment. The project kick-off meeting reviewed the total architecture set and approved the selection of the bounded architectures. These were provided in the Briefing document for the Group 1 stakeholders and are provided in Appendix D (Description of the Bounded Architectures).

2.4 Assessment of Impact Topics

The next step in the approach is to assess the impact of implementing each of the bounded architectures.

The impact assessment identified the issues that are likely to be contentious or high risk, be it for UAV/S manufacturers, UAV/S operators, Air Navigation Service Providers (ANSP) or safety regulators. It is essential that the impact assessment covers a wide range of issues and includes:

- Investment costs (to develop and procure suitable avionics equipment and associated ground/space infrastructure)
- Practical limitations (size and weight of avionics equipment)
- Operational costs
- Operational limitations.

To achieve this, the impact of each of the bounded architectures was assessed in detail for the following five areas:

- Economic (cost and weight of the avionics and/or cost of modifications to ATS/ATC systems)
- Social Impact (slower or faster development of EU UAS industry), with a benchmark prediction as to the size of the industry by 2020
- Use of Electromagnetic Spectrum (estimated total requirement)
- Global Interoperability (ability to operate in different States, and to transit FIR boundaries)
- Impact on other existing EU rules (i.e. compatibility with SESAR regulations and ESARRs).

The assessment culminated in a number of questions within the topics that were put to the stakeholder groups. These are described in later sections of this report. Group 1 questions can be found in section 5.2. Group 2 stakeholder questions can be found in Appendix E - Group 2 Stakeholder Questionnaire.

2.5 Stakeholder Engagement

For the purpose of this study, stakeholders were formed into two groups:

- Group 1 – Regulatory, Safety and ATM (EASA plus selected NSAs and ANSPs)
- Group 2 – All stakeholders (UAS manufacturers[1], UAS operators[1], ANSPs, EASA and other safety regulators).

2.5.1 Group 1

Engagement with Group 1 stakeholders was in the form of face-to-face interviews that described the bounded architectures and the rationale for their selection. To allow the Group 1 stakeholders to prepare for the interview a briefing document was sent prior to the interview that described the background and architectures around which the questions are set. The architectures notes are reproduced in Appendix C. The questions for Group 1 were open questions to facilitate discussion and elicit a detailed rationale for the answers during the interview. All responses were reviewed and agreed with stakeholders to ensure that their opinions had been captured correctly.

Group 1 stakeholders serve two purposes by enabling a qualitative and quantitative review of responses. Interviews were held with the following stakeholders:

- European Commission (DG-TREN)
- European Aviation Safety Agency (EASA)

[1] Manufacturers and operators of UAV with MTOM of 150 kg or more

- EUROCONTROL
- European Defence Agency (EDA)
- SESAR Joint Undertaking (SJU)
- French Civil Aviation Authority (DSNA)
- UK Civil Aviation Authority (CAA)
- ESA (ESTEC)

Firstly, a comprehensive qualitative review was performed on all responses and key messages captured to see where there was a strong or general consensus on each question. It was also important to capture where there were different views as these are important areas to be resolved. From this analysis, conclusions and recommendations were derived. These were later correlated with the consensus from the Group 2 results to produce a consolidated list of conclusions from which the recommendations are derived.

Secondly, a quantitative assessment was undertaken to enable the Group 2 responses to be weighted by providing an aggregate performance score for each of the impact topics. The responses to the questions were analysed quantitatively to give a numerical analysis enabling key trends and overall results to be elicited. Questions were assigned to the 5 impact topics of economic, social, interoperability, spectrum and regulation. Each question was assigned an impact weighting and scored as values 5, 3 and 1 (high, medium and low). Some of the questions have relevance in more than one topic and for these the relevance for each topic was assessed separately. For example Question 29 (*Do you recognise the potential for "sense and avoid" technology on UAS for supplementing/replacing current "see and avoid" concept?*) was assessed as of medium importance for the economic topic but of high importance for the regulation topic.

Stakeholder responses to questions were assessed and given a numerical score between 1 and 5 whereby:

- 1= Low Importance/ Impact
- 5 = High Importance/ Impact

Group 1

		Stakeholders										
Spectrum Questions		S1	S2	S3	S4	S5	S6	S7	S8	**Arithmetic Mean**	**Mode**	**S.D.**
17	A standardised networked C2 datalink will provide greatest flexibility for UAS operators that need to operate over a wide area, but this is likely to require significantly more spectrum than would be required for individual operation of proprietary systems over a local area. How important is it to secure sufficient spectrum to establish one or more standardised C2 networks across Europe?	5	4	_	4	5	3	4	4	4.14	4	0.69007
18	How important do you believe it is to secure, through ITU World Radio Conferences, a harmonised spectrum allocation for UAS C2 datalink? And it is the same for mission/payload data? Please explain the rationale behind your replies.	5	5	_	5	5	3	3	5	4.43	5	0.9759
19	How important do you believe it is for UAS C2 datalink communications to be wholly contained within aeronautical frequency bands AM(R)S or AMS(R)S?	5	5	_	3	3	4	4	4	4.00	4	0.8165
20	How important is it to have common harmonised global spectrum allocations for UAS C2 datalink communications?	5	4	_	_	3	4	4	4	4.00	4	0.63246
21	How important is it to adopt architectures that minimise the amount of spectrum required?	5	4	4	4	4	5	4	4	4.25	4	0.46291
22	How important is it to use spectrally efficient techniques?	4	5	4	5	5	4	4	5	4.50	4	0.53452
	Aggregate	5	5	4	4	4	4	4	4	4.22		0.46291

Figure 2-1: Group 1 Stakeholder Responses Analysis

As shown in Figure 2-1 Group 1 responses are scored and averaged for each question. To ensure that opposing responses or strong disagreement is not overlooked the mode and standard deviations are also calculated. When the mode and mean are markedly different and the standard deviation is higher the question has clearly evoked a difference of opinion which is noted within our qualitative analysis.

For each impact topic (economic, social, interoperability, spectrum and regulation) all of the relevant questions are given a weighted mean based on the arithmetic mean (as calculated above) and the impact weight (high / medium / low) assigned to the question. The total weighted mean is then calculated. To ensure there is no bias towards a particular topic category, this value is divided by the number of questions giving a normalised 'aggregate performance score'. Figure 2-2 shows an example overview table of the analysis and the blue box shows the spectrum aggregate performance score of 21.1.

SPECTRUM

Number of Questions Used for Analysis: 6

Question	SD	Mode	Arithmetic Mean	Question Impact (QI)	Weighted Mean (Mean x QI)
17	0.6900656	4	4.14	H	20.71
18	0.9759001	5	4.43	H	22.14
19	0.8164966	4	4.00	H	20.00
20	0.6324555	4	4.00	H	20.00
21	0.46291	4	4.25	H	21.25
22	0.5345225	4	4.50	H	22.50
Aggregate			4.22	**Total Weighted Mean:**	126.61
				Spectrum	21.1

Figure 2-2: Group 1 Topic Performance Table

Once all of the scores have been calculated it provided a view of the relative importance of the topic categories to Group 1 stakeholders. Results from Group 1 analysis are presented in section 5.

2.5.2 Group 2

It was recognised at the outset that it was essential to get responses from a large cross-section of stakeholders involved in all aspects of UAV/S and from as many member states of the EU as possible. It was also recognised that relevant stakeholders will not be limited to the European Union. It was clearly impractical to have face-to-face meetings with such a large number of stakeholders therefore the Group 2 stakeholders were consulted using an on-line survey.

Without describing the bounded architecture, the on-line survey asked stakeholders to comment on the importance of a range of topics associated with the impact categories. The questions and the possible responses are provided in Appendix D.

The on line survey went live on 2 June when a number of groups/ organisations were contacted with a request to participate in the survey. This list is shown below:

- EASA Advisory Group of National Authorities (AGNA)
- EASA Safety Standards Consultative Committee (SSCC)
- SES Industry Consultation Body (ICB)
- CANSO (relevant WG's)
- UVS International membership
- AUVSI membership
- EUROCAE WG-73 membership
- RTCA SC-203 membership
- European Aviation Research Partnership Group

- UAVS
- SIGAT Project Consortium
- INNOUI Project Consortium
- SITA
- ARINC
- INMARSAT

Each organisation was contacted by email with a request to distribute the request to its members. The survey was closed on 18 September 2009 with a gross total of 62 respondents registering on the web site. Of these 10 had not completed the survey in full, and were subsequently excluded from the analysis.

2.5.3 Response statistics

The following tables provide a breakdown of the respondents by various categories.

2.5.3.1 Source of Response

Table 2-1 below shows from where the respondent obtained the request for participation. This shows that the WG-73 group were by far the most active providing 56% of the completed questionnaires. Seven respondents did not specify the route by which they heard of the study. The Interim Report was published on the EASA website and this was the source for 3 respondents.

Source of response	Total
EASA Advisory Group of National Authorities (AGNA)	5
CANSO	1
AUVSI members	1
EUROCAE WG-73	29
European Aviation Research Partnership Group	6
Interim Report	3
Anonymous	7
Total	**52**

Table 2-1: Respondents by Group

2.5.3.2 Geographical distribution

Table 2-2 below shows the geographical distribution by country. It is notable that there is a general spread around the countries of the EU with most respondents from the U.K and Spain (8 each) closely followed by France (7). Also notable are the responses from both the USA and Israel. Seven respondents did not specify their country of origin.

Country	Total
Austria	2
Belgium	5
France	7
Germany	3
Israel	1

Country	Total
Italy	3
Netherlands	2
Poland	1
Spain	8
Sweden	3
U.K.	8
U.S.A.	2
Not specified	7
Total	52

Table 2-2: Respondents by country

2.5.3.3 Organisation/ Individual Role

Table 2-3 below shows how respondents classified themselves according to role. The largest group was UA/S Manufacturer (16) followed by 'Other' (12). Of these 12 respondents 9 are research and/or consultancy organisations. The remaining 3 provide services to the UAS industry.

Role	Total
ANSP	5
Other	12
Regulator	9
Support services –e.g. airport/ maintenance/ training	1
Systems/Avionics manufacturer/supplier	8
UA/S Manufacturer	16
UA/S Operator	1
Total	52

Table 2-3: Respondents by Role in the industry

Table 2-4 below shows the number of respondents by the size of the organisation. The minimum was 1 and the maximum was greater than 110,000.

Organisation size	Total
<100	15
100-1000	9
1000-10000	12
>10000	6
(Blank)	10
Total	52

Table 2-4: Respondents by organisation size

2.5.4 Conclusion

The overall conclusion is that the Group 2 survey has been completed by a sufficiently wide representative sample of the UAS industry for the results to reliably reflect the general opinion of the industry.

2.6 Analysis and Correlation

In this step, the scores obtained from stakeholder Group 1 that reflect the safety/regulatory performance will be correlated with the scores obtained from the Group 2 (assessment of importance) survey.

In simple terms, a compounded value for each of the bounded architectures can be obtained by multiplying the aggregated Group 1 performance value with the Group 2 generic 'importance' value. The sum of the values obtained for each of the impact topics provides a value for each of the architectures. Mathematically this can be written as:

$$S_a = \sum_n i_n p_n$$

Where

$S_a =$ Compounded Score for Architecture.

$i_n =$ Aggregate importance (Group 2 stakeholders)

$p_n =$ Aggregate performance (Group 1 stakeholders)

For the Group 2 data it is reasonable to expect different types of stakeholder to provide different scores when assessing the importance of impact issues. For instance, we might expect UAV/S manufacturers to be highly concerned about the weight of data link equipment to be carried by the UAV, whereas this may be of little or no concern to an ANSP. Similarly, we might expect an ANSP or safety regulator to provide higher scores to the question about data link availability requirements than UAV/S manufacturers or operators might.

To reflect the fact that some impacts will be more significant or even critical for particular stakeholders, it is necessary to filter the responses to individual questions according to stakeholder type. For example, questions about equipment size and weight limitations for a UA should only be answered by UA/S Manufacturers and Operators. On the other hand, answers from all categories of stakeholder should be taken account of for a more general question about interoperability.

Finally, a sensitivity analysis was conducted by applying a set of low, medium and high weightings to the Group 2 importance data. This indicated how sensitive the results are to the weightings applied and the overall significance of the results for each of the bounded architectures when compared with each other.

3 Identify Bounded Architectures

This section describes the first part in the methodology described in section 2 where the candidate architectures are developed and filtered using the hazard identification and risk assessment process to select 4 bounded architectures. The rationale that was used to determine the architectures is described.

3.1 Basic Principles

In assessing the needs of UAS communications architectures, the following principles were recognised.

3.1.1 Transparency to ATC (Communications & Surveillance)

- For ATC, the process of monitoring flight progress and issuing instructions to a UAV via voice/data should be no different to that applied to manned aircraft
- A UAV pilot should be able to maintain situational awareness by monitoring voice exchanges between ATC and other aircraft (manned or unmanned)
- Transponders or other surveillance devices (when fitted) should always be physically located on the UAV as they can enable ATC to monitor flight progress independently of the data link and GCS. Also, the UAV will be able to interact with ACAS (and reduce the risk of mid-air collision)

3.1.2 Reliability and Continuity

- Existing (analogue) ATC voice communications are simple and reliable
- Communications failures are seldom, but when they do occur ATC workload can increase significantly
- UAS communications, particularly for ATC must be reliable

3.1.3 Spectrum

- UAS data links will require significant amount of spectrum
- Amount of spectrum required is directly proportional to peak number of UAS operating in a frequency re-use area
- In order to provide good quality of service (QoS), channel rate will be significantly greater than bit rate
- After video, ATC voice relay has greatest demand for bandwidth

3.1.4 Coverage

The object is to maintain communications with ATC and for the ground station to be able to maintain data link communications with the UAV. The mobile nature of a UA means that loss of communications due to the aircraft moving outside coverage is a factor that must be taken account of in each of the architectures as shown in Figure 3-1.

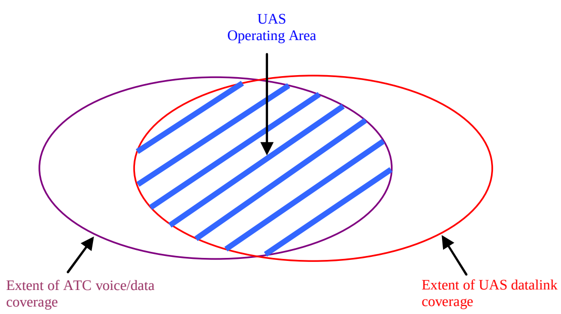


Figure 3-1: Overlapping coverage of UAV data link and ATC limits the UAV operating area

Clearly, a wired architecture will overcome the finite coverage limitations of the ATC voice/data communications system, and this is one aspect that needs to be taken into consideration by the preliminary risk analysis. Whilst the tele-command and telemetry data link will always have finite coverage, a cellular system employing a network of ground stations with overlapping coverage will have superior geographical performance than a single dedicated ground station.

When considering coverage requirements, the following issues must be taken into account:

- The UAV remains within data link coverage for entire flight
- Terrestrial coverage impaired by curvature of the Earth and terrain shadowing
- Satellite provides coverage down to the ground but introduces latency
- LEO provides better coverage than GEO and requires less gain/power per unit bandwidth to achieve link margin

3.2 Candidate Architectures

Candidate architectures were developed according to specific rules in order to develop a comprehensive set of architectures that would encompass as wide a variety and combinations of capabilities as possible. Three overriding variables became the key to developing the architecture matrix:

- ATC relay/ non ATC relay – Whereby the ATC communications with the pilot is through the UAV or direct.
- Dedicated wired interface or single approved interface communications service provider. Logically the ATC relay cannot have a wired interface and this set therefore does not exist.
- Command and Control (C2) implementation using either:
    - Dedicated terrestrial ground station
    - Networked terrestrial ground station(s)
    - Geostationary (GEO) satellite
    - Low Earth Orbit (LEO) satellite
    - High Altitude Platform (HAP)

This gives rise to the matrices in the following paragraphs.

3.2.1 ATC relay architectures

The following architectures represent those where the ATC communications with the pilot is relayed through the UA.

	Dedicated terrestrial GS	Networked Terrestrial GS	GEO satellite	LEO satellite	HAP
ATC Relay	AR1	AR2	AR3	AR4	AR5

Table 3-1: ATC relay type candidate architectures

3.2.2 Non-ATC relay architectures

The following architectures represent those where the ATC communications with the pilot is direct either through a terrestrial ATC radio, a dedicated wired connection, or a wired connection through a communication service provider (CSP).

Non ATC relay	Dedicated terrestrial GS	Networked Terrestrial GS	GEO satellite	LEO satellite	HAP
Terrestrial GS (Radio)	NR1	NR2	NR3	NR4	NR5
Dedicated Wired Interface	NR6	NR7	NR8	NR9	NR10
CSP Wired Interface	NR11	NR12	NR13	NR14	NR15

Table 3-2: Non-ATC candidate architectures

Detailed diagrams and schematics can be found in Appendix A. These candidate architectures were the subject of a preliminary risk analysis as described in the following section.

3.3 Preliminary Hazard Identification and Risk Assessment

The next step is to analyse the candidate architectures using a hazard analysis and risk assessment which was used to rank the architectures with respect to their inherent safety and reliability of operation.

This section describes the hazard identification and risk assessment process, the assumptions that underpin the analysis, the scores that were obtained and finally the rationale for selection of the 4 bounded architectures.

3.3.1 Safety Hazard Identification Process

A hazard identification and analysis workshop was convened with subject matter experts from QinetiQ's Air Traffic Management, Unmanned Aerial Systems and System Safety groups. The meeting attendees are listed in Table 3-3. The aim of the workshop was to identify and record the functional hazards arising from each of the 20 architectures.

Team Member	Speciality
Simon Brown	Safety expert/ facilitator
Adrian Clough	UAS expert/ Project Technical Leader
Phil Platt	Communications expert
Sarah Hunt	Mathematician and analyst
Phil Richards	UAV communications and spectrum specialist
Mike Ainley	Project Manager

Table 3-3: Hazard assessment team of Experts

The candidate architectures were presented to the team as a set of functional diagrams. All architectures were also portrayed as a schematic diagram, showing the system level elements. These diagrams were agreed by the team members to be a reasonable high level abstraction of the critical functions for the architecture.

The risk assessment was based on the EUROCONTROL Safety Assessment Methodology (SAM) preliminary Hazard assessment (PHA) process. This methodology uses a set of severity categories to quantify the risk to ATC. The same categories are also found in ESARR 4. Using the risk scheme described below the architectures were ranked with respect to their perceived safety.

3.3.2 Risk Classification Scheme

The SAM/ESARR 4 classification scheme is reproduced below in Table 3-4. The scheme is qualitative, with the severity classifications defined below in Table 3-5. Frequency of occurrence is divided into five categories between 'HIGH' or category 5, the most likely to occur and 'LOW' or category 1, the least likely to occur. A measure of likely risk, the risk index, is obtained by multiplying severity by frequency. Thus the highest risk would have a risk index of 25. Risk indexes shown in green indicate a level of risk considered to be acceptable by the team subject matter experts. Risk indexes in red were considered to indicate architectures that may be difficult to engineer to be acceptably safe.

Severity Class	**5 [Most Severe]**	**4**	**3**	**2**	**1**
Effect on Operations	**Accidents**	**Serious incidents**	**Major incidents**	**Significant incidents**	**No immediate effect on safety**
Examples of effects on operations	❑ one or more catastrophic accidents, ❑ one or more mid-air collisions ❑ one or more collisions on the ground between two aircraft ❑ one or more Controlled Flight Into Terrain ❑ total loss of flight Control. No independent source of recovery mechanism, such as surveillance or ATC and/or flight crew procedures can reasonably be expected to prevent the accident(s).	❑ large reduction in separation (e.g., a separation of less than half the separation minima), without crew or ATC fully controlling the situation or able to recover from the situation. ❑ one or more aircraft deviating from their intended clearance, so that abrupt manoeuvre is required to avoid collision with another aircraft or with terrain (or when an avoidance action would be appropriate).	❑ large reduction (e.g., a separation of less than half the separation minima) in separation with crew or ATC controlling the situation and able to recover from the situation. ❑ **minor** reduction (e.g., a separation of more than half the separation minima) in separation without crew or ATC fully controlling the situation, hence jeopardising the ability to recover from the situation (without the use of collision or terrain avoidance manoeuvres	❑ increasing workload of the air traffic controller or aircraft flight crew, or slightly degrading the functional capability of the enabling CNS system. ❑ **minor** reduction (e.g., a separation of more than half the separation minima) in separation with crew or ATC controlling the situation and fully able to recover from the situation.	No hazardous condition i.e. no immediate direct or indirect impact on the operations.

Table 3-4: Hazard Classification table

Severity Class		5	4	3	2	1
Likelihood		Accidents	Serious Incidents	Major Incidents	Significant Incidents	No immediate effect
High	5	25	20	15	10	5
Medium/H	4	20	16	12	8	4
Medium	3	15	12	9	6	3
Low/Med	2	10	8	6	4	2
Low	1	5	4	3	2	1

Table 3-5: Hazard severity

3.3.3 Analysis Technique

A top level functional hazard assessment was conducted using keyword prompts to engender discussion between members and to elicit potential plausible hazards. Keywords were selected from the SAM according to ESARR 4. Assumptions made about each of the candidate architectures are listed at Paragraph 3.3.4 below. The results from the risk analysis were compiled into a series of worksheets, one worksheet for each of the proposed architectures. The worksheets are shown in appendix B.

The worksheets were used to record, for each keyword, any plausible hazard, the potential cause of the hazard, the team's evaluation of likelihood of occurrence and severity for each hazard, the resulting risk index and any mitigation that may reduce the hazard risk.

A further weighted score was added to the worksheets to account for potential multiple occurrences of the same hazard within different functional blocks. This score assumed that the functional blocks could be considered to be connected in series. Thus, the risk index for the recurring hazard in each block was a cumulative value; that is risk index multiplied by number of occurrences.

In order to rank the candidate architectures all the risk indexes and weighted indexes for the hazards identified on the worksheets were totalled. These totalled scores, together with the unweighted risk totals and other non-safety technical criteria, were used to select the most suitable bounded architectures on which to conduct the analysis on the remaining topics.

3.3.4 Assumptions

During the course of the risk assessments the following assumptions were identified.

Assumption 1	The UAV has no independent means of providing sense and avoid.
Detail	The UAV is assumed to have no independent means of autonomously maintaining separation from other aircraft, terrain or hazardous weather.
Rationale	Whilst in the future, many unmanned aircraft are likely to be equipped with certified systems capable of independently performing sense and avoid functions, this capability cannot be assumed to exist for all unmanned aircraft. Operation of the UAV is therefore assumed to be reliant on the provision of an ATC separation service or the pilot. Refers to a UAS that would be restricted to operate only inside controlled airspace

Assumption 2	A UAS will do what it is instructed to do by ATC.
Detail	A UAS being operated under an Air Traffic Control Service will comply with ATC instructions in a timely manner. ATC instructions may require the UAV to climb, descend, turn or adjust speed.
Rationale	For a UAS to be able to operate outside segregated airspace amongst other air traffic, it must be able to respond to ATC instructions and react in a timely manner.

