EUROPEAN ORGANISATION
FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

EUROCONTROL AIR TRAFFIC MANAGEMENT GUIDELINES FOR GLOBAL HAWK IN EUROPEAN AIRSPACE

DOCUMENT IDENTIFIER: EUROCONTROL-GUIDELINE-

Edition Number	:	v1.0
Edition Date	:	05/12/2010
Status	:	final release
Intended for	:	Restricted EUROCONTROL
Category	:	EUROCONTROL Guidelines

DOCUMENT IDENTIFICATION SHEET

TITLE		
EUROCONTROL Air Traffic Management Guidelines for Global Hawk in European Airspace		
	Reference:	
Document Identifier	**Edition Number:**	1.0
EUROCONTROL-SPEC-	**Edition Date:**	05/12/2010

Abstract

These Guidelines establish a set of minimum ATM requirements for GH/EH flight in European airspace, with the primary purpose of enabling GH/EH operators to use them as the basis for negotiating access to national airspace within Europe. The Guidelines envisage the isolation of GH/EH from other airspace users by requiring it to climb-out and recover in segregated airspace and to fly IFR/OAT in the cruise in non-segregated airspace at high altitudes that are above those occupied by manned aviation.

Keywords

Global Hawk
European Airspace
Integration

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DOCUMENT STATUS AND TYPE					
Status		**Intended for**		**Category**	
Working Draft	☐	General Public	☑	EUROCONTROL Rule	☐
Draft	☐	Restricted EUROCONTROL	☐	EUROCONTROL Specification	☐
Proposed Issue	☐			EUROCONTROL Guideline	☑
Released Issue	☑				

ELECTRONIC SOURCE		
Path:		
Host System	Software	Size
Windows_NT	Microsoft Word 12.0	4.5 MB

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DOCUMENT APPROVAL

The following table identifies all management authorities who have successively approved the present issue of this document.

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DOCUMENT CHANGE RECORD

The following table records the complete history of the successive editions of the present document.

EDITION NUMBER	EDITION DATE	INFOCENTRE REFERENCE	REASON FOR CHANGE	PAGES AFFECTED
0.1	27/03/09		Initial draft	All
0.2	12/08/09		Following review on 7 May 09	All
0.3	03/11/09		Drafting Group consultation	All
0.4	27/11/09		MILHAG/APDSG consultation	All
0.5	12/03/10		Incorporation of comment received	All
0.6a	29/07/10		Incorporation of comment from workshops	All
0.7	06/10/10		Incorporation of Safety Assessment	All
1.0	05/12.10		Released Issue	All

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EXECUTIVE SUMMARY

Global Hawk (GH) and Euro Hawk (EH) are variants of the same high-altitude long-endurance UAS that will be based at Sigonella (Sicily) and Schleswig (Northern Germany) from 2010 onwards. Although much of their flying will take place outside Europe, they will also be required to fly OAT at high-level throughout Europe on a variety of flight profiles. These Guidelines establish a set of recommended minimum ATM requirements to allow this to happen, with the primary purpose of enabling GH/EH operators to use them as the basis for negotiating access to national airspaces within Europe. The guidelines are non-mandatory. However, it is expected that States will adopt many, if not all, of the guidelines for incorporation into their national ATM rules and procedures in the event they allow GH/EH to fly in their airspace. A further purpose of the Guidelines is to inform, educate and provide guidance to ANSPs, GH/EH operators and other stakeholders on the safe application of ATM for GH/EH.

The Guidelines are a sub-set of previous EUROCONTROL Specifications for the Use of Military UAS as OAT Outside Segregated Airspace, published in December 2007, and accordingly follow the same basic ATM principles prescribed within the Specifications.

Because GH/EH lacks certain capabilities, including sense and avoid, it is necessary to fly the UAS in airspace that, effectively, isolates it from other airspace users. Thus, climb-out and recovery will normally take place in segregated airspace, while the cruise portion of the mission will be flown in accordance with IFR at altitudes above those normally occupied by manned aviation, ie +FL510. These Guidelines accordingly address flight both within and outside segregated airspace.

GH/EH is flown through a mission computer which is loaded with a mission plan before each flight. Nevertheless, the pilot-in-command (PIC) can manually fly the aircraft at any time, whether in response to ATC instructions or to accommodate ad-hoc tasking or for any other reason. Whichever mode is being flown, however, GH/EH remains extremely predictable. Moreover, no flight is undertaken without intensive, meticulous and extended mission planning, with particular emphasis on the selection of divert-alternate and emergency-alternate airfields.

It is expected that the air traffic services for GH/EH will be provided by the same air traffic control units that serve military manned aviation, though this should entail little more than simply monitoring progress of the flight once the unmanned aircraft (UA) is established in the cruise. In addition, GH/EH tracks will be pre-planned and usually selected from a published list of regular routes. Any requirement for active ATC intervention is therefore unlikely. Notwithstanding, flight-planning will accord with the same conventions that apply to manned aircraft.

Even in the event of a malfunction, GH/EH is predictable insofar as it will do as programmed for that particular set of circumstances and at that particular location. In support, the PIC will have a copy of the mission plan with details of all such eventualities, for use in discussion with ATC on how best to resolve the situation safely. Pre-arranged telephone numbers will ensure that ATC and the PIC can continue to communicate if radio communications are lost as part of the malfunction.

GH/EH is in no way regarded as a disposable asset, notwithstanding the absence of an onboard pilot. Instead, its design, manufacture and operation are all intended to ensure that missions are completed safely and successfully, and without risk to other airspace users or people on the ground. These Guidelines support that intent. They exist, moreover, as a living document that is expected to evolve as experience is gained in the operation of GH/EH in European airspace.

Although the Guidelines have been the subject of a safety assurance process by EUROCONTROL, Member States will remain responsible for the safety of other airspace users and members of the general public with regard to the operation of GH within their national airspace.

1 INTRODUCTION

1.1 Global Hawk in Europe

1.1.1 The Northrop Grumman RQ-4 Global Hawk (GH) is a high-altitude long-endurance (HALE) unmanned aircraft system (UAS) designed to perform reconnaissance and surveillance missions over long distances. It can remain airborne for long periods of time.

1.1.2 GH has been operated for some years from and within the United States, where it is permitted to fly in the National Airspace System (NAS) under an arrangement known as the Certificate of Waiver or Authorisation (COA). A brief explanation of this is provided at Annex A.. GH is now due to become operational in Europe - with the United States Air Force (USAF) in mid-2010; with the German Air Force (GAF) as Euro Hawk (EH) (GH with an EADS-built sensor fit) in late-2010; and with the North Atlantic Treaty Organisation (NATO) in 2013.

1.1.3 NATO has selected Sigonella Air Base in Sicily as the Main Operating Airfield[1] for its GHs, which will form the core of the Alliance Ground Surveillance (AGS) capability. The USAF, and later the United States Navy (USN), will also operate GH out of Sigonella, while EH will be flown initially at Manching before being based at Schleswig in Northern Germany.

1.1.4 In addition, GH will operate from Forward Operating Locations[2] as required.

1.1.5 It is possible the unique surveillance capabilities of GH and EH based in Europe may be employed on request in support of humanitarian aid provision in response to natural disasters, as has happened with GH flying out of the United States (see example at Annex B).

1.2 EUROCONTROL UAS ATM Integration Activity

1.2.1 EUROCONTROL is a leading participant in work on the air traffic management (ATM) aspects of UAS flight. Indeed, the pace of work to integrate UAS into European airspace is increasing steadily, and involves a large number of organisations, agencies and representative bodies. EUROCONTROL has therefore established a UAS ATM Integration Activity to develop and progress policy on ATM for civil and military UAS.

1.2.2 EUROCONTROL considers that UAS integration into European airspace will be an incremental process. The introduction of GH will therefore form an important and essential early step in the successful accommodation and safe operation of this rapidly-emerging technology. However, because GH lacks some of the capabilities of manned aviation, a number of specific ATM arrangements tailored to its operation are required, which these Guidelines seek to address.

1.3 Abbreviations

1.3.1 Abbreviations are listed at Annex C.

1.4 Glossary of Terms

1.4.1 A glossary of terms is provided at Annex D.

1.4.2 There is regular confusion between the meanings of 'automatic' and 'autonomous' in the context of UAS operations. For the purpose of these Guidelines, reference to 'automatic' means that although the GH may be flying itself under the direction of its mission computer, the PIC is able to intervene in the management of the flight. 'Autonomous' means, that such human intervention is not possible for whatever reason.

[1] A **Main Operating Airfield** is an airfield where GH is permanently based and from which it will conduct routine flight operations.

[2] A **Forward Operating Location** is an airfield from which GH will conduct routine flight operations for a limited period of time.

1.5 Drafting Conventions

1.5.1 The following drafting conventions are used within this document[3]:

a. Guidelines using the operative verb **'shall'** must be implemented to achieve the minimum objectives of this guidance material.

b. Guidelines using the operative verb **'should**' are *recommended* to achieve the best possible implementation of this guidance material.

c. Guidelines using the operative verb **'may**' indicate *options*.

1.6 Document Structure

1.6.1 After an introduction, this paper identifies the scope of the Guidelines, including their objective and intended application. Information is then provided about GH/EH itself, covering its area and mode of operation and the management of its missions. An ATM overview explains the nature of the environment in which GH/EH will fly. With regard to the guidelines proper, these are presented individually in the form of discussion followed by EUROCONTROL guideline. Every effort has been made to keep the guidelines short and straightforward to assist with incorporation into national regulations or procedures. Where appropriate, supporting information and detail is provided in the form of annexes. For convenience, the last annex (J) repeats the individual guidelines.

1.6.2 These Guidelines are envisaged as a living document that will evolve and be updated as required in the light of experience gained operating GH/EH in European airspace.

[3] Internal Guidelines for the Development of EUROCONTROL Specifications and EUROCONTROL Guidelines (Edition 1.0 dated 30 Nov 07).

2 SCOPE

2.1 EUROCONTROL Regulatory and Advisory Framework

2.1.1 The EUROCONTROL Regulatory and Advisory Framework[4] (ERAF) exists to clarify EUROCONTROL regulatory and advisory material, and encompasses rules, specifications and guidelines. Of these, rules are binding on states and are thus deemed impracticable for enabling the near-term operation of GH in European airspace. Specifications are voluntary but are used most often in support of Single European Sky (SES) regulatory material. Guidelines, however, are used to support the implementation and operation of ATM systems and services, and notably to complement extant EUROCONTROL rules and specifications.

2.1.2 EUROCONTROL has already published a set of high-level, generic specifications for the use of military UAS as operational air traffic (OAT) outside segregated airspace[5]. This subsequent work to develop ATM for GH complements these OAT specifications and will therefore take the form of EUROCONTROL guidelines within the ERAF.

2.2 Objectives

2.2.1 The objectives of these Guidelines are to:

a. Establish a set of recommended minimum ATM requirements for GH in European airspace.

b. Encourage harmonisation of national ATM procedures for GH within Europe.

c. Provide detailed information on the operation of GH.

2.3 Application

2.3.1 The Guidelines deal with how air navigation service providers (ANSPs) should interact with GH, and how GH should fit with ATM in Europe. Their intended application is therefore threefold:

a. It is anticipated that GH operators will use the Guidelines as the basis for negotiating access to the airspace of individual States.

b. It is expected the recommended minimum ATM requirements contained in the Guidelines will be adopted by States for incorporation into national rules and procedures for the operation of GH in the event they allow it to fly in their airspace.

c. The Guidelines aim to inform, educate and provide guidance to ANSPs, GH operators and other stakeholders on the safe application of ATM for GH in airspace where ATM is provided by EUROCONTROL Member States.

2.3.2 In accord with the ERAF, EUROCONTROL guidelines have voluntary status. States are therefore free to decide to what extent they wish to incorporate these particular Guidelines into their national ATM rules and procedures. However, where the Guidelines are so incorporated, it is axiomatic that they will become mandatory upon all involved with the flight of GH in the relevant national airspaces.

2.3.3 Where a State elects not to adopt these Guidelines as the basis of its ATM for GH, then it will be necessary for State and GH operator to agree alternative ATM arrangements.

[4] EUROCONTROL Regulatory and Advisory Framework – Regulatory Provisions (Edition 3.0 dated Nov 05). http://www.eurocontrol.int/enprm/gallery/content/public/docs/eraf_04_002_v_3_0.pdf

[5] EUROCONTROL Specifications for the Use of Military UAVs as OAT Outside Segregated Airspace (Edition 1.0 dated 26 Jul 07). http://www.eurocontrol.int/mil/gallery/content/public/milgallery/documents/UAV specifications/EUROCONTROL Specifications for Mil UAVs as OAT Outside Segregated Airspace (pdf).pdf

2.4 Operational Air Traffic

2.4.1 The GH operations described at para 1.1 are flown by the military, and are therefore classed as Operational Air Traffic (OAT)[6]. These Guidelines accordingly follow the same basic ATM principles as the EUROCONTROL Specifications for the Use of Military UAS as OAT, namely that:

a. UA operations should not increase the risk to other airspace users.

b. ATM procedures should mirror as much as possible those applicable to manned aircraft.

c. The provision of air traffic services to UAS should be transparent to ATC controllers.