Assumption 3	If the UAV loses communications it will continue on its planned route.
Detail	If the UAV loses communications with ATC or its GCS, then it will continue on its planned route at its planned flight level. Note: It is recognised that different UAVs are programmed to do different things in the event of a communications failure, and there is currently no standard procedure.
Rationale	This is what a manned aircraft will do, and procedures exist to enable ATC to continue to provide separation.

Assumption 4	The UAS data link communications system has the ability to detect errors.
Detail	The integrity requirements of the data paths will ensure that undetected errors cannot arise.
Rationale	This is a reasonable expectation for a certified flight safety system.

Assumption 5	No redundancy in sub-system elements
Detail	Regardless of the safety performance requirement, all sub-system elements are assumed to be non-redundant. For example, a communications path between two nodes will be assumed to have a single mode of failure even though it will have been engineered to meet availability requirements.
Rationale	It is not possible to provide an accurate assessment of sub-system elements, and it is therefore necessary to make some general assumptions at this stage.

Assumption 6	A UAV carrying ATC voice/data radios can tune to any valid frequency.
Detail	ATC voice/data radios installed on a UAV can be remotely tuned from the GCS by sending commands over the C2 data link. Tuning of ATC voice/data radios could be remotely controlled via the C2 data link
Rationale	There would be no point having an ATC voice/data radio that could not be remotely tuned.

Assumption 7	One UAV per GCS
Detail	All architectures assume only one UAV per GCS.
Rationale	Whilst it may be technically possible to control more than one UAV from a GCS, there are various legal, operational and human factor issues to be addressed before such operation is likely to be approved. There is no justifiable reason to consider architectures capable of supporting more than one UAV per GCS at this point in time.

Assumption 8	C2 and ATC communications channels always ‘open’
Detail	It shall be assumed that C2 and ATC voice/data communications channels are ‘open’ for the duration of the flight. Whilst private virtual circuits may be used, it is assumed that channels are continuously open, and any information sent to or from the UAS is passed through the communications channel in near real time.
Rationale	In order to comply with ATC instructions in a timely manner, both the ATC voice/data and C2 data link channels must be continuously open. ATC instructions may require the UAV to climb, descend, turn or adjust speed.

Assumption 9	UAVs do not require ‘stick’ input control
Detail	It is assumed that all UAVs capable of operating outside segregated airspace do not require constant control input in order to maintain flight. In other words, autopilot systems will ensure that attitude, roll angle and yaw control inputs are generated to maintain the desired flight path trajectory. (Linked with Assumption 3).
Rationale	Technology required for simple flight control is readily available (i.e. 3-axis autopilot).

Assumption 10	Satcom on UAVs requires a directional antenna
Detail	It is not uncommon for broadband satellite terminals to require a directional antenna. This can be due to the need to avoid interference to/from other satellites, or to ensure enough signal power over a long propagation path. Maintenance of the link from a moving platform (i.e. UAV) is dependent on the ability of automatic antenna steering systems to continuously track the satellite, and this is considered to be a potential mode of intermittent failure. ESA should be included as a stakeholder to ensure that UAS requirements for ATM communications are captured by Iris project.
Rationale	Whilst not all Satcom terminals will require a directional antenna, for the purpose of the PHA it has been assumed that GEO and LEO Satcom terminals will include a directional antenna.

Assumption 11	The UAV will always be within coverage of one satellite.
Detail	The coverage footprints of GEO satellites and orbit paths of LEO satellites are complex and will vary according to each network/constellation. The only safe assumption is to assume that the UAV is only within coverage of a single satellite.
Rationale	It cannot be assumed that other satellites will be within coverage of the UAV. If communications via the satellite fail, no redundancy can be assumed to be available from other satellites.

Assumption 12	All UAVs will be equipped with a Mode S transponder
Detail	A Mode S transponder will provide surveillance information to ATC ground radar systems and is compatible with collision avoidance systems (ACAS II) carried by turbine-powered civil aircraft of 5,700 kg or more.
Rationale	Due to the safety benefits transponder carriage brings, aircraft operating in controlled airspace will be required to carry a transponder, so it is not unreasonable to assume that UAVs will also be required to do so. This is common across all architectures and in a similar approach to the risk analysis where there is commonality across all architectures it is discounted on the basis that this assumption is made a requirement of obtaining an airworthiness certificate. This will be the subject of a survey questionnaire to gauge stakeholder reaction and opinion on the practicality of this assumption.

Assumption 13	Latency in Network Management Centres
Detail	Latency in the ATC voice/data communication path or C2 data link is a potential problem as it can impede the ability for a UAV pilot to comply with ATC instructions. Where signals pass through a network management centre, there is potential for additional latency due to the amount of signal routing and processing that takes place. For this reason, any network management centre shall be assumed to be a source of latency.
Rationale	Where signals pass through a network management centre, there is potential for additional latency due to the amount of signal routing and processing that takes place. For this reason, any network management centre shall be assumed to be a source of latency.

Assumption 14	Latency in Satellite Communications
Detail	Latency in the ATC voice/data communication path or C2 data link is a potential problem as it can impede the ability for a UAV pilot to comply with ATC instructions. Where signals are routed via a geostationary satellite, at least a quarter of a second of additional latency will be introduced. For low earth orbit satellites, propagation paths can be of similar length due to the need to route feeder signals via several intermediate satellites (if a satellite earth station is not within coverage of the satellite being used). For this reason, any satellite communications path shall be assumed to be a source of latency.
Rationale	Where signals are routed via a satellite, there is potential for additional latency due to the length of propagation paths involved. For this reason, any satellite communications path is assumed to be a source of latency.

Assumption 15	Only UAS with MTOM of 150kg or more shall be considered
Detail	This assumption underlies the scope of the project to limit considerations to UAV with a MTOM of greater than 150kg.
Rationale	EASA’s remit only covers UAV of 150 kg or more.

Assumption 16	Architectures considered are only applicable for UAS operations conducted beyond visual line of sight.
Detail	The architectures considered are applicable for UAS operations that extend to a range of more than 500 m, or a height of more than 400 ft (150 m) from the UAV operator. In such cases, it is not considered practical or safe for the UAV operator to control the flight by visual observation techniques.
Rationale	Very short range UAS operations can be safely conducted as long as the UAV operator has good visual awareness of the UAV, and its proximity to other objects (buildings, people etc). For a UAV that is operated beyond visual line of sight the operator will rely on electronic systems (either on the UAV or on the ground), to sense and avoid nearby objects. See assumption 1.

Assumption 17	All ground control stations power supplies will be safe.
Detail	Ground control station power supplies are common to all architectures.
Rationale	The safety effect on the scoring can be ignored for comparison purposes providing this assumption is made and it becomes a requirement that can be demonstrated in practise during the air worthiness certification process.

Assumption 18	Architectures will be suitable for implementation within a SESAR concept environment
Detail	When considering the cost aspects associated with the bounded architectures, it was important to consider what is likely to exist in the 2020 timeframe (i.e. with SESAR concepts and related architectures already in place).
Rationale	The fact that current regulations prevent a type of activity taking place should not necessarily mean that future regulations will prevent it taking place. If there is a good reason for changing existing regulations, then they can be changed, through the appropriate procedures.

3.3.5 Risk Assessment Scores

The following table shows the results of the analysis.

		Risk Score			
Architecture	Description	Weighted	plain	Red Risks	Yellow
AR1	ATC relay: non-networked GS	110	41	1	
AR2	ATC relay: networked GS	69	27	0	
AR3	ATC relay: GEO satellite	171	49	0	1
AR4	ATC relay: LEO satellite	140	40	0	
AR5	ATC relay: HAP	142	44	0	
NR1	ATC via terrestrial GS + DL via non-networked GS	92	33	1	
NR2	ATC via terrestrial GS + DL via networked GS	129	31	0	
NR3	ATC via terrestrial GS + DL via GEO satellite	152	34	0	
NR4	ATC via terrestrial GS + DL via LEO satellite	154	32	0	
NR5	ATC via terrestrial GS + DL via HAP	153	36	0	
NR6	ATC via dedicated wired i/f + DL via non-networked GS	91	35	1	
NR7	ATC via dedicated wired i/f + DL via networked GS	126	40	0	1
NR8	ATC via dedicated wired i/f + DL via GEO satellite	146	38	0	
NR9	ATC via dedicated wired i/f + DL via LEO satellite	146	38	0	
NR10	ATC via dedicated wired i/f + DL via HAP	146	42	0	
NR11	ATC via CSP wired i/f + DL via non-networked GS	101	37	1	
NR12	ATC via CSP wired i/f + DL via networked GS	128	38	0	1

		Risk Score			
Architecture	Description	Weighted	plain	Red Risks	Yellow
NR13	ATC via CSP wired i/f + DL via GEO satellite	161	38	0	
NR14	ATC via CSP wired i/f + DL via LEO satellite	161	38	0	
NR15	ATC via CSP wired i/f + DL via HAP	353	58	0	2

Figure 3-2: Hazard assessment scores

3.4 Bounded Architecture Selection

As a result of the risk analysis the following architectures were proposed to the EASA focal point Mr F Tomasello and representatives of the Project Steering Group (PSC). These were accepted as the bounded architectures to be used for the Preliminary Impact Assessment.

3.4.1 AR2 - Networked terrestrial GS providing C2 and ATC Voice/Data Communications

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 data link.

3.4.2 NR1 - Non-networked terrestrial for C2 and ground-based ATC Voice/Data COM equipment

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).

3.4.3 NR3 – C2 via GEO satellite and ATC Voice/Data via networked ground-based COM equipment

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.

3.4.4 NR12 – ATC Voice/Data via CSP wired interface and C2 via networked terrestrial GS

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 was possible to explore issues associated with the use of a CSP managed wired interface to the ATC voice/data network.

4 Assessment of Impact Topics

This section covers the assessment of potential impact undertaken on the 4 bounded architectures. There was firstly an initial impact assessment from which the stakeholder questionnaires were devised. The aim of this initial assessment was to identify broad areas of impact, and to use this to focus on the issues that need to be addressed in the Group 1 stakeholder interviews and the Group 2 on-line survey.

4.1 Scope

The initial impact assessment identified the issues that are likely to be contentious or high risk, be it for UAV/S manufacturers, UAV/S operators, Air Navigation Service Providers (ANSP) or safety regulators. It covered a wide range of issues including:

- Investment Costs (to develop suitable avionics equipment and associated ground/space infrastructure)
- Practical limitations (size and weight of equipment)
- Operational Costs
- Operational Limitations.

To achieve this, the impact of each of the bounded architectures was assessed in detail in the following five areas:

- Economic (cost and weight of the avionics and/or cost of modifications to ATS/ATC systems)
- Social Impact (slower or faster development of EU UAS industry), with a benchmark prediction as to the size of the industry by 2020.
- Use of Electromagnetic Spectrum (estimated total requirement)
- Global Interoperability (ability to operate in different States, and to transit FIR boundaries)
- Impact on other existing EU rules (i.e. compatibility with SESAR regulations and ESARRs)

The purpose of the initial assessment process culminated in a list of topics that were investigated further through the stakeholder engagement. Both positive and negative attributes associated with each topic were summarised. However, to ensure that only the issues likely to have significant impact were addressed by stakeholders, judgement was applied during this stage to ensure that issues of little impact were not included in the questions presented to stakeholders.

4.2 Approach

All the bounded architectures were analysed against each of the topics above. To perform this analysis a series of questions were developed, the purpose of which was to identify assumptions and issues relevant to the implementation of the architecture. It was not the intention at this stage to provide definitive answers, more to 'tease out' the questions that need to be asked of the stakeholder community in general. The answers to these questions should not be seen as definitive or representing anything other than an initial view from a range of experts.

4.3 Economic

The economic impact assessment concentrated on the cost and other implications of implementing the architectures both on the UAS and for ANSPs to provide the support infrastructure. The findings of the economic assessment can be summarised as follows:

- Regardless of architecture, UAS data link will require significant spectrum and communications infrastructure
- Implementation of dedicated ground/radio networks, managed by communication service providers and used by several UAS/air operators, will provide maximum user flexibility and minimise total spectrum requirement

- Users must be prepared to pay for spectrum licences and where relevant, the use of networks, which could be cheaper than installing a communication system for each individual UAS
- Mobile phone networks, terrestrial data networks for aviation such as those provided by ARINC or SITA and satellite-based mobile networks such as Inmarsat provide good indication of charges for voice and data services. Their historical development shows that charges tend to progressively decrease in parallel with technological evolution and increased utilization of the network
- Public and industry investment has focused on research and development of UAS technology and the drafting of technical standards and regulations
- To date, there is no evidence of any public investment into suitable infrastructure or services to support UAS operation in non-segregated airspace, including for the safety regulation of these specific COM Service Providers.

4.4 Social

Results from the social impact assessment concluded that:

- Published market forecasts vary wildly. Although all predict growth to some extent, it is not clear when this is likely to occur, and which aspects of UAS operation will see most growth (and hence what type of communications architecture and infrastructure will be required and when)
- There are many candidate applications for UAS technology. However, viability will largely depend on enabling infrastructure and the regulatory environment that is put in place. In turn the regulatory environment may delay or contribute to allow market development
- It is not clear how many UAS applications will need to operate in the airspace as GAT (General Air Traffic) amongst other (manned) traffic
- Spectrum requirements can be reduced and quality/reliability of voice/data communications with ATC could be improved by using non-ATC relay architectures
- Use of communication service providers is of key importance to many of the potential architectures, but this may raise social issues in the absence of proper regulation
- Wired architectures are attractive as they offer high bandwidth, high integrity and high reliability connections with minimal need for spectrum, or for UA to carry ATC radio equipment. This solution is unconventional and needs to be explored in detail with safety regulators, industry and ANSPs
- Similarly, whilst offering potential benefits, the use of ground-based ATC radio equipment in some of the bounded architectures is also unconventional, and needs to be explored in detail with safety regulators and ANSPs
- In the future, many UA are expected to be highly autonomous. It is not clear what regulatory expectations will be for the performance of command, control and ATC communications links for such UAS. This topic needs to be discussed in detail with safety regulators, industry and ANSPs.

4.5 Electromagnetic Spectrum

Results from the Electromagnetic Spectrum impact assessment concluded that:

- Harmonised UAS spectrum allocations do not exist at present. Existing allocations are either ad hoc or assigned at a national level.
- The total requirements for UAS spectrum (C2/C3 data link, Sense and Avoid and payload) are still to be defined (although work is on-going within ITU-WP5B to estimate the C3 requirement).

- The market split between local (short range UAS operation) and wide area operation (using satellites or networked terrestrial ground stations) is not clear, but it is likely that different user needs will emerge.
- New spectrum allocations are difficult to acquire and the UAS industry will have to compete with other applicants or find a way to co-exist with existing aeronautical services.
- Almost all the present aeronautical frequency bands are already congested, and it is not obvious where capacity will be found for new (UAS) allocations.
- Some modern communications technologies are very spectrum efficient, but these methods are not necessarily as reliable as more traditional (less spectrally efficient techniques) due to the need for substantial amounts of signal processing.
- In any case networks operated by COM service providers, serving more than one UAS and avoiding retransmitting in space the ATC communications, could reduce the total spectrum demand.

4.6 Global Interoperability

Results from the interoperability impact assessment concluded that:

- Party line is still recognised as being important for ATC voice communications
- It is not clear how important party line communications will be in the SESAR concept, given the expected predominance of data link communications.
- Additional latency is likely to be introduced for communications via geostationary satellite or digital switching networks. The potential impact of latency on ATC communications (voice or data) and C2 needs to be explored in detail with safety regulators and ANSPs.
- In networked architectures, interoperability standards will be required to allow users to access networks in different geographical regions
- Wired architectures may not be fully interoperable with all ATC ground infrastructure and this may lead to operational limitations
- Sense and avoid could provide greater levels of safety than ‘see & avoid’ for today’s manned aviation community
- The need for ATC surveillance, situational awareness and collision avoidance necessitates the carriage of transponders or position squittering devices (i.e. ADS-B concept) by all UA (other than those operating within visual line-of-sight of the pilot). This is the only safe and fully interoperable means of providing surveillance data. These systems are independent from communications.
- It is not clear what percentage of UAS will operate (i) outside the coverage footprint of a single terrestrial ground station or (ii) perform longer flights that transit across national or regional boundaries. This will impact on the type of communications infrastructure required.
- Given that full capability ‘Sense and Avoid’ technology is unlikely to be certified for some time, there is an expectation that some UAS will seek to be approved to operate under IFR only in controlled airspace, with ATC providing a separation service (with appropriate separation minima to be defined) . This issue needs to be explored with regulatory authorities, because if it is deemed to be acceptable, it could lead to greater demand for UAS communications infrastructure in the short-medium term.

4.7 Regulation

Results from the regulatory impact assessment concluded that:

- SES regulations mandate carriage of 8.33 kHz communications[2] and VDL M2[3] for aircraft operating in controlled airspace (or a known environment). In addition ECAC States require

[2]Commission Regulation (EC) No 1265/2007 of 26 October 2007

carriage of Mode S airborne transponders. Many UAS may be too physically small or not have sufficient electrical power to support such systems. Regulators have to assess whether alternative means exist to provide equivalent functionality (e.g. non-ATC relay).

- ATS Providers must comply with ESARRs as transposed in SES legislation (governing the design, maintenance and operation of ATM systems).
- UAS are not specifically mentioned in current regulations and are currently outside the scope of SESAR. Despite this, the ICAO UAS Study Group and EASA[4] are progressing in cooperation with States and industry, the development of policies, rules and technical guidance material, to formally recognise UAS, and ensure that appropriate regulations are put in place.

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[3]Commission Regulation (EC) No 29/2009 of 16 January 2009

[4]http://www.easa.europa.eu/ws_prod/r/doc/Explanatory%20Note%20to%20CRD-16-2005.pdf on the policy for airworthiness of UAS and rulemaking task MDM.030 in the rulemaking programme: http://www.easa.europa.eu/ws_prod/g/doc/Agency_Mesures/Agency_Decisions/2009/Appendix%20to%20ED%20Decision%202009_002_R%20(4-y%20RMP).pdf

5 Group 1 Stakeholder Results

This section provides analysis of responses from the engagement with the Group 1 stakeholders. Group 1 stakeholders have two purposes, firstly, responses to the questions are analysed and scored. This is used to create an aggregate performance score for each of the topics that were used as a weighting to multiply Group 2 scores and produce a compounded score for each of the bounded architectures. Secondly, through a qualitative analysis, areas of agreement and disagreement are considered to produce observations and conclusions. These observations and conclusions are correlated with the Group 2 qualitative analysis and the combined quantitative analysis to produce final conclusions and recommendations.

To preserve the anonymity of the stakeholders they are referred to as S1 to S8. The questions can be found later in section 5.2.

5.1 Quantitative Analysis

For the sake of simplicity the Group 1 questions were grouped into the impact categories for the interviews. However, it will be seen that some of the questions and answers have relevance in different categories and that in the other impact categories a different impact weighting might be appropriate. The results that follow are an analysis based on the method outlined in section 2.5.

5.1.1 Economic Results

Figure 5-1 shows all Group 1 stakeholder responses to interview questions with economic relevance. The third column shows the question impact as to whether it is high, medium or low - this will be used in later analysis to calculate the weighted mean. Columns labelled S1 – S8 are the numerical scores given to answers for each of the topic questions; from these the arithmetic mean, mode and standard deviation are calculated for all questions. These extra statistics allows review of the answers that may be missed if only an average is examined. Each of the answers was scored 1-5 depending on their response where:

1 = low importance/impact and 5 = high importance/impact.

If a stakeholder has not responded to a question or thinks it is not applicable to their role, answers are left blank and not included in numerical analysis.

			Stakeholders										
Economic Questions		Question Impact (QI)	S1	S2	S3	S4	S5	S6	S7	S8	Arithmetic Mean	Mode	S.D.
1	Do you believe there is a market for UAS, and if so, what type of applications do you expect to emerge initially?	H	2	5	5	4	5	3	4	4	4.0	5	1.07
2	Do you have any investment plans to provide infrastructure and services specific to support the operation of UAS?	H	2	5	5	5	5	2	2	1	3.4	5	1.77
7	Overall, how critical is the need for economic investment to facilitate the development of necessary communications infrastructure to permit UAS operation outside segregated airspace?	H	3	5	4	5	3	3	2	4	3.6	3	1.06
9	What percentage of GAT flights (i.e. by civilian operators, by military services under GAT or by non military governmental organisations in controlled airspace or a known traffic environment) do you believe will be unmanned by: a) 2015? b) 2020? c) 2030?	M	4	5	4	5	4	1	4	3	3.8	4	1.28
17	A standardised networked C2 datalink will provide greatest flexibility for UAS operators that need to operate over a wide area, but this is likely to require significantly more spectrum than would be required for individual operation of proprietary systems over a local area. How important is it to secure sufficient spectrum to establish one or more standardised C2 networks across Europe?	M	5	4	_	4	5	3	4	4	4.1	4	0.69
21	How important is it to adopt architectures that minimise the amount of spectrum required?	M	5	4	4	4	4	5	4	4	4.3	4	0.46
22	How important is it to use spectrally efficient techniques?	M	4	5	4	5	5	4	4	5	4.5	4	0.53
29	Do you recognise the potential for "sense and avoid" technology on UAS for supplementing/replacing current "see and avoid" concept?	M	2	5	4	4	_	4	5	5	4.1	5	1.07
	Aggregate		2	5	5	5	4	3	3	3	3.8	5	1.16

Figure 5-1 Group 1 Stakeholder Reponses Analysis - Economic

Overall Group 1 expect there to be a market for UAS however the actual market mix could form any number of applications including but not limited to:

- Very small LOS operations
- Governmental such as border control, maritime surveillance, fire fighting, search and rescue
- Maritime Surveillance
- Peace Keeping

Question 2 highlights a numerical difference between the mode and mean. On closer inspection of results this is due to the dichotomy of responses given by stakeholders. There is a real split in consensus with some very strongly expecting to have investment plans for the provision of infrastructure and services specific to UAS. Whereas, other stakeholders do not envisage any specific plans either as it is inappropriate for their role or they do not see any specific service provision for UAS separately from current operations.

Overall Figure 5-1 shows strong agreement with most stakeholder responses scoring, either 4 or 5 for most questions. The overall mean for the economic questions is approximately 3.8 and the most common response (mode) was 5 showing the high importance of economic issues for Group 1.

The arithmetic means for each of the questions above are weighted by the Question Impact (QI) using the following numerical scale:

Low = 1, Medium = 3 and High = 5

This ensures that some of the more important issues within a topic have a higher weighting within the topic category. The total weighted mean is then divided by the number of questions within the topic category to give an aggregate performance score.

Figure 5-2 shows the economic aggregate performance score $p_{Economic} = 14.7$. This will be compared with each of the other topic category scores to determine their relative importance.

ECONOMIC

Number of Questions Used for Analysis: 8

Question	SD	Mode	Arithemtic Mean	Question Impact (QI)	Weighted Mean (Mean x QI)
1	1.069045	5	4.00	H	20.00
2	1.767767	5	3.38	H	16.88
7	1.0606602	3	3.63	H	18.13
9	1.2817399	4	3.75	M	11.25
17	0.6900656	4	4.14	M	12.43
21	0.46291	4	4.25	M	12.75
22	0.5345225	4	4.50	M	13.50
29	1.069045	5	4.14	M	12.43
Aggregate			3.75	**Total Weighted Mean:**	117.36

Economic	14.7

Figure 5-2 Group 1 Performance Result - Economic

5.1.2 Social Results

The social impact category is concerned with the speed of development of the market and its effect on jobs and market penetration. Hence questions 1 and 2 from the economic category have been included within the social results as the economic market impact has social significance.