2.4.2 Notwithstanding, there is a necessary degree of compromise in these Guidelines. GH was not originally designed with ATM in mind, so there are features of the UAS which are not readily compatible with how manned aircraft file and fly. This needs to be recognised and accepted in order to allow GH to operate in European airspace, though mitigated as much as possible. An example of such mitigation is restricting GH to airspace where - other than *in extremis* - it is isolated from other traffic.

2.4.3 With regard to air traffic services for GH as OAT in non-segregated airspace, it is anticipated that these will be provided by the same air traffic control units that serve military manned aviation.

2.5 Other HALEs

2.5.1 The Guidelines are unusual insofar as they are written for a specific type of UAS and operation. Indeed, at the time of writing, GH is the only operational HALE UAS. Notwithstanding, the Guidelines could reasonably be expected to become the ATM baseline for the operation of other HALE UAS in European airspace.

2.6 Low-Intensity Operations

2.6.1 As written, the Guidelines only envisage low-intensity operations by GH. In the event that flights in Europe by military HALEs increase notably in number, it will be necessary to review the Guidelines.

2.7 Not Included in Guidelines

2.7.1 As will be seen at para 4.4, a central tenet of these Guidelines is the isolation of GH from other traffic, either by use of segregated airspace or by flying it at very high altitudes where there is little or no other traffic. However, it is known that at least one State intends to allow the integration of EH with other traffic in certain classes of controlled airspace using standard separation minima, subject to validation of the associated ATM by a national safety case. Nothing in these Guidelines precludes other States from doing the same. However, the ATM arrangements required for full integration of GH with other traffic will undoubtedly be complex and detailed, and are likely to be the exception rather than the rule in the early years of GH operation in Europe. They are therefore not addressed in these Guidelines.

2.7.2 The Guidelines also do not address ATM for GH at airfields.

[6] EUROCONTROL efforts to harmonise and standardise national rules for OAT at European Civil Aviation Conference (ECAC) level are expected to conclude shortly with the publication of a set of *EUROCONTROL Specifications for Harmonised Rules for OAT-IFR Inside Controlled Airspace of the ECAC Area.*

3 GLOBAL HAWK

3.1 Variants

3.1.1 Variants of GH are described by reference to 'Block' numbers, eg Block 10, Block 20, Block 30, etc. Although there may be differences in size and operational capability between these variants, there are no appreciable performance differences for the purposes of ATM. Reference to GH in these Guidelines therefore encompasses all Block numbers and EH and the USN Broad Area Maritime Surveillance (BAMS) UAS.

3.2 Physical Attributes and Performance Data

3.2.1 Details of the physical attributes and performance data for a GH Block 20 UAS are provided at Annex E.

3.3 Rates of Climb and Descent

3.3.1 Despite its passing resemblance to a glider, GH is surprisingly agile in both climb and descent. Exemplar fully-fuelled climb rates are:

Sea Level	4000 ft/min
FL100	3500 ft/min
FL200	3000 ft/min
FL300	2300 ft/min
FL400	1000 ft/min
FL500	400 ft/min

3.3.2 In descent with normal divert fuel from cruise until established on approach (approximately 7500ft), GH will take 12 mins to descend from FL600 to FL300, 8 mins to descend from FL300 to FL150, and then 2 mins to descend from FL150 to 7500ft.

3.3.3 These figures apply when GH is being flown by its mission computer. In the event that manual control is taken by the PIC, then maximum rates of climb and descent are no more than 1500 ft/min.

3.4 Bank Angle

3.4.1 GH is not able to execute standard (ie 30 degrees) rate turns. Instead, its bank angles for normal operations are:

Altitude Band	Bank Angle
Sea level to 24,000 ft	20 degrees
24,000ft to 27,000 ft	20 degrees reducing to 15 degrees with increasing altitude
Above 27,000 ft	15 degrees

3.4.2 The rate of turn resulting from these bank angles varies from approximately 2.5 degrees per second at sea level to 0.8 degrees per second at FL500 and above. Zero-wind turn radius also varies from 1 nm at sea level to 6.5 nm at FL500 and above

3.5 Area of Operation

3.5.1 Although GH is foreseen to be based at just 2 airfields, there is a requirement for it to fly at high-level throughout Europe on a variety of flight profiles, eg ferry, proving and training flights, localised tactical flying, and transit to and from areas beyond Europe. Additionally, GH will require divert-alternate airfields[7] and emergency-alternate airfields[8], and transit to and from these in the event of their use. Notwithstanding, access and overflight arrangements in European airspace for GH are expected to replicate those already in place for manned State aircraft.

3.6 Numbers

3.6.1 European skies are not about to become crowded with GH. Present planning is to base approximately 20 GHs at Sigonella and 5 EHs at Schleswig. Because of the extended nature of GH missions, such numbers are unlikely to generate more than a few flights per day.

3.7 Management of GH Missions

3.7.1 Launch and Recovery Elements (LREs) located at the Main Operating Airfield or a Forward Operating Location will control GH during taxi, launch and recovery. However, for most of the mission, GH will be controlled by a Mission Control Element (MCE, The USN term for a MCE is a Tactical Auxiliary Ground Station (TAGS), which may be located at the Main Operating Airfield or elsewhere. The MCE is able to provide command, control and communications redundancy in the event of a failure of any of these at the LRE.

3.7.2 The pilot in control of the GH from the LRE or MCE is the PIC and is responsible for safe operation of the UA. The PIC is the final authority as to operation of the aircraft. PIC responsibilities will change between the LRE and MCE during the mission dependant on the phase of flight. In addition, the PIC will change during the flight as the MCE pilot changes during missions.

3.7.3 Pilots will control only one GH at a time.

3.7.4 Each MCE will be supported by a GH Operations Centre (GHOC)[9]. Amongst other things, the GHOC provides supervisory oversight and expertise, and filters and prioritises information flows to the MCE. Normal GHOC manning comprises a pilot and a sensor operator to support their counterparts in the MCE, plus a duty officer. Typically, one member of the GHOC will be a qualified GH instructor who is therefore well-placed to provide support to the MCE in the event of an emergency. The GHOC also oversees handovers between MCE crews in a structured way that ensures safe and positive control of GH at all times.

3.8 Mode of Operation

3.8.1 GH does not have the kind of flight management system (FMS) common to manned aviation. It is instead flown through a mission computer which is loaded with a mission plan before each flight. Indeed, if required, GH can fly a mission entirely automatically, from take-off to landing, a capability which makes it very predictable. Malfunctions apart, and in the absence of intervention by the PIC, GH will therefore do - very precisely - what it is programmed to do.

3.8.2 Although a mission plan cannot be changed once GH is airborne, the PIC can manually fly the aircraft at any time, whether in response to ATC instructions or to accommodate ad-hoc tasking or for any other reason. Having thus intervened, the PIC can thereafter return GH to its programmed route.

[7] **Divert-alternate airfields** are not for routine operation but are available if a GH cannot land at its normal operating base due to weather or temporary airfield closure.
[8] **Emergency-alternate airfields** are those which will only be used in emergency conditions.
[9] GHOC are supporting flight operations at all times

3.8.3 Mission planning is an intensive, meticulous and extended dynamic process which may involve:

- ICAO and State airspace restrictions.
- Over-flight and diplomatic clearances.
- Airfield surveys, especially to obtain accurate runway and taxiway data.
- Selection of divert-alternate and emergency-alternate airfields.
- Approach and departure construction.
- Mission assessment with pre-mission planning tools.
- Test case simulations.

3.9 Waypoints/Contingency Routes

3.9.1 The primary GH mission route may involve doglegs that reflect the availability of divert-alternate and emergency-alternate airfields.

3.9.2 GH is programmed to fly via a series of waypoints, which may number up to several hundred for a typical sortie. Each waypoint has up to 4 contingency routes 'stitched' (ie connected) to the primary route; these contingency routes are commonly referred to as:

C1 = Lost command and control.

C2 = Return to base.

C3 = Emergency landing.

C4 = Go round/Take-off abort.

3.9.3 Contingencies are prioritised from C3 (highest priority), then C4, then C2 and then C1 (lowest priority. This means, for example, that a GH which is returning to base on either a C1 or C2 route will transit to a C3 route in the event of requiring an emergency landing. In contrast, a GH already on a C3 route would not transition to a C1 route in the event of loss of its data-link.

3.9.4 Some GH contingency routes have additional branches. For example, a C1 (lost communications) event for a particular waypoint might thereafter be programmed for either a C2 (return to base) or a C3 (emergency landing). A graphic portrayal of this GH mission plan and logic is provided at Annex F

3.9.5 The PIC will have details of all waypoints, contingency routes and additional branches.

3.9.6 In the event that a GH is assigned ad-hoc tasking, the PIC will 'stitch in' new divert alternate- and/or emergency-alternate airfields as required to keep the UA within safe range of such facilities.

3.10 Typical Mission Profile

3.10.1 A typical GH mission profile is portrayed at Annex G.

3.11 Airworthiness

3.11.1 <u>USAF</u>

3.11.1.1 The airworthiness process for all Department of Defense (DoD) GH aircraft is the same. GH has been certificated for airworthiness in accordance with AF Policy Directive 62-6, *USAF Aircraft Airworthiness Certification*, and by a tri-service memorandum of agreement, applied also to the BAMS-D aircraft. The certification basis for the GH was derived from the criteria contained in DoD MIL HDBK 516, *Airworthiness Certification Criteria*. The system is under the command and authority of USAF for the USAF configuration, and under the command and authority of USN for BAMS-D. Operations, maintenance and training are conducted under directives of the USAF for the USAF configuration, and directives of the USN for BAMS-D configuration. Operational responsibility is delegated to the operational unit of assignment. Liability is carried by the US Government.

3.11.2 GAF

3.11.2.1 EH will be certificated by the Airworthiness Centre Bundeswehr (WTD 61). It will have a military licence. Safety criteria are as for manned aircraft.

3.11.3 Other

3.11.3.1 Statements on airworthiness arrangements for NATO AGS and USN BAMS UAS will be added to these Guidelines closer to their 2013 planned in-service date.

3.12 Pilot Qualification

3.12.1 US GH pilots will be certified military aviators or will hold a civil license level CPL/IFR. EH pilots will hold a current military license for a manned aircraft or a civil license level CPL/IFR.

4 ATM OVERVIEW

4.1 Airspace

4.1.1 Upper Limit of Controlled Airspace

4.1.1.1 There is no harmonized upper limit to controlled airspace (CAS) in Europe. Most countries opt for either FL460 or FL660, although there is one instance where no upper limit is stated. Excepting two countries, the airspace classification for CAS between FL195 and these upper limits is Class C, wherein an air traffic control service is provided to separate IFR from IFR, IFR from VFR and VFR from IFR. Regardless of the upper limit of CAS, however, manned aircraft flying en-route GAT will be known to and under the positive control of ATC, and will normally be in receipt of a radar service based on the use of secondary surveillance radar (SSR). Above CAS (ie +FL460 or +FL660), in the absence of any stated classification, the airspace should be regarded as equivalent to Class G. GH in the cruise at high altitude will therefore be in Class C or Class G equivalent airspace.

4.1.2 Segregated Airspace

4.1.2.1 In the context of these Guidelines, segregated airspace is regarded as airspace into which unauthorized traffic is not permitted. It therefore includes restricted areas, temporary reserved areas (TRAs) and temporary segregated areas (TSAs), all as defined in the EUROCONTROL Handbook for Airspace Management[10]. The Guidelines do not embrace mobile airspace reservations which, although referred to in the EUROCONTROL Specification for the Application of the Flexible Use of Airspace[11], have yet to be established as a common procedure.

4.1.2.2 Timely and accurate notification of airspace segregated for the purpose of accommodating flight by GH is essential, and should be undertaken using arrangements already in place for other segregated airspace, eg AIP, NOTAM, etc. Unless considered relevant, there is no requirement to include specific reference to the operation of GH in the segregated airspace.

4.2 High-Altitude Tracks

4.2.1 High-altitude GH tracks in Europe will be coordinated and agreed beforehand with ANSPs. Such tracks will normally be planned to avoid flying over densely populated areas and congested or complex airspace, and will take into consideration the proximity of suitable divert-alternate and emergency-alternate airfields. This arrangement is expected to result in a published list of regular high-altitude tracks in European airspace. Random routing during the cruise portion of a GH mission is unlikely.

4.3 Divert Alternate/Emergency Alternate Airfields

4.3.1 GH divert-alternate and emergency-alternate airfields will normally be military-operated, although joint-use or civil airfields are not excluded. Regardless, all divert-alternate and emergency-alternate airfields will be subject to individual prior negotiation and agreement. This will include a detailed airfield survey, with particular emphasis on obtaining sufficiently accurate runway data to allow a GH to perform an automatic landing using GPS/DGPS. As far as practical, recovery profiles will be designed to avoid over-flight of populated areas.

[10] EUROCONTROL Handbook for Airspace Management (Edition 2.0 dated 22 Oct 03.

[11] Requirement L1-APPC-08-06 of EUROCONTROL Specification for the Application of the Flexible Use of Airspace (Edition 1.0 dated 1 Jul 08).

4.4 Isolation from Other Traffic

4.4.1 Because GH lacks certain capabilities, including sense and avoid (S&A), it is necessary to fly it in airspace that, effectively, isolates it from other airspace users. Thus, climb-out and recovery will take place in segregated airspace, while the cruise portion of the mission will be flown at altitudes above those normally occupied by manned aviation.