Social Questions		Question Impact (QI)	Stakeholders S1	S2	S3	S4	S5	S6	S7	S8	Arithmetic Mean	Mode	S.D.
1	Do you believe there is a market for UAS, and if so, what type of applications do you expect to emerge initially?	H	2	5	5	4	5	3	4	4	4.0	5	1.069
2	Do you have any investment plans to provide infrastructure and services specific to support the operation of UAS?	H	2	5	5	5	5	2	2	1	3.4	5	1.768
8	How important is datalink reliability and continuity for fully autonomous UA?	L	3	3	4		4	3	3	_	3.3	3	0.516
9	What percentage of GAT flights (i.e. by civilian operators, by military services under GAT or by non military governmental organisations in controlled airspace or a known traffic environment) do you believe will be unmanned by: a) 2015? b) 2020? c) 2030?	H	4	5	4	5	4	1	4	3	3.8	4	1.282
13	Some of the architectures are only likely to be economically viable using a communication service provider. Do you see any issues associated with the use of a service provider to provide UAS voice/data communications?	M	1	1	1	2	1	_	1	5	1.7	1	1.496
15	Overall, do you believe UAS will represent a significant proportion of traffic in the European ATM system (a) before 2020 and (b) after 2020?	H	3	5	5	4	4	4	3	2	3.8	4	1.035
16	Do you believe that it is acceptable to use innovative/novel communications architectures, potentially involving new service providers to achieve safe and effective communications with UAS?	M	4	4	_	4	5	3	4	4	4.0	4	0.577
28	In the case of a communication service provider that provides C2/C3 link to several UAS operators, how might this be acceptable?	M	4	4	4	4	4	4	4	4	4.0	4	0
30	In the short term do you support UAS operating as IFR in controlled airspace with limited "sense and avoid" capability?	M	3	4	3	5	_	_	3	1	3.2	3	1.329
	Aggregate		3	4	4	4	4	3	3	3	3.5	4	0.535

Figure 5-3 Group 1 Stakeholder Reponses Analysis – Social

Question 13 shows a lower scoring of answers, where respondents did not foresee any associated issues it was expected that this had little social impact.

Questions 13 and 30 each show an outlier response - this is when an answer is completely different to all other responses. Sensitivity tests were performed to see the impact of outlier results, when they were removed from the response it had little or no impact on the overall aggregate performance scores as shown in the table within Figure 5-11.

Social impact is generally seen as important by Group 1. There is general consensus on most of the questions; however, answers are more variable than the previous economic category. The aggregate mean response is 3.5 and the mode score is 4, both of which are lower than the economic topic.

Figure 5-4 shows the social aggregate performance score $p_{Social} = 12.9$ notably lower than the previous economic scoring.

SOCIAL

Number of Questions Used for Analysis: 9

Question	SD	Mode	Arithemtic Mean	Question Impact (QI)	Weighted Mean (Mean x QI)
1	1.069045	5	4.00	H	20.00
2	1.767767	5	3.38	H	16.88
8	0.5163978	3	3.33	L	3.33
9	1.2817399	4	3.75	H	18.75
13	1.4960265	1	1.71	M	5.14
15	1.0350983	4	3.75	H	18.75
16	0.5773503	4	4.00	M	12.00
28	0	4	4.00	M	12.00
30	1.3291601	3	3.17	M	9.50
Aggregate			3.50	**Total Weighted Mean:**	116.35

Social	12.9

Figure 5-4 Group 1 Performance Result – Social

5.1.3 Spectrum Results

The spectrum impact category is concerned with the amount of spectrum required and issues associated with protection of existing users.

Spectrum Questions		Question Impact (QI)	Stakeholders S1	S2	S3	S4	S5	S6	S7	S8	Arithmetic Mean	Mode	S.D.
17	A standardised networked C2 datalink will provide greatest flexibility for UAS operators that need to operate over a wide area, but this is likely to require significantly more spectrum than would be required for individual operation of proprietary systems over a local area. How important is it to secure sufficient spectrum to establish one or more standardised C2 networks across Europe?	H	5	4	_	4	5	3	4	4	4.14	4	0.6901
18	How important do you believe it is to secure, through ITU World Radio Conferences, a harmonised spectrum allocation for UAS C2 datalink? And it is the same for mission/payload data? Please explain the rationale behind your replies.	H	5	5	_	5	5	3	3	5	4.43	5	0.9759
19	How important do you believe it is for UAS C2 datalink communications to be wholly contained within aeronautical frequency bands AM(R)S or AMS(R)S?	H	5	5	_	3	3	4	4	4	4.00	4	0.8165
20	How important is it to have common harmonised global spectrum allocations for UAS C2 datalink communications?	H	5	4	_	_	3	4	4	4	4.00	4	0.6325
21	How important is it to adopt architectures that minimise the amount of spectrum required?	H	5	4	4	4	4	5	4	4	4.25	4	0.4629
22	How important is it to use spectrally efficient techniques?	H	4	5	4	5	5	4	4	5	4.50	4	0.5345
	Aggregate		5	5	4	4	4	4	4	4	4.22	4	0.4629

Figure 5-5 Group 1 Stakeholder Reponses Analysis - Spectrum

Generally within Figure 5-5 the low standard deviation (S.D) values in the rightmost column show the relatively strong agreement in responses from Group 1 stakeholders. Most emphasised the importance for spectrally efficient techniques and architectures that minimise the overall need for spectrum.

Results below have a high mean value = 4.22, much larger than previous scores showing the importance spectrum has amongst the topics considered. The low S.D. in responses also shows agreement of answers.

Figure 5-6 shows the spectrum aggregate performance score $p_{Spectrum} = 21.1$ showing a higher weighting than other topic categories. It can also be noted from the table below that all questions have a high impact.

SPECTRUM

Number of Questions Used for Analysis: 6

Question	SD	Mode	Arithmetic Mean	Question Impact (QI)	Weighted Mean (Mean x QI)
17	0.6900656	4	4.14	H	20.71
18	0.9759001	5	4.43	H	22.14
19	0.8164966	4	4.00	H	20.00
20	0.6324555	4	4.00	H	20.00
21	0.46291	4	4.25	H	21.25
22	0.5345225	4	4.50	H	22.50
Aggregate			4.22	**Total Weighted Mean:**	126.61
				Spectrum	21.1

Figure 5-6 Group 1 Performance Result – Spectrum

5.1.4 Global Interoperability Results

Global interoperability is concerned with the ability for UAS to be safely operated in different states, and to conduct flights that transit FIR boundaries from one state to another. It is important to consider factors that may enable global interoperability, including a standardised network across Europe, sufficient spectrum and latency.

Interoperability Questions		Question Impact (QI)	Stakeholders S1	S2	S3	S4	S5	S6	S7	S8	Arithmetic Mean	Mode	S.D.
17	A standardised networked C2 datalink will provide greatest flexibility for UAS operators that need to operate over a wide area, but this is likely to require significantly more spectrum than would be required for individual operation of proprietary systems over a local area. How important is it to secure sufficient spectrum to establish one or more standardised C2 networks across Europe?	H	5	4	_	4	5	3	4	4	4.14	4	0.6901
18	How important do you believe it is to secure, through ITU World Radio Conferences, a harmonised spectrum allocation for UAS C2 datalink? And it is the same for mission/payload data? Please explain the rationale behind your replies.	M	5	5	_	5	5	3	3	5	4.43	5	0.9759
19	How important do you believe it is for UAS C2 datalink communications to be wholly contained within aeronautical frequency bands AM(R)S or AMS(R)S?	H	5	5	_	3	3	4	4	4	4.00	4	0.8165
20	How important is it to have common harmonised global spectrum allocations for UAS C2 datalink communications?	H	5	4	_	_	3	4	4	4	4.00	4	0.6325
24	How important will it be to continue to provide voice party line to pilots in the SESAR environment, where trajectory management via data link and improved situational awareness in the cockpit may be available?	L	3	2	_	3	_	3	_	3	2.80	3	0.4472
26	Latency is potentially an issue both for ATC communications and C2, particularly where geostationary satellites are used. How much latency can be tolerated?	H	5	3	4	1	3	4	4	_	3.43	4	1.2724
30	In the short term do you support UAS operating as IFR in controlled airspace with limited "sense and avoid" capability?	H	3	4	4	4	_	3	3	1	3.14	3	1.069
	Aggregate		4	4	4	3	4	3	4	4	3.71	4	0.4629

Figure 5-7 Group 1 Stakeholder Reponses Analysis – Interoperability

Question 17 shows general consensus that sufficient spectrum will be required to provide a networked communications facility for wide area operations. Respondents believed that such a network is critical to allow some UAS applications and associated markets to develop.

Latency and sense and avoid are recognised as two particularly significant issues that have an impact on interoperability. Latency is viewed as a particular problem for ATC communications in high density airspace. There were differing views as to the requirements for Sense and Avoid that would be acceptable.

The interoperability mean = 3.71 and mode = 4 again showing an importance of this category.

Figure 5-8 shows the interoperability aggregate performance score $p_{Interoperability} = 15.7$ this is higher than economic and social scorings.

INTEROPERABILITY

Number of Questions Used for Analysis: 7

Question	SD	Mode	Arithmetic Mean	Question Impact (QI)	Weighted Mean (Mean x QI)
17	0.6900656	4	4.14	H	20.71
18	0.9759001	5	4.43	M	13.29
19	0.8164966	4	4.00	H	20.00
20	0.6324555	4	4.00	H	20.00
24	0.4472136	3	2.80	L	2.80
26	1.272418	4	3.43	H	17.14
30	1.069045	3	3.14	H	15.71
Aggregate			3.71	**Total Weighted Mean:**	109.66

Interoperability	15.7

Figure 5-8 Group 1 Performance Result – Interoperability

5.1.5 Regulation Results

Regulation looks at the impact on existing EU rules (e.g. compatibility with SESAR and ESARRs) and whether there are any prevalent issues to be considered.

			Stakeholders										
Regulation Questions		**Question Impact (QI)**	S1	S2	S3	S4	S5	S6	S7	S8	**Arithmetic Mean**	**Mode**	**S.D.**
6	How do you believe the cost of UAS regulation (rulemaking plus certification and oversight) should be funded?	L	5	5	4	_	_	5	5	5	4.8	5	0.408
18	How important do you believe it is to secure, through ITU World Radio Conferences, a harmonised spectrum allocation for UAS C2 datalink? And it is the same for mission/payload data? Please explain the rationale behind your replies.	H	5	5	_	5	5	3	3	5	4.4	5	0.976
19	How important do you believe it is for UAS C2 datalink communications to be wholly contained within aeronautical frequency bands AM(R)S or AMS(R)S?	H	5	5	_	3	3	4	4	4	4.0	4	0.816
20	How important is it to have common harmonised global spectrum allocations for UAS C2 datalink communications?	H	5	4	_	_	3	4	4	4	4.0	4	0.632
26	Latency is potentially an issue both for ATC communications and C2, particularly where geostationary satellites are used. How much latency can be tolerated?	L	5	3	4	1	3	4	4	_	3.4	4	1.272
28	In the case of a communication service provider that provides C2/C3 link to several UAS operators, how might this be acceptable?	M	5	5	5	5	5	5	5	5	5.0	5	0
29	Do you recognise the potential for "sense and avoid" technology on UAS for supplementing/replacing current "see and avoid" concept?	H	3	5	5	4	_	4	5	5	4.4	5	0.787
30	In the short term do you support UAS operating as IFR in controlled airspace with limited "sense and avoid" capability?	H	3	4	4	4	_	3	3	1	3.1	3	1.069
31	Overall, how essential is it for UAS to be fully compliant with SES regulations?	H	5	5	4	5	4	5	4	5	4.6	5	0.518
32	If necessary, do you support the drafting of new SES regulations specifically for UAS to ensure that they can be accommodated in future ATM environment?	H	4	5	5	5	_	_	4	4	4.5	4	0.548
	Aggregate		5	5	4	4	4	4	4	4	4.3	4	0.463

Figure 5-9 Group 1 Stakeholder Reponses Analysis – Regulation

Questions 30 and 31 specifically show strong agreement for UAS to be complaint with current SES regulations with the potential for additional regulations to be drafted if required. Overall Group 1 felt that UAS should be treated no differently to manned aircraft and that compliance with SES regulations is essential. However, some expressed a view that in the short term special arrangements or modifications could be made.

There was general agreement that new regulations will need to be drafted, including implementing rules governing operation of UAS, and potentially a new airworthiness standard (CS-UAS) will need to be developed.

Results in Figure 5-9 show a mean regulation score of 4.3 and mode value of 4 showing that this category is of relatively high importance to Group 1 stakeholders.

Figure 5-10 shows the regulation aggregate performance score $p_{\mathrm{Re}\,gulation} = 16.9$

REGULATION

Question	SD	Mode	Arithmetic Mean	Question Impact (QI)	Weighted Mean (Mean x QI)
6	0.4082483	5	4.83	L	4.83
18	0.9759001	5	4.43	H	22.14
19	0.8164966	4	4.00	H	20.00
20	0.6324555	4	4.00	H	20.00
26	1.272418	4	3.43	L	3.43
28	0	5	5.00	M	15.00
29	0.7867958	5	4.43	H	22.14
30	1.069045	3	3.14	H	15.71
31	0.5175492	5	4.63	H	23.13
32	0.5477226	4	4.50	H	22.50
Aggregate			4.25	**Total Weighted Mean:**	168.89

Regulation	16.9

Figure 5-10 Group 1 Performance Result - Regulation

5.1.6 Overall Group 1 Aggregate Performance Scores

Each of the impact topics discussed above have been summarised below by the Aggregate Performance Score (APS) column highlighted blue. This was converted into a percentage scoring to assess the relative importance of the impact topics the pie chart below depicts the overall Group 1 weightings.

Impact Topic	Aggregate Performance Score (APS)	APS (%)		APS (%) Outliers Modified		APS (%) Normalised		APS(%) Mode Test	
Economic	14.7	18.1%	4	18.8%	4	20.1%	3	20.7%	3
Social	12.9	15.9%	5	16.4%	5	17.3%	4	18.6%	4
Spectrum	21.1	26.0%	1	22.9%	1	24.5%	1	23.5%	1
Interoperability	15.7	19.3%	3	20.4%	3	15.1%	5	14.6%	5
Regulation	16.9	20.8%	2	21.5%	2	23.0%	2	22.5%	2
	81.2								

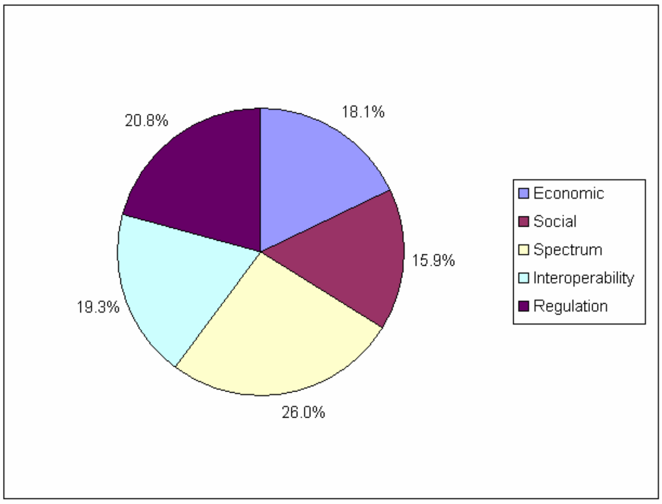

Figure 5-11 Group 1 Aggregate Performance Score

Based on these results the order of importance of the impact topics for Group 1 is:

1. Spectrum
2. Regulation
3. Interoperability
4. Economic
5. Social

The Aggregate Performance Score (%) will be used to weight Group 2 results to give a combined numerical analysis (see section 7).

Three numerical tests were performed on the data to assess the sensitivity of results.

1) Outliers Modification

As previously discussed, when a stakeholder had answered completely differently to all other stakeholders the score was removed to see how it affected the average for that question and the subsequent overall result. There was a small increase or decrease in some of the percentage results; however, the overall effect on the importance ranking remained unchanged with the same impact topic order, showing the robustness of the result.

2) Normalisation

A crude method of normalisation was performed with removal of the top and bottom answers for each question. This resulted in the top two topics remaining constant, however economic and social categories rose above interoperability.

3) Mode Testing

The mean value for each of the questions was calculated and used to determine an overall weighted mean for the topic. Averages tend to reduce the extreme opinions. This test allowed the most popular answer (i.e. mode) to replace the average. It had a similar impact to the normalisation result whereby the top two topics remained constant and economic and social rose above interoperability.

The last two tests are a means of approximation and serve to exclude differences of opinion and hence for the purposes of this investigation should not be taken any further. The outliers' analysis was used to see whether results were being unnecessarily skewed by one random answer. The result of this test confirms that the results were not skewed and therefore the original analysis results will be used.

5.2 Qualitative Analysis

The following paragraphs summarise the responses and classifies them according to the level of consensus.

The following definitions have been used in analysing the responses;

- Strong consensus - where the same response was given by nearly all stakeholders, and there were no opposing views
- General consensus: Where the same response was given by the majority of stakeholders
- Other responses: where issues were raised by one or two stakeholders. These responses may complement or oppose the general consensus.

It should be noted that the bullet points summarise the views of different stakeholders, and therefore can appear to be inconsistent when grouped together. This is intentional in order to give readers the full picture of the responses given.

5.2.1 Responses to Economic Questions

Q1. Do you believe there is a market for UAS, and if so, what type of applications do you expect to emerge initially?

<u>Strong Consensus</u>

- There is potentially a large market for state sponsored civil applications (i.e. governmental nature, but non military) such as State services (police, fire etc), border patrol, search and rescue etc.
- Significant growth in military UAS applications driven by operational requirements and lower operating costs
- Other civil applications will be market driven (i.e. where unmanned operation is more cost effective than manned).

<u>General Consensus</u>

- Peace Keeping – the need to provide surveillance of ground activity in remote/hostile territory
- Maritime Surveillance – already UA are being procured to replace existing manned platforms
- Cargo – urgent delivery of high value goods (i.e. delivery of transplant organs from one hospital to another).

<u>Other Responses</u>

- Humanitarian Missions/Disaster Relief. For example, organisations like Medicine sans Frontier could use UAS to deliver food and medical supplies in areas where ground transportation (road/rail etc) was either impractical, non-existent or too dangerous
- Environmental and spectrum monitoring

- High altitude communications relays – less expensive and easier to put in place than traditional communications satellite
- Reduced crew manning is likely to be viable for long haul cargo operations, as GCS crew will not be subject to jet lag, and assuming on-board crew only accrue hours during take-off and landing phase of each flight. If shown to be safe, this could significantly reduce the total number of crew required to operate a long haul freighter. From the regulatory point of view this means that the UAS domain and manned aviation have to be considered in a total system approach
- Satellite for C2 in BLOS applications such as monitoring of remote pipelines.

Q2. Do you have any investment plans to provide infrastructure and services specific to support the operation of UAS?

<u>Strong Consensus</u>

(none)

<u>General Consensus</u>

- Most stakeholders have no specific plans for investment to provide dedicated UAS infrastructure or services at this time
- Most national regulatory authorities provide support to the UAS industry through attendance at standardisation groups (i.e. EUROCAE WG-73) and by providing temporary segregated airspace within which UAS may be operated. Other activities include providing regulatory advice and guidance to the UAS community, and supporting activities for new spectrum allocations through CEPT, ITU and ICAO meetings.

<u>Other Responses</u>

- The EC and EDA are funding large research and development programmes (INUOI, MIDCAS, SIGAT etc) with the aim of providing enabling technology for UAS operation in non-segregated airspace
- Any new development of ATM infrastructure must be compatible with that being developed within the SESAR programme and dedicated additional infrastructures for UAS, if necessary, must be funded by the UAS industry
- The EC will increase the awareness of the benefits of UAS and assist in building political consensus on integrating UAS into the European framework over the next few years
- Funding exists through IAP for R&D on SATCOM in support of UAS.

Q3. If so, what infrastructure or services are planned, and when will they be available?

<u>Strong Consensus</u>

(none)

<u>General Consensus</u>

- No planned new infrastructure or services at this time.

<u>Other Responses</u>

- None planned but if WRC-2011 allocated 45MHz then potential applications and/ or service options could be researched.

Q4. If you have no direct investment plans at present, what would be required to justify such investment (e.g. legal certainty; public incentives; business plan; etc.)? Could there be any synergism with infrastructure or services stemming from SESAR (e.g. for

C, N and S)? And/or which part of the infrastructure should be directly provided by the UAS operators?

Strong Consensus

(none)

General Consensus

- The need to maintain safety is generally what drives investment by aviation safety regulators.

Other Responses

- The situation today, with UAS only operating inside segregated airspace means that there are no additional ATM safety issues to be managed, and hence there is no justification for investment by safety regulators
- NAA's are largely funded by the manned aviation community, so it could be difficult to justify a disproportionate level of investment to support a minority group
- From the EC perspective, sufficient interest from industry has been demonstrated to initiate new activity. In addition synergies with the SESAR programme are being explored
- It is likely that R&D funding will be required for demonstration systems.

Q5. Should the development of UAS communications infrastructure to permit voice/data communications with ATC have a cost implication for ANSPs?

Strong Consensus

(none)

General Consensus

- There should be no cost implications for ANSPs
- Aside from the military, most ANSPs are commercial organisations and are unlikely to invest in dedicated infrastructure to enable UAS communications without a compelling business case.

Other Responses

- UAS must be included within the SESAR architectures, which will minimise additional cost
- Costs should be borne by the user community.

Q6. How do you believe the cost of UAS regulation (rulemaking plus certification and oversight) should be funded?

Strong Consensus

- In line with other areas of the industry, the cost of certification should be paid for by those being regulated.

General Consensus

- Within Europe, the cost of rule making activity is generally centrally funded and charged on the totality of the population (i.e. by the European Commission).

Other Responses

- May contribute indirectly through research and studies.

Q7. Overall, how critical is the need for economic investment to facilitate the development of necessary communications infrastructure to permit UAS operation outside segregated airspace?

<u>Strong Consensus</u>

(none)

<u>General Consensus</u>

- The need for infrastructure is generally seen as critical for UAS that need to operate beyond line-of-sight (BLOS)
- The need for UAS infrastructure (and certified detect and avoid technology) is seen as critical in the long term to overcome the need for segregated airspace which is inefficient and places a burden on other airspace users.

<u>Other Responses</u>

- EASA recognises that for all but very short range UAS operating in Class F and G airspace, the need for appropriate infrastructure will be essential in order to reduce demand on the electromagnetic spectrum. It is possible that up to 90% of UAS platforms might depend on such infrastructure
- Economic investment is critical in order to develop appropriate infrastructure (ground or satellite) to permit GAT operation of military UAS, both in European airspace, and in other regions.

5.2.2 Responses to Social Questions

Q8. How important is data link reliability and continuity for fully autonomous UA?