4.4.2 Data from the EUROCONTROL Central Flow Management Unit (CFMU) shows FL470 as the highest recorded level filed and flown by contemporary General Air Traffic (GAT) in European airspace, although the Cessna Citation X business jet has a theoretical service ceiling of FL510.

4.4.3 These Guidelines do not preclude extending the use of segregated airspace to above FL510 to include the cruise portion of a GH mission. However, this would reduce operating flexibility and could further complicate already complex mission planning. This will be a decision for States.

4.5 Radio Communications with ATC

4.5.1 A description of present-day radio communications between ATC and LRE/MCE is provided at Annex H.

4.5.2 There is no communications latency when GH is flying within radio line-of-sight (LOS) of the LRE/MCE. However, some latency may be evident when GH is in the cruise beyond radio LOS of the MCE, and voice communication with ATC is effected via SATCOM. FAA experience of operating GH in the NAS when using SATCOM is that the lag-time in radio communication between the GH pilot and ATC is noticeable although of a very short duration. While this was not intuitive to ATC, and controllers were bothered by it at first, they very quickly adjusted.

4.6 Loss of Control Link

4.6.1 In the event of loss of control link, the cockpit display in front of the PIC freezes, and the PIC is neither able to monitor the health of the UA nor verify the UA is adhering to the programmed lost-link procedure (see para 6.3). FAA experience shows that this can be disconcerting to ATC controllers when the PIC calls them on the telephone to ask or verify the UA's position, altitude and flight path. It is not intuitive to ATC that loss of the control link effectively causes the PIC to 'go blind'.

4.6.2 Another potential for controller confusion is that GH is programmed to squawk 7600 (see para 6.3.3) as part of its lost-link procedure[12] when, in fact, radio communication may still be possible between ATC and the PIC.

[12] The requirement for a squawk that is globally unique to indicate lost-link in a UAS is recognised, but must await consideration by ICAO.

5 EUROCONTROL GUIDELINES - ATM

5.1 ATM Mode of Operation

5.1.1. Notwithstanding any programmed mission autonomy, the primary mode of operation of GH for the purposes of ATM must entail oversight by the PIC, who will at all times be able to intervene in the management of its flight. However, in the event of loss of the control link between the PIC and the GH, a back-up mode of operation must enable the GH to revert to autonomous flight that is predictable and is aimed at facilitating resolution of the problem and obviating risk to other airspace users.

Guideline ATMGH1. For ATM purposes, the primary mode of operation of GH shall be automatic and shall entail oversight by the PIC, who shall at all times be able to intervene in the management of the flight. A back-up mode of operation shall enable the GH to revert to autonomous flight in the event of loss of the control link between the PIC and the UA.

5.1.2 Primarily because of the absence of any S&A capability, GH will always be flown under instrument flight rules (IFR) under the ATM arrangements prescribed in these Guidelines. Coordination and transfer procedures (COTR) are considered to be carried out equivalent to the standard COTR for manned aircraft. Due to potential internal (GH) system generated failures (other than emergencies), vectoring of GH shall only be considered, if there is no better alternative available.

Guideline ATMGH2. All GH sorties flown in accord with these ATM guidelines shall be classified as IFR/OAT. Separation minima shall be at least the same as for manned aircraft. Coordination and transfer (COTR) of GH flights shall be carried out in accordance with normal coordination and transfer procedures. Vectoring GH shall be considered if there is no better alternative (e.g. for resolving a conflict with another airspace user).

Guideline ATMGH3. ATC shall monitor GH's conformance to its clearance, irrespective of whether it is following its pre-defined 3D route or is being vectored by ATC, and issue corrective instructions as necessary.

5.2 Departure and Arrival

5.2.1 Departure and arrival of GH will normally require the establishment of segregated airspace through the levels normally occupied by conventional manned aircraft, including notification of all airspace users sufficiently in advance to activation. Where practicable, this should be undertaken in accordance with the Flexible Use of Airspace Concept.

Guideline ATMGH4. Where required for departure and arrival, segregated airspace for GH shall be established in accordance with the Flexible Use of Airspace Concept, and should extend to an altitude above the maximum normally used by conventional manned aircraft. Segregated airspace for the climb and descent phases of flight shall be pre-defined for each airfield such that it begins from the boundary of aerodrome operations to not less than FL510. Airspace users shall be notified sufficiently in advance of a forthcoming activation of segregated airspace. The climb and descent phases shall be managed using programmed 3D routes within segregated airspace.

5.2.2 If circumstances (eg sustained loss of control link) dictate an early return to base by GH, it is important that segregated airspace is activated in sufficient time to accommodate the UA during its premature arrival. In the absence of such an arrangement, it will be necessary for GH to loiter at high altitude until its pre-notified segregated airspace becomes active.

Guideline ATMGH5. Arrangements for the establishment of segregated airspace for GH should include consideration of an early return to base.

5.2.3 If necessary, GH departures and arrivals can be designed to accommodate limited segregated airspace. For example, at Beale AFB in the USA, GH climbs and descends within the confines of a vertical cylinder of segregated airspace that is 20 nm in diameter. EH is similarly capable of departing and recovering within a small amount of segregated airspace.

5.2.4 The 3D geometry of segregated airspace established for the purpose of the departure and arrival of GH shall be of sufficient dimensions to take into account the flight characteristics of GH and the nature and intensity of flying activity in the adjacent airspace. The design shall take into account the manner in which GH climbs and descends, its mission requirements, its navigation performance, the class of airspace through which it passes, and the minimum separation of the airspace.

Guideline ATMGH6. The 3D geometry of segregated airspace shall be designed to maintain separation between GH and other airspace users. The design shall take into account the manner in which GH climbs and descends, its mission requirements, its navigation performance, the class of airspace through which it passes, and the minimum separation of the airspace.

.5.2.5 Where segregated airspace is established for GH departure and arrival, air traffic service provision with surveillance radar and appropriate communications between controller and PIC is required to be available to:

a. Assist with ensuring GH remains within the segregated airspace.

b. Provide an air traffic service, including separation provision where applicable.

c. Monitor for, and contribute to the safety of, intruding aircraft.

Guideline ATMGH7. An air traffic service utilising surveillance radar and communications between controller and PIC shall be employed to support GH during departure and arrival in segregated airspace.

5.2.6 In order to at least maintain minimum separation with other aircraft operating outside segregated airspace, the planned 3D route according to the mission plan shall take account of local arrangements for the provision of a buffer,

Guideline ATMGH8. While GH is within segregated airspace, the planned 3D route (in the Mission Plan) shall take account of local arrangements for the provision of a buffer in order that at least the minimum separation is maintained with other aircraft outside segregated airspace.

5.2.7 In the event that ATC needs a GH to manoeuvre for separation during the climb or descent phase of its sortie, operating preference is for the UA to level off rather than be required to change heading.

Guideline ATMGH9. During the climb or descent phase, and subject to traffic, if ATC requires GH to manoeuvre for separation, this should be effected wherever possible by instructing the UA to level off until clear of the confliction.

5.2.8 In order to maintain adequate separation between GH and terrain and obstacles taking account of the height and track keeping performance of the GH, the planned 3D route in the mission plan shall be designed accordingly.

GuidelineATMGH10. The geometry of the 3D route (in the Mission Plan) shall be designed to maintain adequate separation between GH and terrain and obstacles taking account of the height and track keeping performance of the aircraft.

5.2.9 In case there is an operational need to have multiple GH operations using one segregated airspace at the same time, its design shall allow passing each other whilst maintaining at least the minimum separation from each other and with other aircraft outside segregated airspace.

<u>GuidelineATMGH11</u>. Segregated airspace shall be designed to allow two GHs to pass each other while maintaining at least the minimum separation from each other and other airspace users in the airspace being transited. Additionally it shall be designed to accommodate the route and climb profile for autonomous modes of flight.

5.2.10 In case planned and coordinated operations foresee more than one GH using one segregated airspace, their 4D trajectories shall be mutually deconflicted prior to departure in accordance with relevant separation minima for the airspace concerned.

<u>GuidelineATMGH12</u>. More than one GH may use the segregated airspace at the same time, in which case the mission profiles shall be planned and coordinated such that their 4D trajectories are mutually deconflicted prior to departure in accordance with relevant separation minima for the airspace concerned.

5.2.11 For initial climb and while a risk for wake vortex exists, operating with one or more GH in segregated airspace, GH shall be separated according to the appropriate wake vortex separation minima.

<u>GuidelineATMGH13</u>. During the initial climb and while a risk from wake vortices persists, GH shall be separated according to the appropriate wake vortex separation minima.

5.3 Cruise

5.3.1 Once GH is established in the cruise at high altitude, any requirement for level change is likely to be temporary. Nevertheless, experience shows that it is often more convenient for ATC to allocate altitude blocks (ie minimum and maximum flight levels) within which GH is free to manoeuvre without the PIC needing to obtain clearance every time a level change is required.

<u>Guideline ATMGH14</u>. If there is a requirement for GH to vary its level once at operating altitude, clearance for this shall be obtained by the PIC from ATC. Where convenient, ATC should issue a clearance for a GH to operate within an altitude block agreed beforehand with the PIC.

5.3.2 Within CAS, separation from other airspace users is normally achieved as part of the provision of an air traffic control service. When in CAS, therefore, GH will be separated from other traffic by ATC in line with the airspace classification, using at least the same separation minima as for manned aircraft. In uncontrolled airspace, ATC shall provide an air traffic service to GH that is sufficient to ensure separation from other airspace users.

<u>Guideline ATMGH15</u>. Separation from other airspace users shall be achieved by compliance with ATC instructions. GH shall be separated from other airspace users in accordance with the minimum separations that apply for that airspace.

5.3.3 At high altitude, GH is slow in the turn and may be unable to climb any higher. Conversely, it can descend very quickly. Therefore, in the event that ATC requires a GH to manoeuvre for separation while at high altitude, this can be achieved most readily by instructing the UA to descend. However, where separation is only possible in the horizontal plane, then the slow rate of turn of GH may dictate earlier initiation of avoiding action by ATC than would be the case for manned aircraft.

<u>Guideline ATMGH16</u>. At high altitude, and subject to traffic, if ATC requires GH to manoeuvre for separation, this should be effected by instructing the UA to descend, if safe to do so. However, where separation is only possible in the horizontal plane, ATC should take into account the slow rate of turn of GH.

5.3.4 In the rare case GH operation above FL 510 encounter additional traffic, ATC shall plan to keep such traffic away from GH in order to avoid vectoring.

<u>GuidelineATMGH17.</u> When GH is outside segregated airspace (e.g. above FL510) ATC shall plan to keep other aircraft away from GH in order to avoid having to vector GH.

5.4 Collision Avoidance

5.4.1 Collision avoidance becomes necessary when separation provision fails for whatever reason, but is not a feature of any air traffic service. In manned aviation, responsibility for collision avoidance rests with the pilot in the cockpit, and is achieved by visual lookout supplemented by an airborne collision avoidance system (ACAS) where fitted. Although GH (but not EH) is equipped with a Traffic Collision Avoidance System (TCAS), ICAO[13] considers that further safety studies and analyses are required before the operation of ACAS is permitted on any UAS. Therefore, with no pilot on board and operation of its TCAS not allowed, GH lacks a collision avoidance capability. This is instead addressed by flying it within segregated airspace at or below FL 510 or at extreme altitudes where other aircraft do not normally fly.

Guideline ATMGH18. Collision avoidance for GH shall normally be addressed by operating it either within segregated airspace at or below FL 510 or in airspace where it is isolated from other aircraft by virtue of its extreme altitude.

5.5 Strategic Deconfliction

5.5.1 While there should be no GAT to conflict with GH during the cruise portion of its flight, other manned and unmanned strategic reconnaissance assets are known to fly at the same extreme altitudes. In addition, military aircraft may occasionally venture that high under the control of air defence radars (ADR). Such other high-altitude traffic may or may not be known to ATC. As part of their mission planning, therefore, GH operators are required to liaise with nations being over-flown and with other HALE operators for the purpose of avoiding potential confliction.

Guideline ATMGH19. GH operators shall liaise with nations being over-flown and with other HALE operators for the purpose of avoiding potentially conflicting tracks at high altitude.

5.5.2 Even operating at such high altitudes does not preclude GH operations from encountering airspace that prohibits its use by other than designated purposes especially defined for such an area. GH operations shall respect such prohibited areas.

Guideline ATMGH20. The geometry of the 3D route (in the Mission Plan) shall be designed not to allow GH infringing prohibited airspace at any point during its flight.

5.5.3 From a network perspective flight planning should integrate pertinent weather information well in advance to allow for maximum mission effectiveness through avoidance of such operating areas in adverse weather.

GuidelineATMGH21. GH shall plan to avoid predicted adverse weather.

5.6 Flight Planning

5.6.1 Selection of diversion airfields for GH needs to consider the fact that the UA lacks a collision-avoidance capability, that it may be operating autonomously during its diversion, and that there is unlikely to be sufficient time in which to establish temporary segregated airspace to safeguard other airspace users. Such diversion planning should therefore take the classification of local airspace into account, with the aim of avoiding or reducing to an absolute minimum any flight by GH through non-segregated, uncontrolled airspace.

Guideline ATMGH22. In the absence of local segregated airspace, diversion airfields shall be selected so, where practicable, that the programmed 3D route (in the Mission Plan) will avoid *uncontrolled* airspace while at or below FL510 for *normal* and *abnormal* situations.