<u>Strong Consensus</u>

(none)

<u>General Consensus</u>

- Some level of autonomy will be needed in case of communication failures
- Any data link would need to be reliable and have good continuity to allow continuous monitoring and override of the autonomous system by the human operator as and when required
- The link between GCS and ATC is less critical than the C2 link between the GCS and the UA. Loss of communications with ATC occurs today, and there are established procedures for handling such eventualities
- The performance requirement for the C2 link will be determined according to the UA’s kinetic energy, using established certification methods (i.e. similar to CS-25/1309). This is driven by the need to protect people (on the ground or in other aircraft) from an out of control UA.

<u>Other Responses</u>

- There is an important social dimension to the issue of the public acceptability of autonomous UA’s and there have already been concerns expressed on the adequate control of UA’s
- Safety and reliability of the data links may be driven by the insurance industry
- Performance requirements should be specified to meet a target safety level. Security requirements will be in addition to this.

Q9. What percentage of GAT flights (i.e. by civilian operators, by military services under GAT or by non military governmental organisations in controlled airspace or a known traffic environment) do you believe will be unmanned by (a) 2015, (b) 2020 and (c) 2030?

Strong Consensus

- All stakeholders believe that percentage will be around 1% by 2015
- All stakeholders recognise that it is extremely difficult to predict the percentage for 2030, but that it could be as much as 20%.

General Consensus

- Most stakeholders believe that percentage will start to rise sometime from 2020 onwards when more experience and acceptance of UAS operations has been achieved.

Other Responses

(none)

Q10. Some of the architectures identified utilise ground-based radio equipment located close to ATC ground radio equipment, and linked to UAS ground control stations via a wired network. Are there any reasons why voice/data communications could not be provided via a ground-based radio system?

Strong Consensus

(none)

General Consensus

- This type of architecture should be acceptable as long as equivalence with the current method of operation can be demonstrated
- Ground-based equipment must be carefully sited to ensure that (i) it does not overload ATC receivers and (ii) it can provide similar coverage to ATC transmitters (in order to maintain party line for voice communications).

Other Responses

- The use of fixed ground-based equipment may not be permitted by ITU as part of aeronautical mobile (route) service
- Airborne radio equipment will generally provide the UAS pilot with better situational awareness
- There is an increased risk of 'step-on' if the transmissions from the ground-based equipment cannot be heard by other aircraft on the frequency
- In some countries, there might be public opposition to the establishment of new radio masts (where necessary to correctly site the additional ground-based equipment).

Q11. Some of the architectures identified have a wired connection to the ATC voice/data communications system. Are there any reasons why, subject to equipment meeting safety and reliability requirements, a wired connection could not be provided?

Strong Consensus

- This type of architecture should be OK as long as transparency can be maintained.

General Consensus

- It was noted that although it might be difficult to achieve connectivity with all ATC units today, it should be much easier in the future infrastructure being considered within the SESAR programme.

Other Responses

- This architecture will be limited to national ATC infrastructure, ATC centres or major airports with the capability for a 'wired' connection. The value of such architectures was questioned if the UAS still has to carry an ATC radio in order to communicate with ATC infrastructure without a wired interface (e.g. small airfields or military sites)

- The availability of Voice over IP (VoIP) technology may be able to more easily facilitate a wired connection
- It is important to take a total system approach and not to decouple ATC and C2 communication requirements
- It will be important to ensure that ATC are aware of any malfunction of the wired system
- It appears to be in the spirit of the SESAR SWIM concept.

Q12. If a wired connection is acceptable, would there be any constraints on the number of connections that could be made?

Strong Consensus

- No, as long as safety, interoperability and performance are not compromised.

General Consensus

(none)

Other Responses

(none)

Q13. Some of the architectures are only likely to be economically viable using a communication service provider. Do you see any issues associated with the use of a service provider to provide UAS voice/data communications?

Strong Consensus

(none)

General Consensus

- No, as long as safety and interoperability are not compromised.

Other Responses

- The use of commercial communications service providers raises some interesting issues for military UAS
- For safety critical applications, the design of equipment and software used must be approved. This might make it difficult to use existing infrastructure (i.e. mobile telecoms networks)
- Equipment maintenance staff will be subject to a personnel licensing regime (to ensure technical competency through training and recency requirements)
- Service Level Agreements must be put in place to ensure that performance requirements are met. Commercial incentives should be used to help guarantee the performance of the service.

Q14. Do you believe that the number of service providers should be limited?

Strong Consensus

- No, as long as safety is not compromised.

General Consensus

(none)

Other Responses

- More service providers encourage competition and could reduce costs.

Q15. Overall, do you believe UAS will represent a significant proportion of traffic in the European ATM system (a) before 2020 and (b) after 2020?

Strong Consensus

(none)

General Consensus

- No, the proportion of UAS traffic in the ATM is expected to remain low both before and increase steadily at some point after 2020.

Other Responses

- Peak Instantaneous Aircraft count (PIAC) estimated to be 4200 in 2020. Based on the assumption that 200 of these are UAS that gives a figure of 5%, which is significant.

Q16. Do you believe that it is acceptable to use innovative/novel communications architectures, potentially involving new service providers to achieve safe and effective communications with UAS?

Strong Consensus

- Yes, as long as safety and interoperability can be maintained.

General Consensus

(none)

Other Responses

(none)

5.2.3 Responses to Spectrum Questions

Q17. A standardised networked C2 data link will provide greatest flexibility for UAS operators that need to operate over a wide area, but this is likely to require significantly more spectrum than would be required for individual operation of proprietary systems over a local area. How important is it to secure sufficient spectrum to establish one or more standardised C2 networks across Europe?

Strong Consensus

(none)

General Consensus

- The amount of spectrum required should be commensurate with the operational requirement
- The ICAO position for UAS spectrum allocations must be supported in preparation for WRC11. This currently includes 49 MHz for the operation of satellite based services for BLOS operation (which is expected to be networked) and 35MHz for terrestrial LOS operation.

Other Responses

- The ability to maintain control of the UA and know where it is will require a high integrity, high availability radio link. Any single radio link is unlikely to achieve the same availability as onboard avionics systems, so back-up communications systems (and associated spectrum) will be required if the continued safe operation of a UA is not to be hindered by the radio link
- To fully achieve the goals of SESAR, aviation will require more spectrum in general and that any additional spectrum needed for UAS technology should be seen as part of a common pool for use by all aviation users including manned aircraft
- Sufficient spectrum for networked operation will be critical for the applications that require satellite operation.

Q18. How important do you believe it is to secure, through ITU World Radio Conferences, a common spectrum allocation for UAS C2 data link? And is it the same for mission/payload data?

Strong Consensus

- A common spectrum allocation is key to global operability.

General Consensus

- Either global allocations or recognised region allocations within common global allocations could be suitable.

Other Responses

- It is not possible to standardise spectrum for the payload as the requirements are so different for the wide range of applications. However, there are benefits in the C2/C3 link operating in nearby band as this could allow reuse of common avionic components
- Solutions operating in different bands using software-defined radios could also be possible
- X band is more secure but not currently recognised as a candidate ICAO AMS(R)S band.

Q19. How important do you believe it is for UAS C2 data link communications to be wholly contained within aeronautical frequency bands AM(R)S or AMS(R)S?

Strong Consensus

- For civil UAS this is essential. However, it is not essential for military aircraft to operate in AM(R)S or AMS(R)S bands (as long as protected spectrum is used)
- Civil users must obtain allocations in civil bands.

General Consensus

(none)

Other Responses

- As it is predicted that most of the initial operations will be military UAV flights in GAT (~85% of UAV flights), the allocation could be from within the existing military allocations. A portion of military bands could be converted to protected spectrum for military UAS operations in GAT.

Q20. How important is it to have a single harmonised global spectrum allocation for UAS C2 data link communications?

Strong Consensus

(none)

General Consensus

- This is both important from a regulatory perspective, and also for manufacturers as it will minimise the number of systems that have to be developed and certified. Unmanned aircraft that need to cross national or operate in different regions should not have to be equipped with entirely separate communications equipment.

Other Responses

- A lack of harmonised bands would make operation and management difficult.

Q21. How important is it to adopt architectures that minimise the amount of spectrum required?

Strong Consensus

- Yes, it is important that the need for spectrum is kept low as ultimately there will be a cost of ownership including the cost of using spectrum.

General Consensus

(none)

Other Responses

- The cost of providing alternative infrastructure (i.e. wired networks) should not be overlooked when trying to reduce the need for spectrum
- This is an important consideration but not the primary driver. Security must be considered which could result in more spectrum utilisation, but this requires further study.

Q22. How important is it to use spectrally efficient techniques?

Strong Consensus

- Spectrally efficient techniques should be used as long as they do not have an adverse impact on performance (integrity, continuity or latency).

General Consensus

(none)

Other Responses

- The aeronautical community needs to show that it is doing everything possible to encourage efficient use of spectrum to Radio Regulators.

5.2.4 Responses to Interoperability Questions

Q23. Which of the 4 bounded architectures are acceptable in terms of the provision of party line voice communications? (i.e. in today's pre-SESAR environment).

Strong Consensus

(none)

General Consensus

- All 4 architectures are considered acceptable as long as quality of 'party line' communications is no worse than today's environment.

Other Responses

- The delay associated with use of geostationary satellites for C2 poses a potential problem.

Q24. How important will it be to continue to provide voice party line to pilots in the SESAR environment, where trajectory management via data link and improved situational awareness in the cockpit may be available?

Strong Consensus

- Wherever it is important to provide party line to manned aviation, the requirement should exist for unmanned aircraft.

General Consensus

- In general, the need for party line communications is expected to be less in future ATM concepts e.g. the SESAR target concept where data link will become more widespread and applications such as TIS-B will provide pilots with greater situational awareness.

Other Responses

- The need for, and benefit of, party-line may be over emphasised. Full party line may not be achieved today in mixed VHF/UHF environment or when pilots speak different languages on the same channel

- The on-going need for voice communication and party line in the SESAR target concept is not clear. This is currently being studied.

Q25. Is it acceptable for a UAS to only have voice/data communications capability with the relevant ATC sectors and units whose area of responsibility the flight is planned to enter/transit?

Strong Consensus

(none)

General Consensus

- Yes, as long as operation (including emergency situations) can be managed safely.

Other Responses

- A system without the ability to communicate with all ATC sectors (either wired or radio-based) could be acceptable if it can be shown to be acceptably safe
- The UAS communications capability must be able to cope with the need for ATC to unexpectedly divert a UAS on an unplanned route. Basically a UAS needs to have the same capability as manned aircraft to cater for all contingencies.

Q26. Latency is potentially an issue both for ATC communications and C2, particularly where geostationary satellites are used. How much latency can be tolerated?

Strong Consensus

- The amount of latency that can be tolerated for ATC communications will depend on the operational environment (i.e. type of airspace and traffic density).

General Consensus

- System latency (introduced by satellite communications or switching networks) is generally not significant given the reaction/thinking time where there is a human-in-the-loop
- The latency of a C2 link may not be an issue if autonomous collision avoidance systems were used to overcome the need for pilot intervention.

Other Responses

- The latency of data over existing airline data link systems can be as much as 30 to 40 seconds, and this amount of latency is considered unacceptable for C2 in any circumstances
- A system approach must be adopted and it is the combination of systems that is important. The communication requirements depend on type of communication system e.g. aircraft spacing and density, operational environment, etc.
- A EUROCONTROL report indicated that up to 2 minutes was acceptable in low density airspace. In high density airspace the technical element of latency was small – typically 3.5 seconds.

Q27. Is it acceptable, in case of 'wired' voice communications exchanges between ATC and the UAS pilot, that such communications be broadcast by the ATC transmitters, so as to provide a party line to other aircraft in the same sector? Do you see technical or operational issues connected to this possibility?

Strong Consensus

- Yes, as this already happens today when ATC voice channels are cross-coupled.

General Consensus

(none)

Other Responses

(none)

Q28. In the case of a communication service provider that provides C2/C3 link to several UAS operators, how might this be acceptable?

Strong Consensus

(none)

General Consensus

- This is entirely acceptable as long as the service provider is under appropriate safety oversight.

Other Responses

- This is entirely acceptable as long as the service provider is under an appropriate service level agreement, the limitations of which are accounted for in the operator's safety case
- A single service provider does not mean a single point of failure.

Q29. Do you recognise the potential for "detect and avoid" technology on UAS for supplementing/replacing current "see and avoid" concept?

Strong Consensus

- Yes, if it can be shown to provide real safety benefits.

General Consensus

(none)

Other Responses

- Yes indeed. The accident rate for aircraft operating in non-controlled airspace is unacceptably high. TCAS has already demonstrated how similar technology can bring safety benefits to larger (commercial) operations in controlled airspace.

Q30. In the short term do you support UAS operating as IFR in controlled airspace with limited "detect and avoid" capability?

Strong Consensus

(none)

General Consensus

- Yes, detect and avoid is not required for IFR GAT operation, and this makes UAS operation potentially feasible
- Yes, this is very much how military UAS are expected to operate in the ATM system initially.

Other Responses

- No, this could set a precedent that could reduce the overall level of aviation safety and place greater responsibility on the controller which would be unacceptable. All aircraft currently have a legal responsibility to maintain separation and collision avoidance. ATC can only provide separation from other known traffic, and aircrew are responsible for separation from other objects. Aircraft operating IFR in CAS still have a 'last-ditch' capability to detect visually and avoid conflicting objects.

5.2.5 Responses to Regulation Questions

Q31. Overall, how essential is it for UAS to be fully compliant with SES regulations?

Strong Consensus

- UAS must be fully compliant with SES regulations applicable to their area of operation
- Every effort must be made to treat UAS, from the legal and regulatory point of view, in exactly the same way as other aircraft.

General Consensus

(none)

Other Responses

- In the medium term, ICAO plans to modify Appendixes to make them applicable for UAS operation
- Regulations must be put in context. For example, there is no sense in a UA being compliant with the 8.33kHz Implementing Rule if it does not operate with ATC radios i.e. it uses a wired ATC service.

Q32. If necessary, do you support the drafting of new SES regulations specifically for UAS to ensure that they can be accommodated in future ATM environment?

Strong Consensus

- Yes, where aspects of UAS operation that are not covered by existing SES regulations (e.g. detect and avoid or C2 data link performance requirements)
- As well as implementing rules governing the operation of UAS, it is likely that a new airworthiness standard (CS-UAS) will be developed. There will also be rules for UAS operators and competency requirements for UAS, flight crews and strict operating procedures to ensure that UAS are not vulnerable to hijack or misuse.

General Consensus

(none)

Other Responses

- Such regulations should not be reserved exclusively for UAS. Instead, they should be equally applicable to manned aircraft (i.e. to allow carriage of detect and avoid technology, or to use data link for reduced crew operation etc)
- Additional SES regulations should permit military UAS operation in non-segregated airspace.

5.3 Conclusions

The following table summarises the observations and conclusions that can be derived from the above analysis.

No.	Title	Observations	source
1	Applications	There is a large market for state sponsored applications such as border patrol, search and rescue etc. There is also a strong military requirement to traverse non segregated airspace for operational requirements and where this provides cost benefits. Commercial operations will be more cost benefit driven.	Q1
2	R&D cooperation	A number of organisations are providing R&D into aspects of UAS in GAT. It is important that regulators provide guidance on the performance standards that UAS must adhere to, to ensure consensus and integration focus for the	Q2, Q4

No.	Title	Observations	source
		research.	
3	Link to SESAR	R&D for UAS and subsequent exploitation, must be compatible with SESAR concepts	Q2
4	Development of infrastructure	There is little or no visible activity to provide infrastructure and services to support UAS communications. Two reasons stand out. Firstly, it is difficult to provide a meaningful business plan when the traffic forecasts are uncertain and secondly there are neither safety rules nor guidelines or performance requirements that can be used to develop the infrastructure. Requirements and performance standards need to be developed and a reliable forecast of realistic usage will be a pre-requisite to develop a business case. This is seen as particularly important for BLOS applications where the infrastructure is likely to be cost prohibitive for a single UAS manufacturer to provide alone.	Q3, Q4, Q5, Q7, Q9
5	Data link reliability	Standards need to be developed for data link reliability that take account of UAS autonomy	Q8
6	Voice communication with ATC	New architectures to support ground based ATC communication equipment might require new standards to be set (e.g. radios sited close to existing ATC transmitters).	Q10
7	Voice communication with ATC	Step-on was identified as a particular issue that might cause ATC issues due to excessive latency or through the use of Ground based radio	Q10
8	Wired ATC comms	Need to set safety and reliability standards and potential radio backup systems	Q11
9	Wired ATC comms	Wired infrastructures appear to be compatible with SESAR concepts.	Q11
10	Coupled C2 and ATC	Concern was expressed that standards need to be set to cover the system as well as individual constituents	Q11
11	communications service providers	Need to set rules and standards for safety and reliability etc. including maintenance and SLAs. Security issues were raised in the context of the standards that are needed for a military UAS to operate through civil C2 bands: i.e. can a civil C2 link provide the necessary security for military aircraft.	Q13, Q29
12	Traffic forecasts	On going requirement to refine traffic forecasts - including civil/ military split	Q15, Q19
13	Spectrum requirements	Need to take into account security and reliability including back-up systems that are considered necessary	Q17,Q21,Q22
14	Spectrum requirements	A common spectrum allocation should be sought at WRC-11	Q18,Q20
15	Spectrum requirements	Can the Military bands be used for civil UAS?	Q19

No.	Title	Observations	source
16	Satellite Latency	Need to set standards for latency etc on all communications links, for all conditions	Q23,Q26
17	Voice party line	Need to determine what requirement exists now and in SESAR environment and set standards, also for relay to manned aircraft when wired interface is used	Q24,Q 27
18	Voice data comms	Need to set safety standards for planned limited ATC communications capability	Q25
19	UAS using IFR	Need to establish rules and minimum Sense and Avoid functionality	Q30
20	SES regulations	Need to review all extant regulations with regard to applicability to UAS and amend if necessary	Q31,Q32

6 Group 2 Stakeholder Results

This section provides analysis of the Group 2 Stakeholder results obtained through the on-line survey. Details of the survey and the questions that were asked can be found at Appendix D.

6.1 Multi-Criteria Analysis

The Multi-Criteria Analysis (MCA) technique used in this study allows data to be analysed in various ways to ascertain user needs with respect to communications infrastructure and architectures.

Firstly, a numerical analysis was performed on the data to determine the importance of each impact category. This analysis identified user needs based on the range of applications to which the UAS community have indicated are of most importance both now and in the future.

The user needs were compared to the four bounded architectures to determine an overall value to show how each of the architectures met those needs. The architecture-based assessment of the results can be found in 6.2.

Secondly, a qualitative analysis was performed that summarises the results on a question-by-question basis. This is used to identify common themes and highlights consensus or disagreement amongst the user community. This general assessment of results can be found in section 6.3.

6.2 Quantitative Analysis

The quantitative analysis provides an importance score for the questions that are relevant to the impact topics against each of the bounded architectures.

6.2.1 Method

The first step is to determine which Group 2 questions are relevant to each impact category.

The answers to each question need to be averaged, and the result normalised to provide a value between 0 and 1.

The relevant questions and their associated normalised importance scores can be found in sections 6.2.3.1, 6.2.4.1, 6.2.5.1, 6.2.6.1 and 6.2.7.1.

It can be seen that questions often have several parts, each of which produces a separate importance score. This enhances the assessment process, as the more importance scores there are for each impact category, the more accurate the averaged final result is likely to be in terms of reflecting perceived user importance.

In the second step, the importance scores are combined with the coarse indicator values (as can be found in 6.2.3.2, 6.2.4.2, 6.2.5.2, 6.2.6.2 and 6.2.7.2). The coarse indicators represent how useful each of the architectures is judged to be. For example, in economic terms, the bounded architecture(s) that can be safely implemented for the lowest cost should have a coarse indicator of 1.0, which is the highest possible value. The more costly the architecture is judged to be, the closer to zero the coarse indicator would be. (The coarse indicators used for each impact category are listed in the following sections).

The aggregate answer to each of the associated ‘importance’ questions asked in the on-line survey is then multiplied by the appropriate coarse indicator values to produce a set of relative scores for the architectures. Finally, to allow sensitivity testing when these results are combined with Group 1 results, each score is multiplied by 3.

Answers are grouped according to the impact categories they are relevant to, and the mean scores for each set of answers are then calculated. For example, we might find that having asked all of the economic questions, we end up with the following mean scores:

AR2	NR1	NR3	NR12
1.8	2.7	0.9	2.1

This example would suggest that from an economic perspective (i.e. importance x cost), NR1 is the most beneficial architecture for Group 2, and NR3 is the least.

6.2.2 Applicability

Those completing the survey were asked to identify their stakeholder category from the following list:

- UA/S Manufacturers (M)
- UA/S Operators (O)
- Systems/Avionics Manufacturers/Suppliers (E)
- Communications Service Provider (C)
- Air Navigation Service Provider (A)
- Regulator (R)
- Support Services (S)
- Other

Although all stakeholders were free to answer all of the questions in the on-line survey, it is recognised that the views of some stakeholder answers will be more relevant than others for particular answers. For example, questions about equipment size and weight limitations for a UA should only be answered by UA/S Manufacturers and Operators. On the other hand, answers from all categories of stakeholder should be taken account of for a more general question about interoperability.

Consequently, an applicability matrix is applied to each question in the survey, and only answers from applicable stakeholders are taken into consideration.

It should also be noted that stakeholders that used the ‘Other’ category were manually re-assigned the most relevant category, based on their job title and parent organisation.

6.2.3 Economic

6.2.3.1 Importance

	Survey Question	Mean Importance Score
Q1	Which UAS applications commencing outside segregated airspace do you foresee before 2020?	
	Border Patrol	0.567
	Atmospheric Research	0.600
	Search & Rescue	0.800
	Maritime Surveillance	0.733
	Law Enforcement	0.700
	Humanitarian Aid	0.733
	Aerial Imaging & Mapping	0.767
	Drug Surveillance & Interdiction	0.633
	Utility Inspections	0.633
	Natural Hazard Monitoring	0.867
	Airborne Pollution Observation Tracking	0.500

	Chemical & Petroleum Spill Monitoring	0.567
	Communications Relay	0.400
	Traffic Monitoring	0.500
	Port Security	0.500
	Cargo	0.200
	Agricultural Applications	0.667
Q2	Which UAS applications commencing outside segregated airspace do you foresee after 2020?	
	Border Patrol	0.400
	Atmospheric Research	0.367
	Search & Rescue	0.200
	Maritime Surveillance	0.233
	Law Enforcement	0.267
	Humanitarian Aid	0.233
	Aerial Imaging & Mapping	0.233
	Drug Surveillance & Interdiction	0.333
	Utility Inspections	0.300
	Natural Hazard Monitoring	0.133
	Airborne Pollution Observation Tracking	0.400
	Chemical & Petroleum Spill Monitoring	0.333
	Communications Relay	0.533
	Traffic Monitoring	0.533
	Port Security	0.467
	Cargo	0.767
	Agricultural Applications	0.300
Q9	How would you see the [communications infrastructure] being provided?	
	Not important	0.310
	Desirable	0.483
	Essential	0.655
Q14	What are your expected data throughput requirements?	
	C2 and Sense & Avoid	0.600
	Total data throughput	1.000
Q15	Operating costs for C2/C3 datalink?	
	C2 and Sense & Avoid	0.600
	Total data throughput	1.000

Mean Importance Score (Economic): 0.526

6.2.3.2 Coarse Indicators

The following questions were deemed to be relevant to the choice of architecture, from an economic perspective. Alongside each question, the applicability and coarse indicator values are listed, and the rationale for these values is given in the final column.

Q1 – Which UAS applications commencing outside segregated airspace do you foresee before 2020?

Applicability: M, O, E, C & S

Application	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
Border Patrol	0.5	-	0.25	0.75	NR12 least costly, then AR2. NR3 is most costly. NR1 not suitable for application.
Atmospheric Research	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Search & Rescue	0.5	-	0.25	0.75	NR12 least costly, then AR2. NR3 is most costly. NR1 not suitable for application.
Maritime Surveillance	0.5	-	0.25	0.75	NR12 least costly, then AR2. NR3 is most costly. NR1 not suitable for application.
Law Enforcement	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Humanitarian Aid		-	0.25		NR3 is only suitable architecture, but costly.
Aerial Imaging & Mapping	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Drug Surveillance & Interdiction	0.5	-	0.25	0.75	NR12 least costly, then AR2. NR3 is most costly. NR1 not suitable for application.
Utility Inspections	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Natural Hazard Monitoring	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Airborne Pollution Observation Tracking	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Chemical & Petroleum Spill Monitoring		-	0.25		NR3 is only suitable architecture, but costly.
Communications Relay	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Traffic Monitoring	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Port Security	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Cargo	0.5	-	0.25	0.75	NR12 least costly, then AR2. NR3 is most costly. NR1 not suitable for application.

Agricultural Applications	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.

Q2 – Which UAS applications commencing outside segregated airspace do you foresee after 2020?

Applicability: M, O, E, C & S

Application	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
Border Patrol	0.5	-	0.25	0.75	NR12 least costly, then AR2. NR3 is most costly. NR1 not suitable for application.
Atmospheric Research	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Search & Rescue	0.5	-	0.25	0.75	NR12 least costly, then AR2. NR3 is most costly. NR1 not suitable for application.
Maritime Surveillance	0.5	-	0.25	0.75	NR12 least costly, then AR2. NR3 is most costly. NR1 not suitable for application.
Law Enforcement	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Humanitarian Aid		-	0.25		NR3 is only suitable architecture, but costly.
Aerial Imaging & Mapping	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Drug Surveillance & Interdiction	0.5	-	0.25	0.75	NR12 least costly, then AR2. NR3 is most costly. NR1 not suitable for application.
Utility Inspections	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Natural Hazard Monitoring	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Airborne Pollution Observation Tracking	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Chemical & Petroleum Spill Monitoring	-	-	0.25	-	NR3 is only suitable architecture, but costly.
Communications Relay	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Traffic Monitoring	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Port Security	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.
Cargo	0.5	-	0.25	0.75	NR12 least costly, then AR2. NR3 is most costly. NR1 not suitable for application.

Agricultural Applications	0.5	1	0.25	0.75	NR1 is least costly, followed by NR12 then AR2. NR3 is most costly.

Q9 – How would you see the [communications infrastructure] being provided?

Applicability: All stakeholder categories

Answer/Option	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
In house development of proprietary networks	1	-	1	1	Substantial costs associated with AR2, NR3 and NR12. NR1 is not applicable.
Privately funded development of standardised networks	1	-	1	1	Substantial costs associated with AR2, NR3 and NR12. NR1 is not applicable.
Publicly funded development of standardised networks	0	-	0	0	No investment costs for users. NR1 not applicable.

Q14 – What are your expected data throughput requirements?

Applicability: M, O & E

	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
Average expected requirement for C2 + downlink S&A	0.5	1	0	0.5	NR1 will be least costly, NR3 will be most costly for C2 and S&A data.
Average total expected requirement	0.5	1	0.25	0.5	NR1 will be least costly. NR3 and NR12 will be less costly solution for C3 data.

Q15 – Operating costs for C2/C3 datalink?

Applicability: M, O & E

	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
Average expected requirement for C2 + downlink S&A	0.5	1	0.25	0.5	NR1 expected to have lowest operating costs, followed by NR12, AR2 then NR3.
Average total expected requirement	0.5	1	0.25	0.5	NR1 expected to have lowest operating costs, followed by NR12, AR2 then NR3.

By multiplying the coarse indicator by the mean importance score, the following economic compound scores can be obtained for Group 2.

Average (normal weighting) scores for economic questions:

AR2	NR1	NR3	NR12
0.878834	1.113821	0.517858	1.229647

This result shows that NR12 is the most beneficial architecture, closely followed by NR1. This result reflects the fact that NR12 is the most cost effective solution for beyond line of sight operation. However, for short range line of sight operations, NR1 scores highly due to its simplicity and lack of infrastructure. NR3 is expected to be the most expensive, and least favourable from an economic perspective.

6.2.4 Social

6.2.4.1 Importance

Questions with Social Relevance:

	Survey Question	Mean Importance Score
Q1	Which UAS applications commencing outside segregated airspace do you foresee before 2020?	
	Border Patrol	0.567
	Atmospheric Research	0.600
	Search & Rescue	0.800
	Maritime Surveillance	0.733
	Law Enforcement	0.700
	Humanitarian Aid	0.733
	Aerial Imaging & Mapping	0.767
	Drug Surveillance & Interdiction	0.633
	Utility Inspections	0.633
	Natural Hazard Monitoring	0.867
	Airborne Pollution Observation Tracking	0.500
	Chemical & Petroleum Spill Monitoring	0.567
	Communications Relay	0.400
	Traffic Monitoring	0.500
	Port Security	0.500
	Cargo	0.200
	Agricultural Applications	0.667
Q2	Which UAS applications commencing outside segregated airspace do you foresee after 2020?	
	Border Patrol	0.400
	Atmospheric Research	0.367
	Search & Rescue	0.200
	Maritime Surveillance	0.233

	Law Enforcement	0.267
	Humanitarian Aid	0.233
	Aerial Imaging & Mapping	0.233
	Drug Surveillance & Interdiction	0.333
	Utility Inspections	0.300
	Natural Hazard Monitoring	0.133
	Airborne Pollution Observation Tracking	0.400
	Chemical & Petroleum Spill Monitoring	0.333
	Communications Relay	0.533
	Traffic Monitoring	0.533
	Port Security	0.467
	Cargo	0.767
	Agricultural Applications	0.300
Q9	How would you see the [communications infrastructure] being provided?	
	Not important	0.310
	Desirable	0.483
	Essential	0.655

Mean Importance Score (Social): 0.482

6.2.4.2 Coarse Indicators

The following questions were deemed to be relevant to the choice of architecture, from a social perspective. Alongside each question, the applicability and coarse indicator values are listed, and the rationale for these values is given in the final column.

Q1 – Which UAS applications commencing outside segregated airspace do you foresee before 2020?

Applicability: M, O, E, C & S

Application	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
Border Patrol	1	0	0.75	1	Networked architectures will allow market to expand rapidly. Maintaining AR2 and NR12 infrastructure is likely to provide the greatest number of jobs.
Atmospheric Research	1	0	0.75	1	(ditto)
Search & Rescue	1	0	0.75	1	(ditto)
Maritime Surveillance	1	0	0.75	1	(ditto)
Law Enforcement	1	0	0.75	1	(ditto)
Humanitarian Aid	1	0	0.75	1	(ditto)

Aerial Imaging & Mapping	1	0	0.75	1	(ditto)
Drug Surveillance & Interdiction	1	0	0.75	1	(ditto)
Utility Inspections	1	0	0.75	1	(ditto)
Natural Hazard Monitoring	1	0	0.75	1	(ditto)
Airborne Pollution Observation Tracking	1	0	0.75	1	(ditto)
Chemical & Petroleum Spill Monitoring	1	0	0.75	1	(ditto)
Communications Relay	1	0	0.75	1	(ditto)
Traffic Monitoring	1	0	0.75	1	(ditto)
Port Security	1	0	0.75	1	(ditto)
Cargo	1	0	0.75	1	(ditto)
Agricultural Applications	1	0	0.75	1	(ditto)

Q2 – Which UAS applications commencing outside segregated airspace do you foresee before 2020?

Applicability: M, O, E, C & S

Application	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
Border Patrol	1	0	0.75	1	Networked architectures will allow market to expand rapidly. Maintaining AR2 and NR12 infrastructure is likely to provide the greatest number of jobs.
Atmospheric Research	1	0	0.75	1	(ditto)
Search & Rescue	1	0	0.75	1	(ditto)
Maritime Surveillance	1	0	0.75	1	(ditto)
Law Enforcement	1	0	0.75	1	(ditto)
Humanitarian Aid	1	0	0.75	1	(ditto)
Aerial Imaging & Mapping	1	0	0.75	1	(ditto)
Drug Surveillance & Interdiction	1	0	0.75	1	(ditto)
Utility Inspections	1	0	0.75	1	(ditto)
Natural Hazard Monitoring	1	0	0.75	1	(ditto)
Airborne Pollution Observation Tracking	1	0	0.75	1	(ditto)

Chemical & Petroleum Spill Monitoring	1	0	0.75	1	(ditto)
Communications Relay	1	0	0.75	1	(ditto)
Traffic Monitoring	1	0	0.75	1	(ditto)
Port Security	1	0	0.75	1	(ditto)
Cargo	1	0	0.75	1	(ditto)
Agricultural Applications	1	0	0.75	1	(ditto)

Q9 – How would you see the [communications infrastructure] being provided?

Applicability: All stakeholder categories

Answer/Option	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
In house development of proprietary networks	0.25	0	0.25	0.25	Social impact of proprietary networks will be limited.
Privately funded development of standardised networks	1	0	0.75	1	Networked architectures will allow market to expand rapidly. Maintaining AR2 and NR12 infrastructure is likely to provide the greatest number of jobs.
Publicly funded development of standardised networks	1	0	0.75	1	(ditto)

By multiplying the coarse indicator by the mean importance score, the following social compound scores can be obtained for Group 2.

Average (normal weighting) scores for social questions:

AR2	NR1	NR3	NR12
1.7544	0	1.3174	1.7544

This result shows that AR2 and NR12 will have the greatest impact on social aspects, closely followed by NR3.

6.2.5 Spectrum

6.2.5.1 Importance

	Survey Question	Mean Importance Score
Q14	What are your expected data throughput requirements?	

	C2 and Sense & Avoid	0.600
	Total data throughput	1.000

Mean Importance Score (Spectrum): 0.800

6.2.5.2 Coarse Indicators

The following questions were deemed to be relevant to the choice of architecture, from a spectrum perspective. Alongside each question, the applicability and coarse indicator values are listed, and the rationale for these values is given in the final column.

Q14 - What are your expected data throughput requirements?

Applicability: M, O & E

	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
Average expected requirement for C2 + downlink S&A	0.5	1	0.75	0.5	NR1 expected to have minimum requirement for spectrum. NR3 will have greatest demand for spectrum, due to feeder links and less frequency re-use.
Average total expected requirement	0.5	1	0.75	0.5	As above but greater spectrum needed for AR2 due to ATC relay.

By multiplying the coarse indicator by the mean importance score, the following spectrum compound scores can be obtained for Group 2.

Average (normal weighting) scores for spectrum questions:

AR2	NR1	NR3	NR12
1.3750	4.0000	3.0000	2.0000

This result confirms the view that NR1 is likely to have the least requirement for spectrum. AR2 is expected to have the greatest requirement for spectrum.

6.2.6 Interoperability

6.2.6.1 Importance

	Survey Question	Mean Importance Score
Q5	How important is it to have the capability to operate UAS in different countries, and to cross international boundaries?	
	Not important	0.053
	Desirable	0.553

	Essential	0.395
Q11	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 and VHF (voice) transceiver carriage?	
	0-20%	0.292
	21-40%	0.167
	41-60%	0.042
	61-80%	0.292
	81-100%	0.208
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 and VHF (voice and data) transceiver carriage?	
	0-20%	0.478
	21-40%	0.087
	41-60%	0.130
	61-80%	0.087
	81-100%	0.217
Q23	How important is it for the UAS industry to have a standardised and interoperable set of standards for networked C2 datalink communications?	
	Not important	0.000
	Desirable	0.500
	Essential	0.500

Mean Importance Score (Interoperability): 0.250

6.2.6.2 Coarse Indicators

The following questions were deemed to be relevant to the choice of architecture, from an interoperability perspective. Alongside each question, the applicability and coarse indicator values are listed, and the rationale for these values is given in the final column.

Q5 – How important is it to have the capability to operate UAS in different countries, and to cross international boundaries?

Applicability: All stakeholder categories

Answer/Option	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
Not important	0	1	0	0	No importance given to satellite and networked architectures

Desirable	0.5	0.5	0.5	0.5	Equal importance given to all architectures
Essential	1	0	1	1	Importance given to satellite and networked architectures

Q11 – 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 and VHF (voice) transceiver carriage?

Applicability: M & O

Answer/Option	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
0-20%	0.2	1.0	1.0	1.0	Low equipage signifies importance of non-relayed architectures
21-40%	0.4	1.0	1.0	1.0	As above, but AR2 of some importance
41-60%	0.6	1.0	1.0	1.0	As above, but AR2 of increased importance
61-80%	0.8	1.0	1.0	1.0	As above, but AR2 of increased importance
81-100%	1.0	1.0	1.0	1.0	High equipage signifies equal importance of architectures

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 and VHF (voice and data) transceiver carriage?

Applicability: M & O

Answer/Option	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
0-20%	0.2	1.0	1.0	1.0	Low equipage signifies importance of non-relayed architectures
21-40%	0.4	1.0	1.0	1.0	As above, but AR2 of some importance
41-60%	0.6	1.0	1.0	1.0	As above, but AR2 of increased importance
61-80%	0.8	1.0	1.0	1.0	As above, but AR2 of increased importance
81-100%	1.0	1.0	1.0	1.0	High equipage signifies equal importance of architectures

Q23 - How important is it for the UAS industry to have a standardised and interoperable set of standards for networked C2 datalink communications?

Applicability: M, O, E, C, A and S

Answer/Option	Coarse Indicator	Rationale

	AR2	NR1	NR3	NR12	
Not important	0	1	0	0	If not important, NR1 is only architecture that scores.
Desirable	0.5	0.5	0.5	0.5	If desirable, all architectures score equally
Essential	1	0	1	1	If not essential, all architectures except NR1 score equally.

By multiplying the coarse indicator by the mean importance score, the following interoperability compound scores can be obtained for Group 2.

Average (normal weighting) scores for interoperability questions:

AR2	NR1	NR3	NR12
0.64795	0.55592	0.81908	0.81908

This result shows that NR3 and NR12 are seen as being the most important architectures from an interoperability perspective. As might be expected, NR1 is the least interoperable architecture.

6.2.7 Regulation

6.2.7.1 Importance

	Survey Question	Mean Importance Score
Q5	How important is it to have the capability to operate UAS in different countries, and to cross international boundaries?	
	Not important	0.053
	Desirable	0.553
	Essential	0.395
Q23	How important is it for the UAS industry to have a standardised and interoperable set of standards for networked C2 datalink communications?	
	Not important	0.000
	Desirable	0.500
	Essential	0.500

Mean Importance Score (Regulation): 0.333

6.2.7.2 Coarse Indicators

The following questions were deemed to be relevant to the choice of architecture, from a regulation perspective. Alongside each question, the applicability and coarse indicator values are listed, and the rationale for these values is given in the final column.

Q5 – How important is it to have the capability to operate UAS in different countries, and to cross international boundaries?

Applicability: All stakeholder categories

Answer/Option	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
Not important	0	1.0	0	0	No importance given to satellite and networked architectures
Desirable	0.5	0.5	0.5	0.5	Equal importance given to all architectures
Essential	1.0	0	1.0	1.0	Importance given to satellite and networked architectures

Q23 - How important is it for the UAS industry to have a standardised and interoperable set of standards for networked C2 datalink communications?

Applicability: M, O, E, C, A and S

Answer/Option	Coarse Indicator				Rationale
	AR2	NR1	NR3	NR12	
Not important	0	1.0	0	0	If not important, NR1 is only architecture that scores.
Desirable	0.5	0.5	0.5	0.5	If desirable, all architectures score equally
Essential	1.0	0	1.0	1.0	If not essential, all architectures except NR1 score equally.

By multiplying the coarse indicator by the mean importance score, the following regulation compound scores can be obtained for Group 2.

Average (normal weighting) scores for regulation questions:

AR2	NR1	NR3	NR12
0.9605	0.372807	0.960526	0.960526

This result indicates that AR2, NR3 and NR12 are likely to be most important in terms of standards and regulation. NR1 is expected to be of least importance with regard to standards and regulation.

6.2.8 Summary

It is clear from this analysis of the Group 2 results that different architectures have different appeal according to impact category. There is no single architecture that consistently produces a high score regardless of impact category.

Whilst there are economic incentives to opt for single ground station architectures such as NR1, such architectures provide little or no scope for interoperability. Similarly, architectures that provide good interoperability and high social impact will invariably require more spectrum and more economic investment.

In order to make meaningful sense of these conflicting results, a means of associating value to the various impact categories is needed. Section 7 of this report does this by combining Group 1 and Group 2 results.

6.3 Qualitative Analysis

The data from the survey is analysed qualitatively to determine key observations and conclusions.

6.3.1 UAS Applications

Group 2 stakeholders representing UAS manufacturers, avionics and payload system manufacturers, UAS operators and UAS support services indicated the UAS applications which are expected to commence outside segregated airspace.

Results from this question indicate that prior to 2020 (Figure 6-1) Maritime Surveillance, Search and Rescue and Natural Hazard Monitoring are expected to be the most likely 'early' UAS applications to take place outside segregated airspace. The majority of these early applications are in support of State activities, with utility inspections and agriculture being notable exceptions.

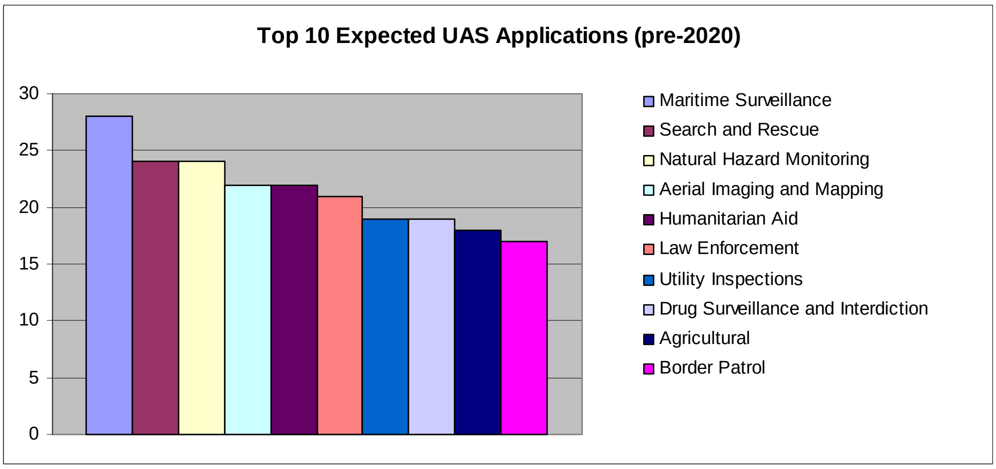

Figure 6-1: Early UAS applications (before 2020)

Cargo operations are predicted to lead the top 10 table post 2020 as shown in Figure 6-2 below. Other applications gaining ground post 2020 include traffic monitoring and communications relay. These represent a mix of State and private sector applications. It is notable that many of the initial (pre-2020) UAS applications gain less votes. For example, Maritime Surveillance drops to 12th place, and Search and Rescue drops to 15th place. This supports the view that initial UAS applications will be low volume State funded activities, and after 2020, the market is expected to open up to a greater volume of applications, the majority of which will be commercial.