5.6.2 All flights by GH in European airspace will be the subject of flight plans submitted to the relevant ATC authorities in accord with the same flight-planning conventions that apply to manned aircraft. An example of a past GH flight plan is provided at Annex I, albeit some details such as

[13] ICAO Doc 9863 – ACAS Manual (1st Edition 2006).

telephone numbers, destination, etc, have been removed. Although the example shows the aircraft identification at Field 7 as RQ4A, GH is not listed in ICAO Doc 8643 (Aircraft Type Designators). It is therefore common practice by GH operators to enter ZZZZ at Field 7 and then explain in Remarks at Field 18 that this equates to an RQ4A aircraft.

5.6.3 Routine communication between ATC and a GH PIC will be by radio. Notwithstanding, the flight plan will need to contain a telephone number to enable ATC to contact the PIC if required during a GH mission.

5.6.4 Divert-alternate and emergency-alternate airfields will be included in a GH flight plan.

5.6.5 Where required, diplomatic clearance remains the responsibility of the GH operator.

Guideline ATMGH23. All flights by GH in European airspace shall be notified to ATC by submission of a flight plan. This shall contain relevant supplementary information, including a telephone number to enable ATC to contact the GH PIC if required during the mission.

5.7 Communications, Navigation and Surveillance (CNS) Functionality

Outwith data-link requirements for command and control, CNS functionality for GH should in general accord with the airspace it flies in.

5.7.1 Reduced Vertical Separation Minima (RVSM)

5.7.1.1 Should GH ever need to fly in RVSM airspace (eg in emergency), it should be treated as none-compliant with RVSM.

5.7.2 ACAS

5.7.2.1 See para 5.4.1 for reference to use of ACAS with regard to GH.

5.7.3 Navigation

5.7.3.1 GH navigation is via inertial navigation with integrated Global Positioning System (GPS) and Differential GPS updates that is accurate to <5m. GH will normally fly the planned mission route from its onboard mission file, although this does not preclude the PIC from intervening and changing the route (but not the mission plan) as required.

5.7.3.2 GH lacks the ability to fly itself to a point that does not exist in its mission plan (ie it cannot fly to somewhere it does not know about). In addition, the mission file will not be programmed with routine navigation features (eg airways, navaids, waypoints, reporting points, etc) that comprise a conventional GAT route structure. Therefore, an instruction from ATC to route directly to such a navigation feature will require interpretation and intervention by the PIC.

5.7.4 Transponder

5.7.4.1 It is essential that GH is fitted with an operable transponder that will allow its PIC to respond to ATC requests to alter code settings and squawk identification. In the event that a transponder becomes inoperative, the mission may be cancelled and/or recalled at the discretion of the GH operator in discussion with ATC. In any case the PIC has to inform ATC of GH's intention as well as its position and altitude / FL.

Guideline ATMGH24. GH shall be fitted with an operable transponder that will allow its PIC to respond to ATC requests to alter code settings and squawk identification. In the event of transponder failure, the PIC shall inform ATC of GH's intentions and shall provide position and altitude / FL information if required. The mission may be recalled on the basis of agreement between GH operator and ATC through (re-)activated segregated airspace.

5.7.5 Radio

5.7.5.1 GH and its control stations must be fitted with radios and supporting architecture to enable the PIC to communicate with ATC on published ATC frequencies.

<u>Guideline ATMGH25</u>. The GH UAS shall be equipped with radios to enable the PIC to communicate with ATC on published ATC frequencies.

5.8 Radio Communications between Pilot-in-Command and ATC

5.8.1 Under normal operating conditions, the command and control link as well as the communication link between the PIC and ATC shall not suffer from significant delay, potentially affecting the safety of GH.

<u>GuidelineATMGH26.</u> Neither the command and control link between the pilot-in-command, nor the voice communications link between the pilot-in-command and ATC shall suffer from significant delay under normal conditions that could affect the safety of GH.

5.8.2 While in receipt of an air traffic service, the GH pilot-in command is required to maintain 2-way communications with the appropriate ATC authorities, and to make all position and other reports as required.

5.8.3 Extant ATC phraseology is adequate for the provision of an air traffic service to GH, except that a GH PIC must include the word 'unmanned' on first contact with an ATC unit to ensure the controller is aware the aircraft is a UAS.

<u>Guideline ATMGH27</u>. While in receipt of an air traffic service, a GH pilot-in command shall maintain 2-way communications with ATC, using standard phraseology when communicating via RTF. The word 'unmanned' shall be included on first contact with an ATC unit.

5.9 Pilot-in-Command

5.9.1 Notwithstanding the programmed nature of a typical GH mission, the PIC remains central to the ATM established for GH flying in European airspace, and to ensuring flights take place safely and with negligible impact on other airspace users.

5.9.2 Pilots of manned aircraft make position reports to ATC in accord with the requirements of ICAO[14] and national AIPs, which *inter alia* ensures that such reports are readily understood by controllers. It is necessary for GH pilots-in-command to do likewise, notwithstanding that GH normally flies via a series of waypoints which may not be related to a conventional GAT route structure.

<u>Guideline ATMGH28</u>. GH pilots-in-command shall conduct position reporting to ATC in terms that are readily understandable to controllers and that accord with procedures and phraseology contained in ICAO PANS-ATM (Doc 4444).

5.9.3 European airspace is complex and busy, and is served by a large number of ANSPs. This may be less relevant while GH is in the cruise, but will become very much more so in the event of an emergency that results in a GH having to descend through levels occupied by manned aviation. It is therefore necessary that GH pilots-in-command understand not only the airspace that GH will fly in during its high-altitude cruise but also the nature of the airspace which lies beneath, including corresponding (if existing) buffers.

<u>Guideline ATMGH29</u>. GH pilots-in-command shall have a full understanding of both the airspace that GH will fly in at high altitude, the corresponding buffers (if existing) and the airspace which lies beneath.

5.9.4 GH must be monitored continuously by its pilot-in command for adherence to the current approved flight plan. Any requests for deviations from the flight plan must be made using established procedures to the appropriate ATC authorities.

[14] Annex 10 – Aeronautical Telecommunications – Communications Procedures; PANS-ATM (Doc 4444); and Doc 9432 – Manual of Radiotelephony.

<u>Guideline ATMGH30</u>. The pilot-in-command shall monitor GH's conformance to its clearance, irrespective of whether it is following its pre-defined 3D route or is being vectored by ATC, and apply corrections to the flight trajectory as necessary.

5.9.5 Any handover of control between pilots-in-command - whether at the same control station or located elsewhere - must include information on the ATC situation.

<u>Guideline ATMGH31</u>. Information on the ATC situation shall be included in any formal handover of control between pilots-in-command.

5.9.6 As the transited airspace of GH operations might change after mission plan is concluded, the programmed 3D route, due to recent published and activated segregated airspace, should regularly be check by the PIC, in order to have GH not pass through such airspace.