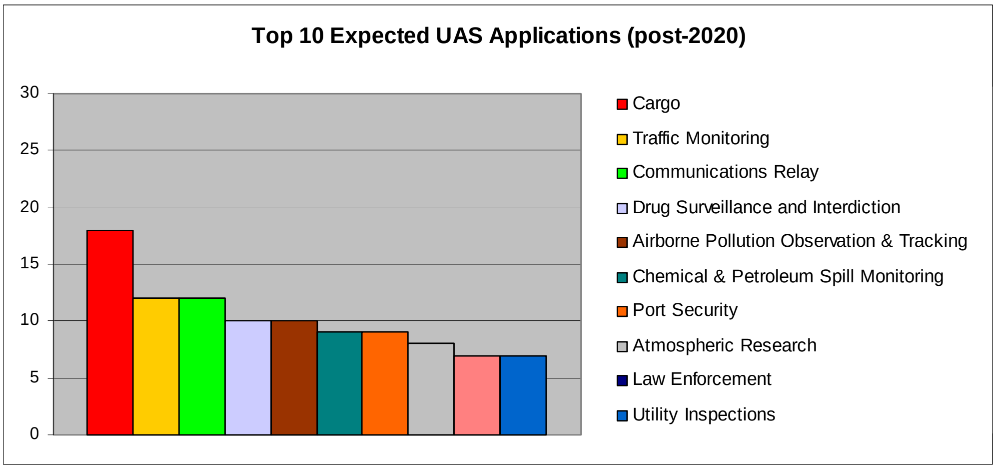

Figure 6-2: Late UAS applications (after 2020)

Other UAS applications identified by stakeholders before 2020 include:

- Fire monitoring and control (1)
- Oil, gas and mineral exploration – geophysical surveys (1)
- Medivac (1)
- Passenger transport (1)
- Freight transport (1)

Other applications identified by stakeholders after 2020 include:

- Commercial (1)

6.3.2 Range and Height Requirements

Group 2 stakeholders were asked to indicate the maximum operating range and height for one or more of the early UAS applications that they foresee. Stakeholders provided maximum operating range and height information for the following UAS applications:

- Aerial survey
- ATC Communications
- Border Patrol (Immigration)
- Cargo
- Civil Defence
- Commercial
- Environment Monitoring
- Event Monitoring
- Fire Management and Control
- Geophysical Surveys
- Homeland Security
- Law Enforcement
- MALE applications
- Maritime Surveillance

- Search and Rescue
- Surveillance
- Traffic Monitoring
- Utility (power line/pipeline) monitoring

Figure 6-3 shows the maximum operating range requirements of the UAS applications supplied. From this cumulative frequency graph, we can see that:

- 13% of applications operate to a maximum range of 24 NM
- 59% of applications operate to a maximum range of 200 NM
- 20% of applications operate beyond 500 NM

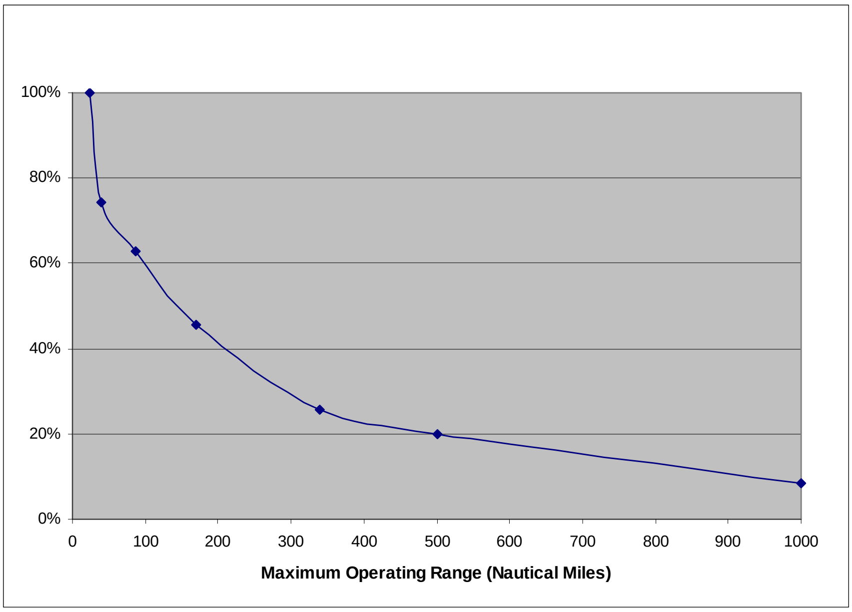

Figure 6-3: Percentage UAS Applications vs Maximum Operating Range

Figure 6-4 shows the maximum operating height (or approximate altitude) for the UAS applications supplied. From this cumulative frequency graph we can see that:

- 24% of UAS applications operate at heights of up to 5,000 ft
- 59% of UAS applications operate at heights of up to 10,000 ft
- 40% of UAS applications need to operate above 20,000 ft
- 18% of UAS applications need to operate above 40,000 ft

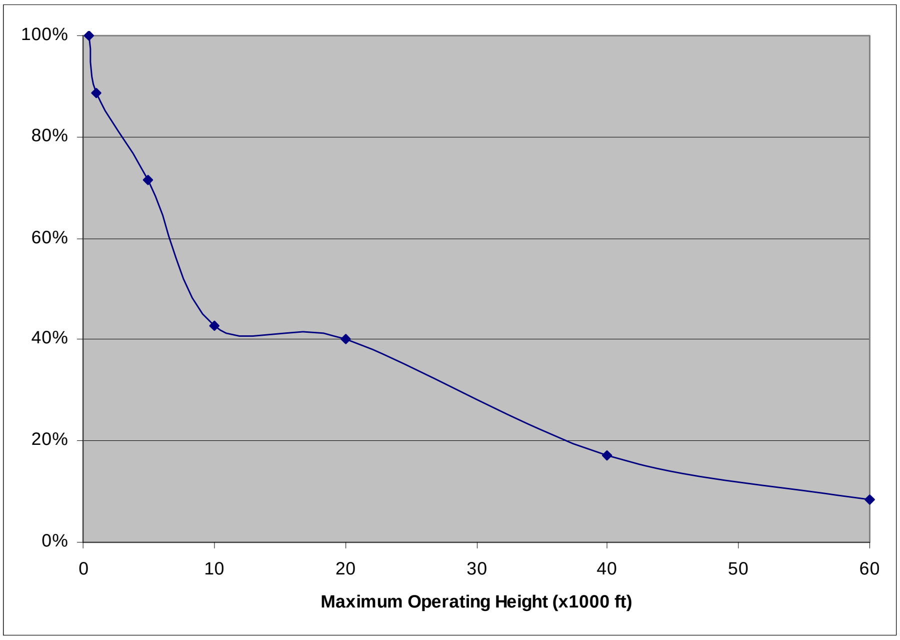

Figure 6-4: Percentage UAS Applications vs Maximum Operating Height

6.3.3 Preferred Methods for C2/C3 Communications

Collectively, the information provided in response to the types of UAS applications envisaged can be used to provide a broad indication of the infrastructure requirements for the C2/C3 datalink communications. For example, the data indicates that a significant percentage of UAS applications will operate beyond the range and coverage achievable from a single ground station, suggesting the need for networked ground stations or satellite architectures. Furthermore, for some of the long range low altitude applications such as maritime surveillance and utility (power line/pipeline) monitoring, satellite communications is likely to be the only practical solution.

When asked what their preferred method for C2/C3 communications was, Group 2 stakeholders indicated a more or less equal demand for single ground stations, networked ground stations and satellite communications, as can be seen in Figure 6-5.

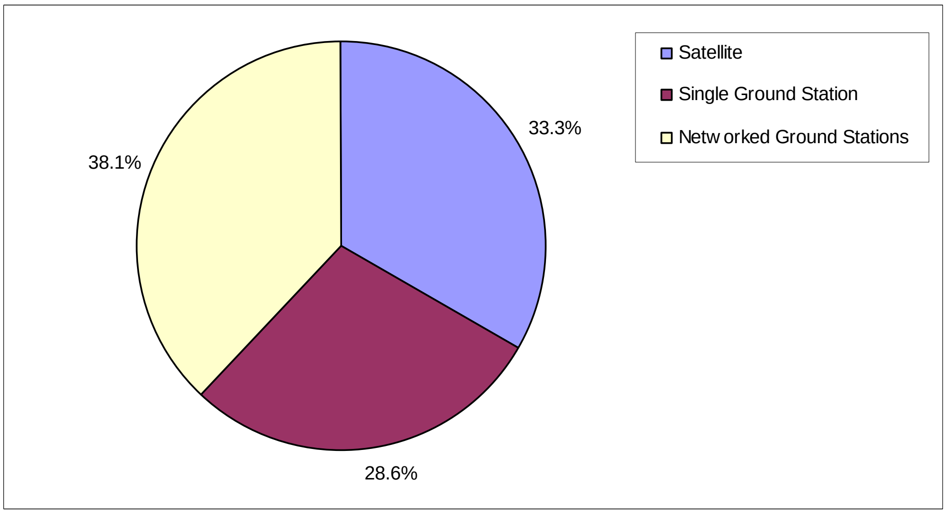

Figure 6-5: Communications Methods Preferred for C2/C3 Datalink

However, in many cases, stakeholders indicated the use of more than one method of communications, as can be seen in Figure 6-6. This demonstrates the importance of being able to choose from a variety of methods, as each will have attributes (whether technical, social, or economic etc) that suit the UAS application in question. This result further supports the view that networked ground stations and/or satellite infrastructure will be required to support the UAS industry.

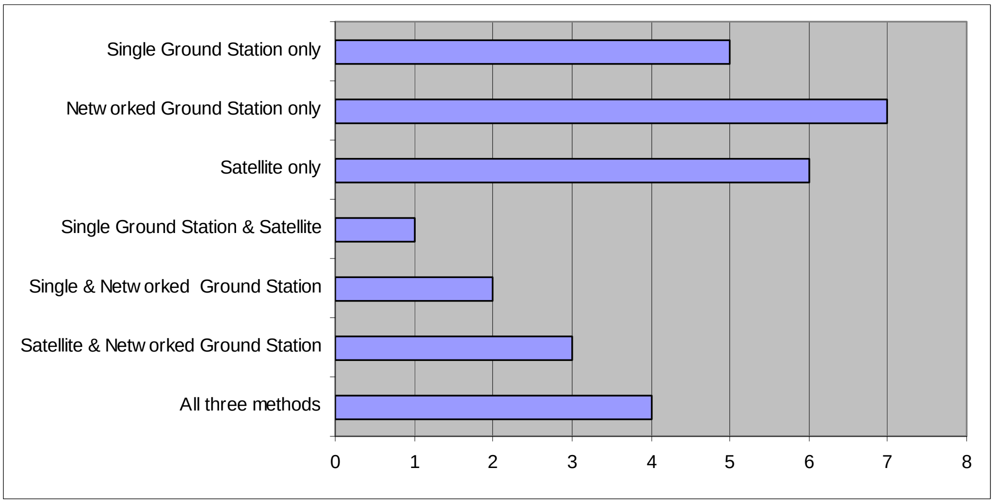

Figure 6-6: Application of Communication Methods

Stakeholders were asked to indicate the approximate percentage of UAS that are expected to use each of the communication methods. This aspect of the survey revealed the two fundamental types of UAS operation catered for by the UAS industry namely (i) short range visual line-of-sight operation generally using small/lightweight UA and (ii) longer range operations beyond visual line-of-sight.

With regard to single ground station communications, one group of stakeholders indicated a high expected level of use (61-80%), and the other group indicated a lower level of use (21-40%). This is not surprising given that many of the smaller, lighter UA used for short range line-of-sight operation are unlikely to support the size, weight and power requirements for satellite communications equipment, and moreover, such UA will be able to perform adequately and more cost efficiently using a single ground station.

A similar result occurred for the combined ground station and satellite, with high numbers of stakeholders expecting high equipage (81-100%), and an equal number expecting low equipage (0-20%). Again, it can be seen that manufacturers and operators of larger, longer range aircraft recognise the importance of satellite communications in order to provide minimal constraints on coverage, and hence operating areas. However, when asked about the expected level of use of networked ground stations, the result was more focussed; recognising that such infrastructure (where available) is likely to benefit both types of UAS operation.

Percentage of use:	0-20%	21-40%	41-60%	61-80%	81-100%	N/A
Responses:	8.7%	30.4%	8.7%	39.1%	13.1%	0%

Table 6-1: Expected level of use of single ground station communications

Percentage of use:	0-20%	21-40%	41-60%	61-80%	81-100%	N/A
Number of Responses:	21.7%	21.7%	26.1%	17.4%	4.3%	8.8%

Table 6-2: Expected level of use of networked ground station communications

Percentage of use:	0-20%	21-40%	41-60%	61-80%	81-100%	N/A
Number of Responses:	30.4%	17.4%	8.7%	17.4%	8.7%	17.4%

Table 6-3: Expected level of use of satellite communications

Percentage of use:	0-20%	21-40%	41-60%	61-80%	81-100%	N/A
Number of Responses:	26.1%	13.0%	17.4%	13.0%	26.1%	4.4%

Table 6-4: Expected level of use of combined ground station and satellite communications

When asked the question, "*Do you foresee any requirement to operate UAS over remote, maritime or polar regions devoid of infrastructure required for terrestrial based datalink ground stations?*", 54% of UAS industry stakeholders said "Yes". This result further emphasises the need for satellite communications, accepting that it may be technically challenging or even impossible to provide terrestrial ground stations in remote, maritime or polar regions.

Finally, when asked about the European Space Agency Iris programme, 95% of respondents indicated that they would support the expansion of the project to include UAS applications.

6.3.4 Interoperability

Several of the questions in the survey focussed on ascertaining the importance of interoperability to the UAS industry.

In response to the question *"How important is it to have the capability to operate UAS in different countries, and to cross international boundaries?"* the majority (95%) stated that interoperability was either desirable or essential, and only 5% said that it was not important.

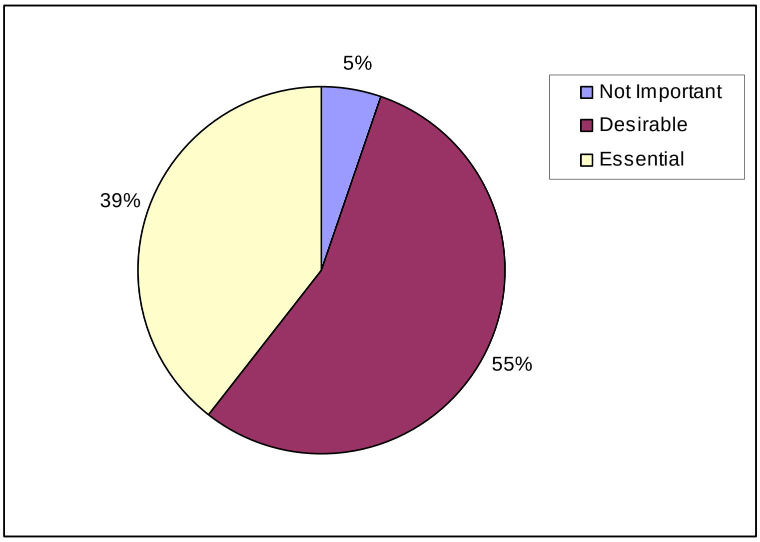

Figure 6-7: UAS Industry view on the need for interoperability

Following on from this question, UAS stakeholders were asked *"If globally standardised and approved C2/C3 datalink equipment were available, would you make use of it?"* Again, a high percentage of stakeholders (84%) indicated that they would make use of standardised C2/C3 datalink equipment.

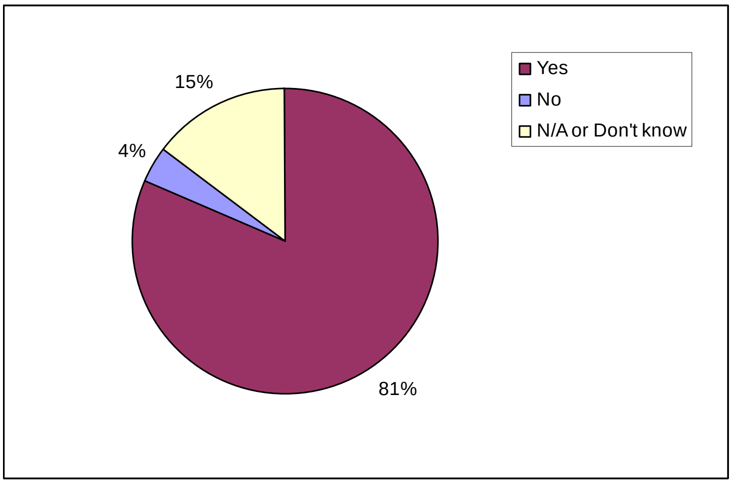

Figure 6-8: Use of standardised C2/C3 datalink equipment

Another interoperability issue is the carriage of transponders and voice/data transceivers for communications with ATC. From a safety perspective, and to be fully transparent, it is expected that UAS will have full ATC communications and surveillance capability, which is an essential requirement for operation inside controlled airspace. However, this does not necessarily mean that the UA needs to be equipped with a transponder and voice/data COM equipment, particularly if innovative communications architectures can provide the same level of safety and transparency. For example, a wired communications architecture for ATC voice/data communications could potentially overcome the need for carriage of COM transceivers.

UAS industry stakeholders were asked what percentage of UAS platforms (intended for operation inside a controlled or a known airspace environment) are expected to be capable of transponder and VHF (voice) transceiver carriage. The response to this question (see Table 6-5) again showed a clear distinction between the small, short range line-of-sight UAS community, and those concerned with larger, long-range operations beyond visual line-of-sight.

Percentage of UAS platforms:	0-20%	21-40%	41-60%	61-80%	81-100%
Number of Responses:	23%	8%	8%	38%	23%

Table 6-5: Percentage of UAS (intended for operation inside controlled airspace) capable of transponder and VHF (voice) carriage

Following on from this, stakeholders were asked what percentage of these unmanned aircraft would be expected to additionally have a VHF data communications capability. The response to this question can be seen in Table 6-6.

Percentage of UAS platforms:	0-20%	21-40%	41-60%	61-80%	81-100%
Number of Responses:	38%	8%	15%	15%	23%

Table 6-6: Percentage of UAS (intended for operation inside controlled airspace) capable of transponder and VHF (voice and data) carriage

As before, the result highlights the different user requirements, and limitations due to aircraft size and capability. Whilst it is expected that a significant proportion of larger UA will be capable of carrying the necessary avionics to ensure interoperability, a large percentage of the industry believe that carriage of equipment will not be possible, and this supports the need for innovative solutions and architectures.

When asked about the importance of having standards for networked C2 datalink equipment, all respondents indicated that it was either desirable or essential.

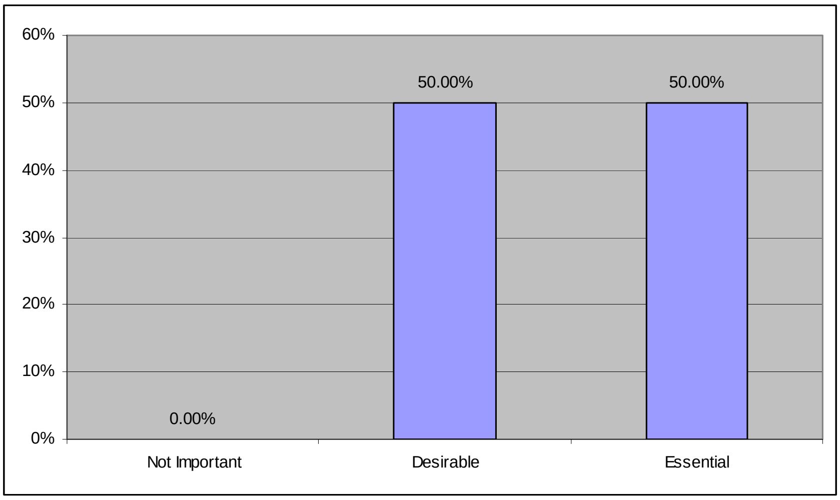

Figure 6-9: Importance of Standards for C2 Datalink

6.3.5 Timescales for Provision of UAS Communications Infrastructure

Stakeholders were asked when different communication infrastructure needs to be available for use by the UAS industry. The majority response indicated that:

- Single Ground Station equipment is required by 2010
- Networked Ground station equipment is required by 2012

- Satellite equipment is required by 2014

6.3.6 Funding of UAS Communications Infrastructure

When asked how they thought UAS communications infrastructure should be funded, Group 2 stakeholders provided the following response:

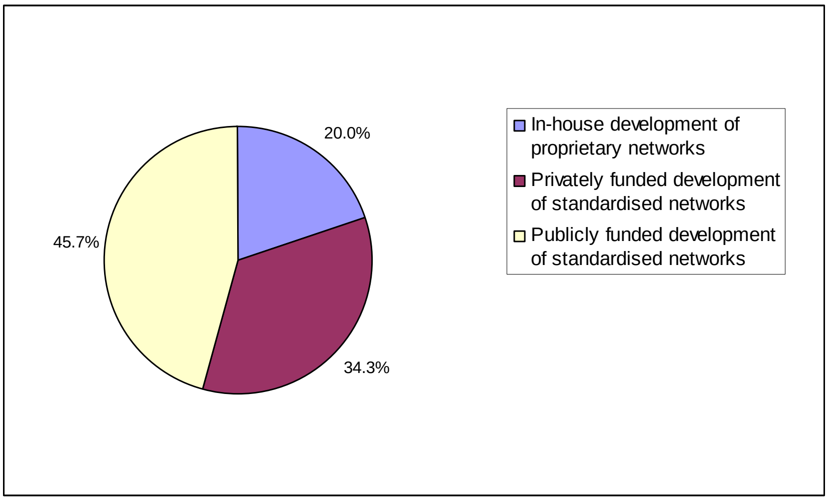

Figure 6-10: Expected Funding of UAS Infrastructure

This result shows that 45.7% of Group 2 stakeholders expect UAS communications infrastructure to be publicly funded.

This result tells us that 54.3% of stakeholders believe that funding (whether in-house or by a third party organisation) will be private.

6.3.7 ATC Voice/Data Communications Path

Stakeholders were asked to indicate how they expected voice/data communications with ATC to be provided in the periods before and after 2020.

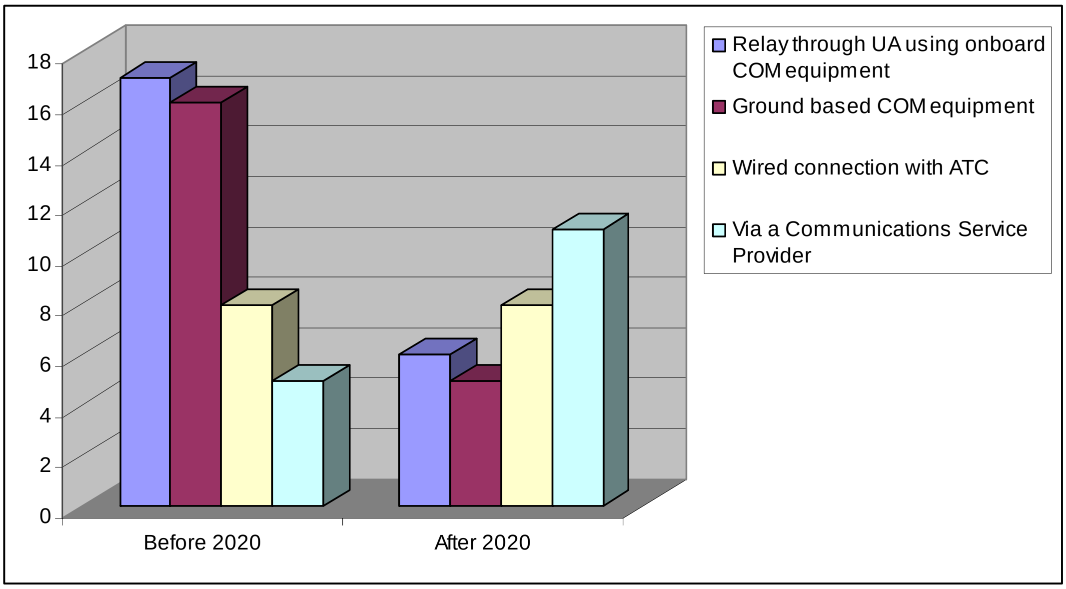

Figure 6-11 Expected Communications Path for voice/data communications with ATC

These results clearly show the preference for relay via on-board COM equipment, or the use of ground based COM equipment in the period leading up to 2020. Although there is less of a consensus for the period after 2020, the use of service providers and wired architectures take over as the preferred methods.

6.3.8 Data Throughput Requirements

Stakeholders were asked to provide an estimate of data throughput requirements for the same four categories. Taking the arithmetic mean of the answers provided reveals the following expected data throughput rates:

Category	Expected throughput kb/s
Command and Control	42.1
Downlink Sense & Avoid	51.7
ATC Voice	27.5
ATC Data	35.0

Table 6-7: Average expected data throughput requirements

This is an interesting result as it shows, perhaps surprisingly, that downlinking of Sense and Avoid information is expected to require more data than Command and Control, and ATC Data communications will require more data than Voice.

From this result, it is also possible to understand how much data throughput is likely to be required between the UA and the Ground Station (i.e. Command, control and downlinking of sense and avoid), and how much is needed for ATC voice/data communications (which does not need to be relayed via the UA).

	Expected throughput kb/s
Command, control and downlinking of Sense and Avoid	93.8
ATC voice/data	62.5

Table 6-8: Average expected data throughput requirements for C2 and ATC communication

In general terms, 60% of the expected data needs to be routed between the UA and the ground Station, and 40% can be sent directly, or relayed via the UA.

6.3.9 Spectrum Requirements

Given the average expected data throughput requirements, and even if spectrally efficient techniques are used, the per UA spectrum requirements are likely to be significant, particularly when overheads are added for link management, error correction and encryption etc. Furthermore, the combined spectrum requirement for a given frequency re-use cell or spot beam will be a multiple of this amount, related to the number of UAs operating at the same time.

Recognising the paucity of spectrum and the likely demands for UAS datalink, stakeholders were asked to score the importance of obtaining sufficient spectrum on a scale of 1 to 5.

- The average response to the statement "Sufficient spectrum should be sought to avoid UAS being constrained in any area, regardless of cost" resulted in a score of **3.3**
- The average response to the statement "Operational limitations due to insufficient spectrum are inevitable, but will be overcome in time as the UAS industry grows" resulted in a score of **3.4**
- The average response to the statement "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" resulted in a score of **2.2**

This result shows that the majority of respondents recognise the difficulty in obtaining sufficient spectrum, and the fact that insufficient spectrum could constrain growth.

When asked about the need to achieve a harmonised frequency allocation for UAS C2 datalink, none of the stakeholders stated that it was not important, and 61.3% stating that it is essential.

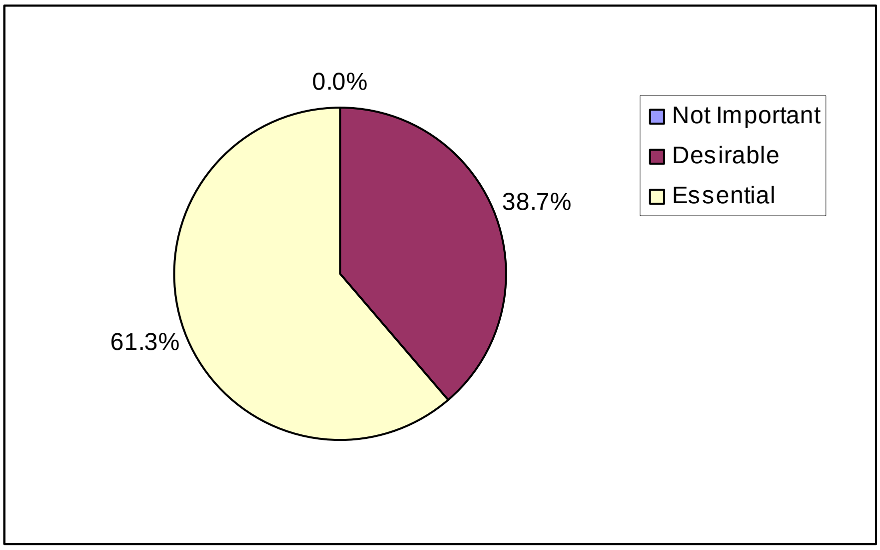

Figure 6-12: The need for a harmonised frequency allocation

6.3.10 Cost of Datalink Services

Whenever there is a need to make use of a third party network or service provider, there will inevitably be costs for the data transmitted. It is important to understand what UAS operators expect to pay for datalink services, to determine whether the provision of such services is likely to be commercially viable.

Stakeholders were asked to provide an indication of expected cost of data for:

- Command and Control
- Downlink Sense and Avoid
- ATC Voice
- ATC Data

Stakeholders indicated an average expected cost of €1.3 per kb/s, for all four data categories. This is commensurate with current market values for data transfer over commercial wireless networks, but slightly less than mobile satellite networks.

The fact that the expected cost is the same for all data categories is to be expected, assuming all data is to be delivered with the same quality of service.

6.3.11 Size, Weight and Power Requirements for Communications Equipment

Stakeholders were asked to provide information about the expected size, weight and power requirements for on-board C2/C3 equipment. Taking the arithmetic mean of the results provided by UAS manufacturers, operators and support services, the following results were obtained:

- Expected power requirements = 123 W
- Expected equipment weight (electronics) = 7.5 kg
- Expected equipment size = 2.4 MCU
- Average antenna diameter = 0.6 m

This result confirms the view that size, weight and power of communications equipment is likely to be critical for many UAS manufacturers and operators. Carriage of equipment which exceeds the above figures is likely to present design or operations constraints for the UAS industry.

Stakeholders were subsequently asked *"What is an acceptable weight of terrestrial communications that a UA can support?"*

Responses to this question showed a clear desire for equipment weighing 14 kg or less. The arithmetic mean response was 9.4 kg, which is commensurate with the answer provided to the previous generic question relating to expected weight of communications equipment.

6.3.12 Expected Growth of Industry

UAS industry stakeholders were asked to provide an estimate of the percentage increase in manpower required to support the UAS industry over the period 2010 to 2020. Figure 6-13 shows the mean expected manpower growth.

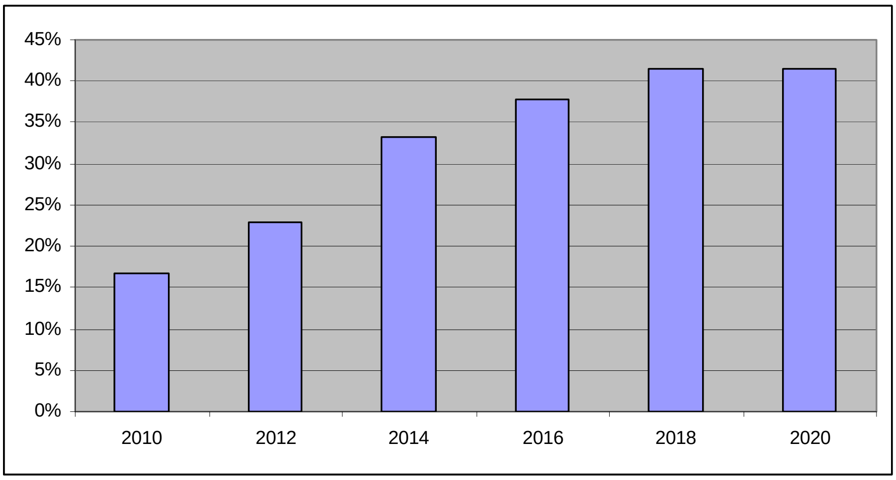

Figure 6-13: Expected number of people employed to support UAS Industry

This shows that steady growth is expected in the period until 2018. Growth in 2020 is expected to slow down.

6.3.13 Constraints to Growth

Stakeholders were asked to indicate on a scale of 1 to 5, the extent to which a range of issues were believed to be constraining development of the UAS industry in Europe.

The results, as depicted in Figure 6-14, show that Regulation, Sense and Avoid, Safety and Global Standards are perceived as the biggest constraints to growth. Environmental issues are considered to be the least constraining factor.

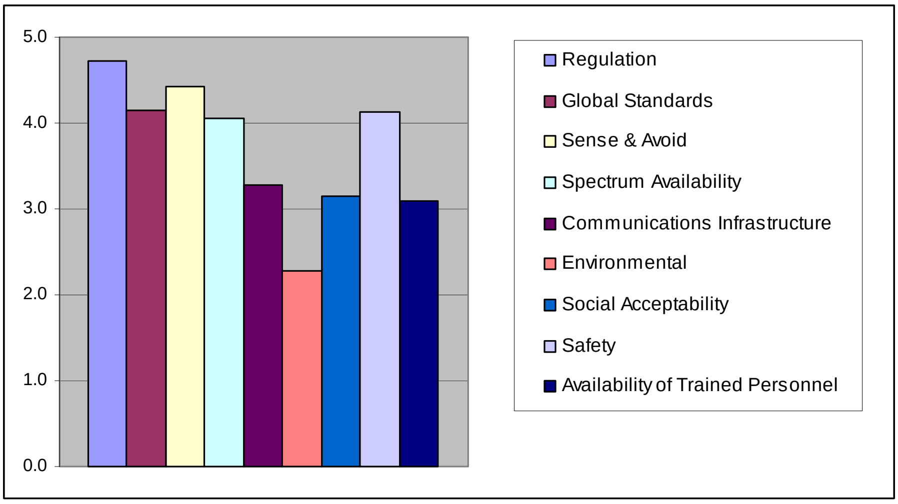

Figure 6-14: Perceived Constraints to Growth

Group 2 stakeholders were asked what factors are likely to constrain the use of satellite for C2 and ATC communications. The results show that equipment costs, the operating costs and latency are recognised as the biggest issues.

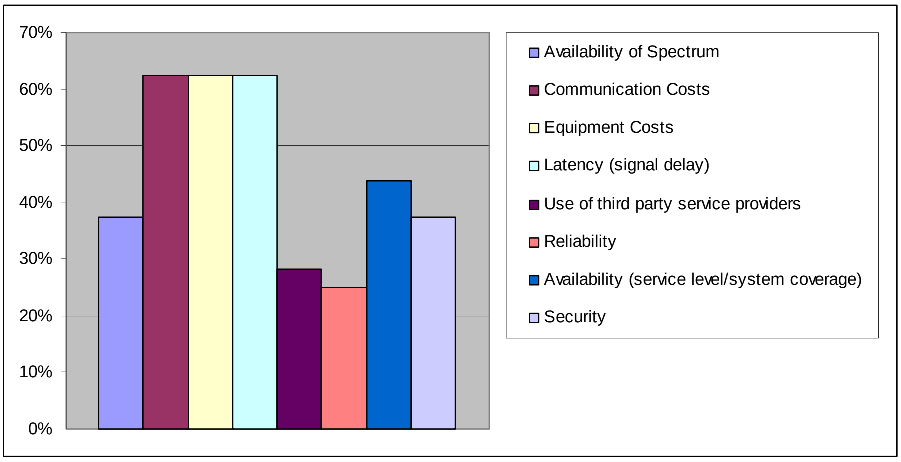

Figure 6-15: Perceived Constraints to the use of Satellite for UAS Communications

6.4 Conclusions

From the analysis of the Group 2 results, the following qualitative results have been derived:

No.	Title	Observation	Source (Section)
1	UAS Applications	The UAS market can be loosely split into two categories; small lightweight UA used for short range (visual line-of-sight), and larger UA that are capable of operation beyond visual line-of-sight. The communication needs of these two categories are very different, and this is reflected in many of the answers to the Group 2 questions.	6.3.1
2	UAS Applications	Early introductions of UAS are expected to be state sponsored surveillance type applications. Post 2020 there is an increasing market for commercial applications	6.3.1

No.	Title	Observation	Source (Section)
		anticipated.	
3	Range and Height Requirements	80% of UAS will operate within 500NM of the GS and 60% below 10,000ft.	6.3.2
4	Communications Methods	No single architecture has been identified as meeting all needs. Single ground station/ network GS and satellite all very nearly get equal scores (29%, 38%, 33% respectively)	6.3.3
5	Constraints to Growth	Over 60% of respondents indicated that equipment costs, communications costs and latency are most likely to constrain the use of satellite communications for UAS	6.3.13
6	Timescales	Modal results indicate that single ground station solutions will be needed immediately (2010). Networked ground stations will be required by 2012, and satellite communications by 2014.	6.3.5
7	Interoperability	84% of UAS stakeholders said that they would make use of standardised and approved C2/C3 datalink equipment if it were available.	6.3.4
8	Funding	There is a majority expectation amongst all stakeholders that the development of UAS communications networks should be publicly funded. However, there is significant expectation for privately funded networks, or a mix of solutions. Some small LOS manufacturers/operators have no interest in private or public investment for networked C2 infrastructure.	6.3.6
9	Communications Method	Before 2020 relay via UA is the most popular method of communication with ATC, closely followed by ground based communications. Post 2020 the majority expect the use of Communications Service Providers and wired infrastructures to communicate with ATC.	6.3.3, 6.3.7
10	Interoperability	A significant percentage of UAS manufacturers recognise need to have UA capable of VHF voice and SSR transponder carriage.	6.3.4
11	Interoperability	There is a significant number of small UA that are not expected to be large enough to support carriage of avionics equipment.	6.3.4
12	UAS Applications	Maritime Surveillance, Search and Rescue and Natural Hazard Monitoring are expected to be the most likely 'early' UAS applications to take place outside segregated airspace. The majority of these applications are expected to be in support of State activities.	6.3.1
13	UAS Applications	Cargo is expected to be the most popular UAS application after 2020. Other popular applications include traffic monitoring and communications relay. These represent a mix of State and private sector applications. It is notable that many of the initial (pre-2020) UAS applications become less popular.	6.3.1
14	Constraints to Growth	The biggest constraints to growth are perceived as regulation, global standards, Sense and Avoid, spectrum availability and safety.	6.3.13
15	Constraints to Growth	Latency and cost have been identified as a major constraint of satellite usage.	6.3.13
16	Expected Growth of Industry	The number of people employed in the UAS industry is expected to grow steadily until 2018. This represents a significant new market for the European Aerospace Industry, and the potential for many jobs to be created exists if constraints to growth can be overcome.	6.3.12
17	UAS Applications	A significant percentage (60%) of UA/S industry	6.3.1

No.	Title	Observation	Source (Section)
		stakeholders recognise the need to operate over remote or maritime areas, and this places a dependency on satellite communications at least for C2 elements.	
18	Interoperability	95% of respondents stated that it was desirable or essential to have the capability to operate UAS in different countries, and to cross international boundaries. This places high importance on the need for standardised architectures that offer good interoperability. It is interesting to note that even those who intend to operate from a single ground station also recognise the need for global interoperability.	6.3.4
19	Spectrum Requirements	In terms of spectrum, a significant number of respondents expressed the view that sufficient spectrum should be sought to avoid UAS operations being constrained. However, an equal number recognised that operational limitations will occur, but will be overcome in time as the industry grows.	6.3.9
20	Spectrum Requirements	There was strong consensus that ad hoc or disparate solutions to spectrum are not acceptable, as they will not support the long-term growth of the industry.	6.3.9
21	Interoperability	100% of responses indicated that it was desirable or essential to achieve a globally harmonised frequency allocation for UAS C2 datalink.	6.3.4
22	Data Throughput Requirements	Data throughput expectations are in line with other industry expectations of spectrum requirements.	6.3.8
23	Data Throughput Requirements	Use of wired or network architectures to communicate with ATC can save up to 40% of the spectrum requirement (compared with a relayed architecture)	6.3.8

7 Combined Quantitative Results

In this section the weightings obtained from the Group 1 stakeholders in the form of the performance scores are applied to the Group 2 stakeholder importance scores to determine overall compounded scores for each of the bounded architectures. Whilst the bounded architectures are not intended as solutions, they do highlight the attributes that are likely to be of most benefit to the development of the UAS industry.

Finally a sensitivity analysis was conducted to determine how sensitive the overall score is to the impact category weightings.

7.1 Method

The Group 1 results produced a performance score as to the importance for each of the five impact categories.

From the analysis described in section 6.2, we have a set of mean normalised scores for each architecture and impact category. These scores are subject to a standard weighting set to a value of 3, (where Low=1[5] and High=5).

The overall compound score is derived from calculations as shown in the table below. The Group 1 performance figure (expressed as a percentage) is multiplied by the Group 2 importance score (represented by the lower case letter) for each architecture and each impact category. The sum of the values for each of the architectures gives the compound score for each of the architectures.

	Group 1 Performance Score	Group 2 Importance Score (standard weighting)			
		AR2	NR1	NR3	NR12
Economic	18.1%	A=a x18.1	B=b x18.1	C=c x 18.1	D=d x 18.1
Social	15.9%	E=e x 15.9	F=f x 15.9	G=g x 15.9	H=h x 15.9
Spectrum	26.0%	I=I x 26.0	J=j x 26.0	K=k x 26.0	L=l x 26.0
Interoperability	19.3%	M=m x 19.3	N=n x 19.3	O=o x 19.3	P=p x 19.3
Regulation	20.7%	Q=q x 20.7	R=r x 20.7	S=s x 20.7	T=t x 20.7
	Compound score:	A+E+I+M+Q	B+F+J+N+R	C+G+K+O+S	D+H+L+P+T

Table 7-1: Calculation of compound score

To understand the significance of the results, and the influence that each impact category has, it is necessary to apply sensitivity testing. Thus, the Group 2 scores for each impact category are replaced one at a time with either low or high weighting scores.

	Sensitivity		
	High	Medium	Low
Low Weighting	3	2	1
Standard Weighting	5	3	1
High Weighting	7	4	1

[5] The low and high scores are used later to perform a sensitivity analysis on selected variables.

7.2 Standard Weighting

The method described in 3.2.1 was applied to produce a compound score for each of the four bounded architectures. The results of this are depicted in Figure 7-1:

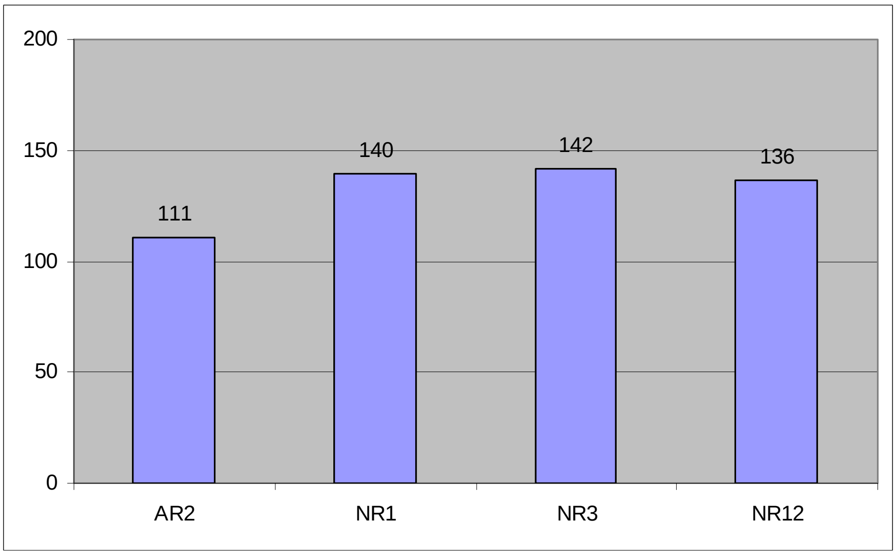

Figure 7-1: Bounded Architectures - Compound Score

This analysis indicates that NR3 (C2 via satellite and ground-based ATC voice/data COM) is overall the most beneficial architecture out of those considered, closely followed by NR1 (single ground station). AR2 (networked ground station) has the lowest compound score.

In order to fully understand this result, it is necessary to look at the constituent elements of each compound score.

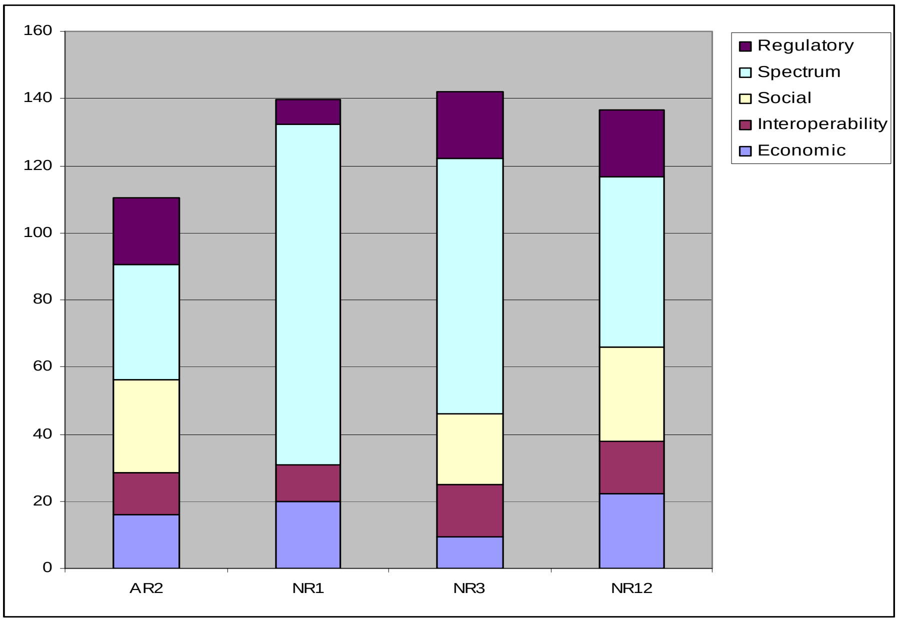

Figure 7-2: Compound Score – Constituent Parts

It can be seen that spectrum is the most dominant factor for all architectures, as a result of it having the highest Group 1 performance score, and the highest mean importance Group 2 scores.

In the case of NR3, it is the combination of spectrum, regulation and interoperability that results in the highest overall compound score.

NR1 is even more dominated by the spectrum influence, and this is supported by a relatively high economic score. These figures overshadow the low values obtained for regulation, interoperability and social.

It is notable that interoperability and regulation have the smallest influence on the overall result, despite having respectable Group 1 performance scores. The dilution of these values is largely down to the split in the Group 2 stakeholders, with a significant proportion of industry stakeholders only interested in short range, line-of-sight operations. Such operations do not place a high importance on interoperability, or the need for regulation.

7.3 Sensitivity Analysis

In order to test sensitivity of the overall result to different impact categories, sensitivity analysis can be performed. This is achieved by changing the weighting applied to the Group 2 results, one impact category at a time (see Tables 7-3 to 7-12).

Increased Weighting for Economic

Increasing the economic weighting results in NR1 replacing NR3 as the most beneficial architecture. This is to be expected given that it has the least economic impact.

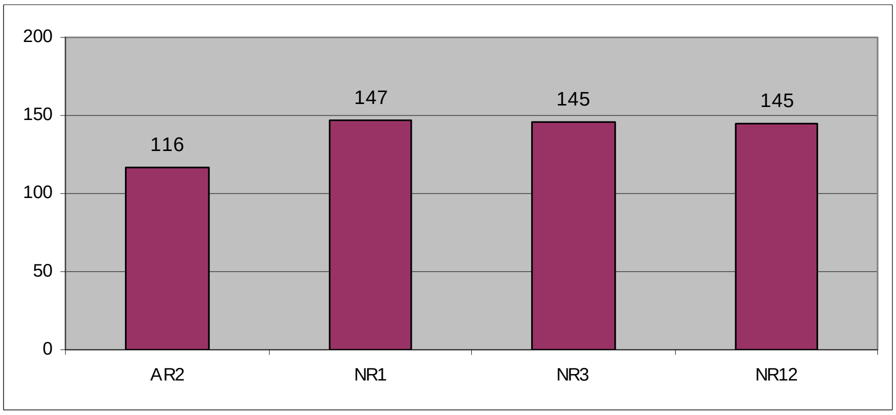

Figure 7-3: Effect of Increased Economic Weighting

Decreased Weighting for Economic

Decreasing the economic weighting does not cause a noticeable effect, and the ranking remains the same as for the standard weighting.

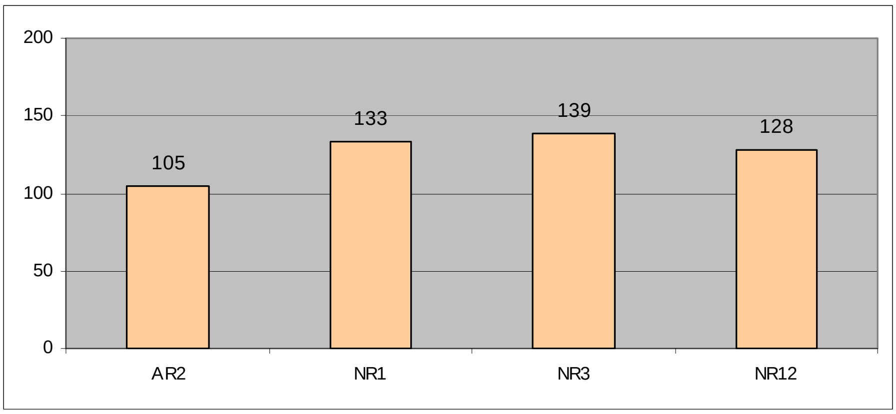

Figure 7-4: Effect of Decreased Economic Weighting

Increased Weighting for Interoperability

Increasing the weighting of interoperability results in a small improvement to the compound score for AR2, NR3 and NR12. This does not change the overall ranking. As previously mentioned, this effect appears to be diluted by the differing requirements of UAS stakeholders.

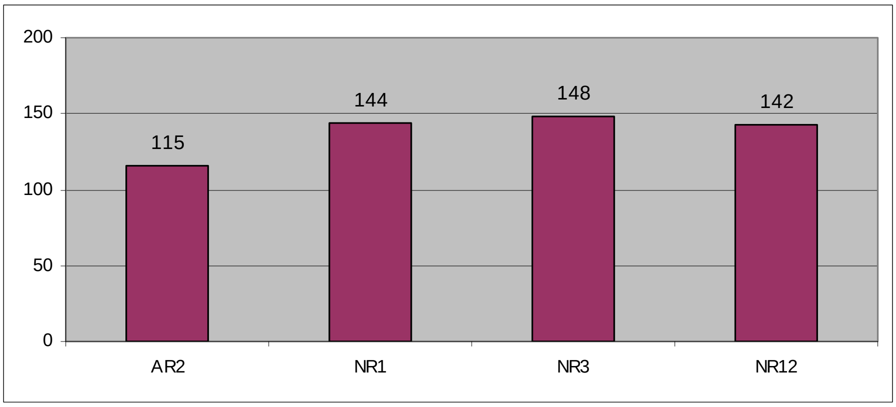

Figure 7-5: Effect of Increased Interoperability Weighting

Decreased Weighting for Interoperability

If the weighting of interoperability is reduced, NR1 just replaces NR3 as the most beneficial architecture. This is to be expected as interoperability is more significant for NR3.

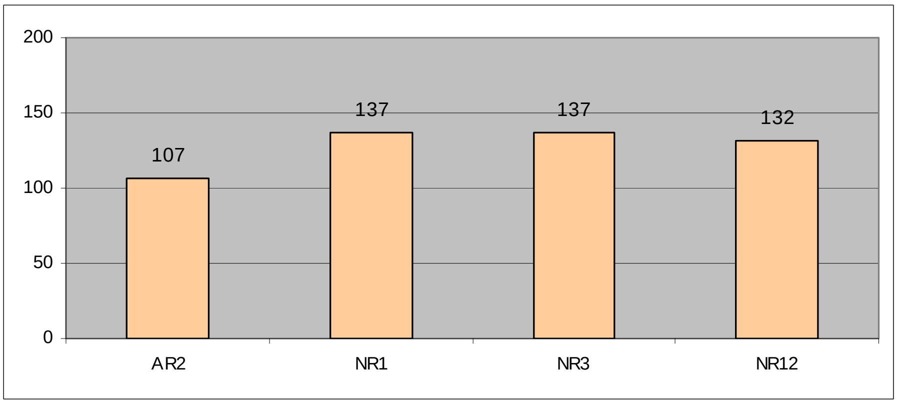

Figure 7-6: Effect of Decreased Interoperability Weighting

Increased Weighting for Social

Increasing the weighting for social causes the biggest changes to the compound score values of AR2 and NR12. This is to be expected as these types of architecture will require the greatest amount of infrastructure, and will result in greatest number of jobs. NR3 undergoes a small increase, and retains the highest compound score.

NR1 is unchanged as there is no social element in its compound score.

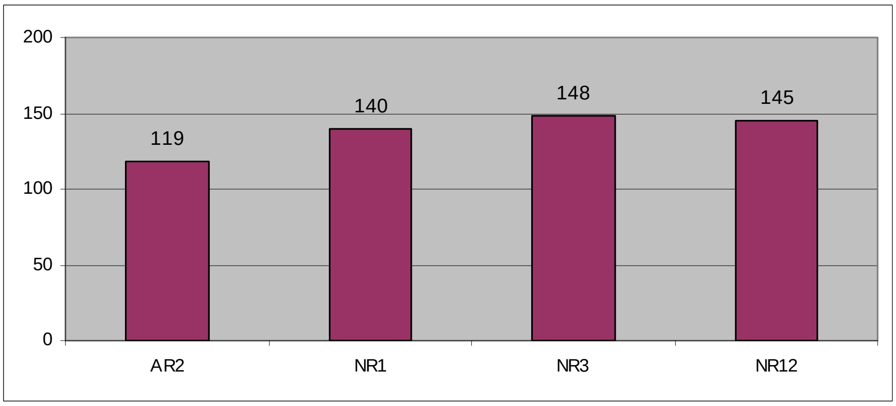

Figure 7-7: Effect of Increased Social Weighting

Decreased Weighting for Social

Decreasing the social weighting results in NR1 becoming the highest scoring architecture. This is to be expected given that the overall compound score will reduce for AR2, NR3 and NR12.

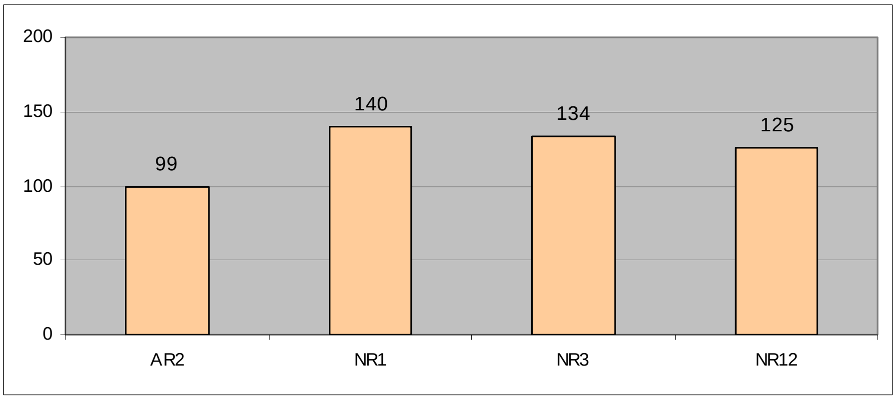

Figure 7-8: Effect of Decreased Social Weighting

Increased Weighting for Spectrum

The dominance of spectrum has a profound impact when its weighting is increased. As would be expected, NR1 sees the biggest change and takes over from NR3 as the most beneficial architecture. AR2 and NR12 show the smallest increase due to the fact that they both employ terrestrial C2 datalink networks that are considered to have the most demanding spectrum requirements.

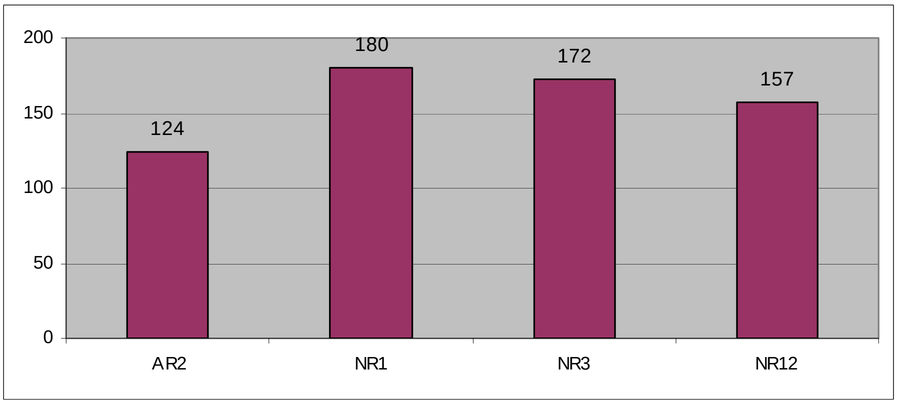

Figure 7-9: Effect of Increased Spectrum Weighting

Decreased Weighting for Spectrum

NR1 is the most sensitive to a decrease in spectrum impact due to the dominance of spectrum in its compound score.

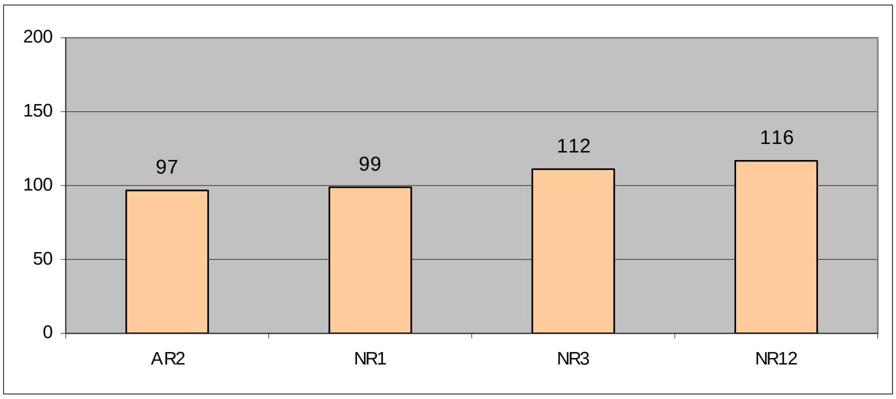

Figure 7-10: Effect of Decreased Spectrum Weighting

Increased Weighting for Regulation

AR2, NR3 and NR12 show the largest change when the regulation weighting is increased.

As with interoperability, the effect of regulation is diluted by the Group 2 results, and were it not for this, a significantly larger change would be expected.

Increasing the weighting does not change the ranking of architectures.

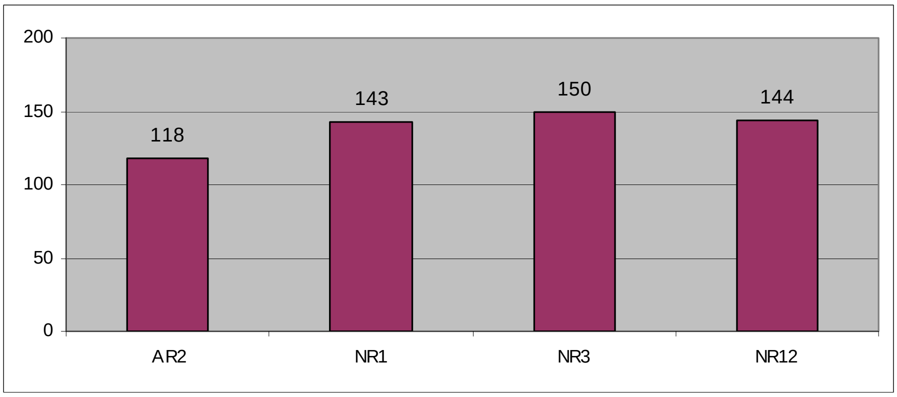

Figure 7-11: Effect of Increased Regulation Weighting

Decreased Weighting for Regulation

Decreasing the weighting of regulation causes NR1 to replace NR3 as the highest scoring architecture. This is to be expected given that regulation plays a more significant part in NR3 than NR1.

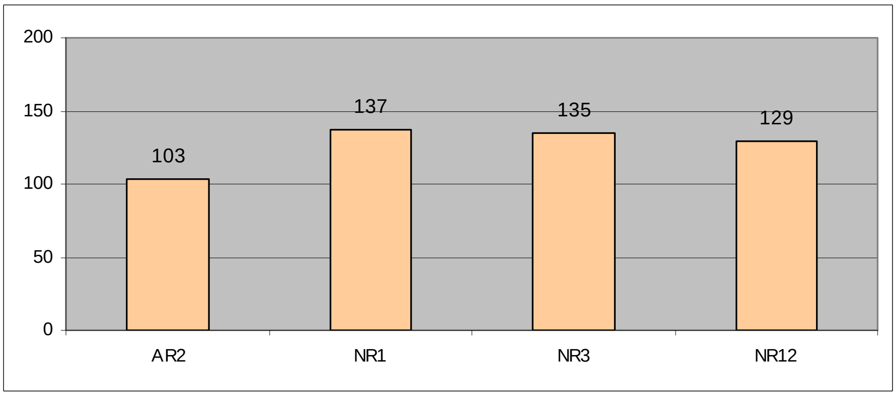

Figure 7-12: Effect of Decreased Regulation Weighting

7.4 Summary

The analysis consistently shows NR3 (networked architecture and COM service provider) and NR1 (single VHF ground station) as the most beneficial architectures, and this appears to complement user requirements and current views on market growth. Satellite-based architectures offer some unique and valuable attributes such as extensive coverage (particularly at low height), the ability to cross international boundaries and operate in areas devoid of terrestrial infrastructure. Furthermore, for many of the UAS applications identified, satellite communications is the only viable solution.

Similarly, NR1 meets the needs of the significant proportion of UAS operators that operate small UAS over short range. As well as not being able to carry physically large or heavy communications equipment, this type of activity is likely to be highly sensitive to cost, and this makes the use of single ground station very attractive.

Throughout the sensitivity testing, the wired architecture (NR12) has a consistently high compound score. This architecture has a lot of potential benefits, such as reduced need for spectrum, high reliability, low latency and low operating costs. It is possible that some of these benefits have not been fully reflected in this analysis, and this may be suppressing the true compound score value to a degree.

Perhaps the biggest surprise is the consistently low score achieved by AR2, (ATC relay and the use of networked terrestrial ground stations). This can be explained by the combination of high infrastructure costs, high spectrum requirements, and inferior interoperability performance (in terms of coverage at low heights and over remote/maritime regions).

8 Conclusions and Recommendations

In this section the various observations and conclusions from the different analysis of Group 1 and Group 2 stakeholders are dawn together and recommendations made.

8.1 Impact Categories

8.1.1 Economic

Market Forecasting

Although there is a degree of consensus as to some of the UAS applications that will exist in the short term, there is no accurate market forecast data available. This lack of accurate market forecast data hinders investment in high value enabling infrastructure (such as satellite or ground based communication networks) that will be required for operation beyond visual line of sight.

There is a strong consensus that state surveillance applications will be the early adopters of UAS missions, although there is a strong view that infrastructure applications (utility surveillance) may also be an early adopter. Post 2020 commercial applications (cargo transport) are expected to dominate the UAS applications.

There is also no reliable data concerning the military requirement to fly through non segregated airspace, even though this is a goal of the military for operational and cost benefit reasons.

Market Segmentation

There is a strong consensus that the market is essentially split between small lightweight UA used for short range (VLOS) and larger UA that are capable of BLOS operations. The survey found that the infrastructure needs of these two camps are very different in many respects, but share some concerns (see global reach below for example).

Timescales

Group 2 stakeholders have expressed a view that UAS operations using a single ground station are required from 2010, followed by network ground stations in 2012 and satellites by 2014. This may be aspirational rather than a realistic belief that these infrastructures will be in place by these timescales. However, it does highlight that there is a developing need and that the infrastructure is required as soon as possible. However, this aspiration appears inconsistent with constraints that have been identified (e.g. Sense and Avoid) that will not be overcome in this timeframe.

Investment

There is little or no visible activity to provide infrastructure and services to support UAS communications. A significant percentage of Group 1 stakeholders (46%) expressed the view that the communications infrastructure should be publicly funded. The majority of Group 2 stakeholders (54%) recognised the need for private investment, but only 20% have any expectation in providing any in-house investment. Group 1 stakeholders are investing in R&D type activities, but this is the limit of their investment plans.

Operating Costs

Both groups recognise the need for minimising the cost impact, whether due to the use of infrastructure, equipage of onboard systems, or the amount of spectrum required. Any negative cost differential from manned aviation will have a detrimental impact on the UAS industry.

8.1.2 Social

Jobs

There is consensus amongst all stakeholders that the UAS sector will continue to grow, and that this will lead to an increase in the number of people employed in the industry.

Constraints

Both groups see lack of global standards, spectrum availability, regulation and Sense and Avoid as the major constraints to UAS market growth. Latency and cost for Satellite communications was also cited as a constraint and possible issue by both groups.

Standardised Service Provision

The vast majority (84%) of Group 2 respondents said that they would make use of standardised and approved C2/C3 data link equipment if it was available. All agreed that it was either essential or desirable to have a standardised and interoperable set of standards for C2 datalink communications. Consideration will need to be given to the level of autonomy of the UA when setting these standards.

The use of safety regulated and standardised service provision is driven in part by cost considerations both for development and operational costs. The users expect that satellite costs (both equipment and operating costs) were likely to be more expensive than terrestrial ground stations.

Concern was raised over the security of using standardised data links for controlling UAs.

8.1.3 Spectrum

Spectrum Availability

All stakeholders recognise spectrum availability as a major constraint to the development of the industry. The initial predominance of state surveillance applications for UAS would lend credibility to the Group 1 view that the military frequency bands might be used, at least initially, to kick start the UAS market.

The use of wired architectures might save up to 40% of the spectrum requirement when compared with relayed architectures.

Spectrum Cost

Many stakeholders recognise the value of spectrum, particularly frequencies suitable for mobile communications for which there is a high demand.

Harmonised Frequency Allocations

All stakeholders expressed the view that a global or regional spectrum allocation is essential to the cost efficient use of UAS and for global interoperability. The data throughput requirements are in line with other spectrum requirement estimates.

8.1.4 Interoperability

Latency

Latency in ATC communications is recognised as a significant issue, particularly for satellite communications.

Infrastructure architectures

No single architecture (or architecture element) stands out as the predominant method of communications. There is no clear preference for a single ground station, networked ground station or satellite for C2 communications (29%, 38% and 33% respectively). It is likely that many UAS applications will utilise a combination of communication methods during the course of a single mission.

Global Reach

There was near unanimity by both groups that global interoperability was an essential aspect to make UAS operations a reality. A significant proportion (60%) of respondents thought that there was a need to fly over remote or maritime areas where it would be impractical to operate ground stations. It was also recognised as important that UAs were able to cross state boundaries. This indicates that although many of the early missions are of a local nature (search and rescue for instance) they have global application and therefore to ensure cost effectiveness of development and deployment the same infrastructure requirements are needed globally. This must apply to all aspects of the communications infrastructure, such as spectrum allocation, communications protocols etc. Also, this must extend to the seamless use of ground station and/ or satellite usage. To go further there may be a requirement that UAS should be able to seamlessly and safely switch between ground station and satellite operation. There are clear economic benefits to having global standardised infrastructure available to all UAS operators through the mass production of avionics and avoidance of multiple system equipage.

ATC Communications

In the short term (before 2020) there is a general expectation that remote pilot communication with ATC will be relayed through the UA. Post 2020 the majority expect to be using a communications service provider or a wired interface.

Step-on was identified as a potential issue to ATC in high traffic periods due to excessive latency.

The carriage of VHF voice and SSR transponders is recognised by the stakeholders but there is a significant number of small UA that are not expected to be large enough to support carriage of avionics equipment.

8.1.5 Regulation

Guidance and Technical Standards

Both groups recognise the need for regulation, and the important role it plays in enabling development of the industry. There is a clear need for regulatory guidance and technical standards for UAS communications infrastructure to be developed that will cover all aspects both individually and systemically. For example:

- Proper safety regulation and oversight of the communication service providers
- Maximum latency for ATC communications will need to be established
- The protocols and specifications of switching C2 between ground station and satellite links will need to be determined (assuming there is a need for this requirement). By extension, the seamless switching between satellites will also be necessary.
- Backup communications requirements may need to be established to ensure that the remote pilot can always communicate with ATC.

There was consensus among the Group 1 stakeholders that the applicability of the current ICAO Standards and Recommended Practices (SaRPs) to support UAS operation need to be established and if necessary amended.

UAS will exhibit different levels of autonomy and this must be taken into account when setting the standards of operation and performance requirements of the communications infrastructure.

SESAR

Group 2 stakeholders were not specifically questioned on SESAR but there is a fundamental requirement that any C3 infrastructure should be compatible with SESAR concepts such as SWIM and compatible networks such as the NEWSKY air-to-ground architecture.

Group 1 stakeholders questioned the continued requirement for a voice party line in the SESAR environment and whether there is a requirement for a relay to manned aircraft when a wired interface is used.

8.2 Architectural Considerations

The following discussion highlights the applicability or otherwise of the conclusions to the various methods of communication described in the bounded architectures.

8.2.1 ATC relay

A radio relay through the UA is seen by most as the initial method of communicating with ATC but there is a strong motivation to replace this with a ground or wired interface in the future. The bounded architecture that included ATC relay scored constantly low in the quantitative analysis, in part because of the increased spectrum requirement.

It is recognised that many smaller UAs cannot carry the avionics to support ATC relay communication and therefore this could constrain market growth.

The use of airborne VHF radio (AR2) had the lowest compound score due to its high economic cost and need for spectrum.

8.2.2 Wired ATC communications

This has the benefit of saving considerable spectrum requirements (estimated up to 40% over relay architectures) and will save weight and cost of equipping the UA with VHF/ UHF radio equipment. It is recognised that although this is a novel architecture it has many potential benefits. However, concern was expressed that there may be safety and interoperability issues.

This approach is seen as compatible with SESAR concepts.

8.2.3 Ground Based ATC Radio Communications

Like the Wired ATC communications method this has the benefit of saving considerable spectrum requirements (estimated up to 40% over relay architectures) and will save weight and cost of equipping the UA with VHF/ UHF radio equipment.

This approach is seen as particularly beneficial in the pre 2020 timeframe.

8.2.4 Single Ground station

This is seen as the initial configuration of ground stations and represents the current state of the art. For many small, short range applications this represents the optimum architecture as a result of its low cost, mobility and low spectrum requirement.

As well as being constrained on operating range and height there are likely to be geographical limitations where the Ground Station can be located.

8.2.5 Network Ground Stations

Network ground stations are likely to be static and operated by a communication service provider (rather than an individual air operator). The majority of users indicated they would use a COM service provider if available. The advantages of a service provider are that benefits of scale will materialise both for the development of the infrastructure and for the operational cost to the user.

There will be the added benefit of standardised communication across all UAS. Safety and security issues were raised as some form of licensing may be required in order for UAS operators to be able to prove airworthiness of the infrastructure.

In the case of NR3, it is the combination of spectrum, regulation and interoperability that results in the highest overall compound score.

8.2.6 Satellite

Satellite was seen as the most expensive option for C3 communications but also the most flexible given its global reach. Other issues highlighted are the latency, particularly for ATC voice communications. However, satellite communications has been identified as the only viable solution for many UAS applications.

8.3 Recommendations

The following recommendations are made for EASA's consideration.

Title	Description
Action plan and industry co-ordination	To develop an action plan in coordination with industry. A key element of this is to gain a more robust forecast of industry expectations of timescales for UAS operations and priorities.
Certification	To investigate the issues surrounding the potential safety certification of communication service providers to operate UAS communications infrastructure.
Performance Standards	To set the minimum performance standards that all UAS communication infrastructures must meet to be certified as airworthy.
Security Requirements	To define the security requirements to enable secure operation of C2 datalinks in the context of networked stations and the ability to transit international boundaries.
Generic safety Case	To develop guidelines and a standardised framework by which potential UAS communications systems manufacturers and service providers can make a safety case for their systems to be demonstrated as safe.
Latency	Investigate the effects of latency on the efficient operation of ATC voice communications in different traffic density environments.
ATC simulation studies	A range of simulation studies to assess the operational impact that novel architectures will have on ATC work load and performance.
Regulation	Continuing engagement with stakeholders in order to identify where ICAO annexes and EC regulations require updating.
Spectrum	Investigate and quantify the potential spectrum savings that could be made in the European region through the use of novel architectures.
Spectrum	Continue to support the requirement for a common globally harmonised spectrum allocation for C2 communications for UAS at WRC-11.
Global Interoperability	To liaise with counterparts in other regions of the world to ensure global interoperability.

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