<u>Guideline ATMGH32.</u> The pilot-in-command shall check regularly that GH's programmed 3D route will not pass through segregated airspace that has been published and activated for other flights after the time that GH's Mission Plan was uploaded.

5.9.7 GH should not deviate from its cleared route without permission.

<u>Guideline ATMGH33.</u> While receiving a separation service, deviations from the primary route (such as an early return to the departure/arrival aerodrome) shall require permission from ATC, where practicable.

6 EUROCONTROL GUIDELINES - EMERGENCIES

6.1 General

6.1.1 It is in the context of emergencies that GH contrasts most starkly with manned aviation. The UA lacks a collision-avoidance capability in the event that it is forced to descend through airspace where other airspace users are flying, and, if the control link is lost, the UA reverts to autonomous flight which the PIC is unable to influence. Nevertheless, the following considerations apply:

- GH tracks will be coordinated and agreed beforehand with ANSPs.
- All divert-alternate and emergency-alternate airfields will be subject to prior negotiation and agreement.
- All divert-alternate and emergency-alternate airfields will be included in the flight plan.
- Procedures to be followed in the event of GH needing to make an emergency landing will be coordinated beforehand with relevant ANSPs.
- Although the response of GH to emergency contingencies is programmed into its mission computer, the PIC can override this provided the control link is working.
- Landline telephones provide a back-up means of voice communication between ATC and the PIC.
- In the event of autonomous flight, the PIC will know exactly what GH is programmed to do and will apprise ATC of this immediately by RTF if available or otherwise by telephone.
- ICAO procedures already cater for manned aircraft making emergency descents and/or emergency landings in circumstances that limit or prevent the pilot from undertaking collision-avoidance.

6.1.2 It is not possible to detail all the possible emergencies that might confront a GH during a mission. However, those involving loss of radio communication with ATC, loss of control link, emergency landing and flight termination are addressed below.

6.2 Loss of Radio Communications with ATC

6.2.1 Standard radio communications procedures for flights in instrument meteorological conditions according to ICAO Doc 4444 shall be followed in case of a loss of voice communication link between the PIC and ATC.

<u>Guideline ATMGH34</u>. In the event of loss of voice communication between the pilot-in-command and ATC, standard radio communications failure procedures shall be followed (described in ICAO's PANS ATM doc 4444) for a flight in instrument meteorological conditions.

6.2.2 Loss of radio communications between the PIC and ATC may or may not happen in conjunction with loss of control link. Regardless, it can be circumvented by use of alternative means of communication, ie telephone, to agree a course of action. Thus, in addition to ATC being provided with a telephone number for the PIC via the flight plan, it is a requirement for GH pilots-in-command to hold the telephone numbers of duty supervisors at the air traffic control units that are expected to provide an air traffic service to the UA. A test call must be made to these numbers by GH operators within the 7 days prior to each flight.

Guideline ATMGH35. GH pilots-in-command shall hold the telephone numbers of duty supervisors at the air traffic control units that are expected to provide an air traffic service to their UA, and these numbers shall be tested within 7 days prior to flight.

6.3 Loss of Control Link

6.3.1 Although capable of flying a mission entirely automatically, from take-off to landing, GH is intended to be managed from the ground via a control link between UA and PIC. The link is normally continuous but may be interrupted or lost, and procedures are required to cater for this. However, any such loss may be very fleeting, in which case it is important that an autonomous lost-link procedure does not initiate immediately. Instead, a communications timer starts when the link is lost. This is variable, and is pre-set to reflect the airspace the UA is flying in; the timer delay may be brief over populated landmasses but longer in mid-ocean. On expiry of the timer delay, GH will automatically initiate its programmed lost-link procedure.

6.3.2 If a manned aircraft begins to malfunction, its pilot - prompted by instruments and/or sensory cues - is well-placed to notice. In contrast, the PIC of a GH is dependant upon a continuous flow of information from the UA in order to be able to monitor its health. It is therefore essential that any interruption in the flow of this information is made immediately apparent to the PIC.

Guideline ATMGH36. The UAS shall provide up to date health information, which shall include up-to-date health information on the aircraft's systems, including the transponder and on the main functions that allow GH to complete its mission including, as a minimum, propulsion, flight control and navigation.

6.3.3 Normal operating procedure for GH on losing its control link is to continue on current routing until the communications timer expires. At that time, GH will autonomously squawk 7600 (ie 'RCF') and proceed on its programmed lost-link routing. Such lost-link routing will be set to avoid deviation from the normal routing whenever feasible.

6.3.4 As soon as possible after becoming aware that the control link has been lost, the PIC must notify ATC - via RTF if available but otherwise by telephone - of the situation and the expected actions of the GH at the expiration of the communications timer.

6.3.5 If the link is regained, the PIC will generally return the GH to its programmed mission, while advising ATC the link has been regained and what to expect the GH to do next.

Guideline ATMGH37. Normal operating procedure for GH in the event of loss of control link shall be for the UA to continue flying its current routing until the communications timer expires. As soon as possible, the PIC shall alert ATC to the situation and to the expected actions of the GH at the expiration of the communications timer. At that time, GH will autonomously squawk 7600 and proceed along its programmed lost-link routing.

6.3.6 To ensure ATC is forewarned, it is necessary that the profile to be followed by GH in the event of loss of control link is coordinated beforehand with relevant ANSPs.

Guideline ATMGH38. The profile to be followed in the event of loss of control link shall be coordinated beforehand by GH operators with the relevant ANSPs. This programmed profile shall follow a route that will minimise the risk to other airspace users and persons on the ground

6.3.7 In the event of loss of control link, the PIC will lose positional information from the UA. Its actions remain predictable, however, because the PIC will know what the UA is programmed to do in such circumstances. More problematic is the related loss of health information from the UA. Thus, if further malfunctions develop, the PIC will most likely be unaware, which is when ATC feedback becomes especially important.

6.3.8 If a GH already suffering loss of control link develops further malfunctions that dictate an emergency landing, it will autonomously change its squawk to 7700 (ie 'Emergency'). On seeing such a squawk change, it is essential that ATC notify the PIC as soon as possible.

Guideline ATMGH39. In the event that a GH known to be suffering loss of control link is seen by ATC to change its squawk to 7700, ATC shall notify the PIC as soon as possible.

6.3.9 If a GH is seen to change squawk from 7600 to 7700, ATC should anticipate the UA beginning a descent and making an immediate turn towards its programmed divert airfield.

6.4 Emergency Landing

6.4.1 Normally, as GH progresses along its planned route, it constantly updates its emergency-alternate airfield based on programmed logic. An element of this logic is that, in the event of a malfunction sufficiently severe to require an emergency landing and which entails reversion to battery power, the latter dictates the landing must be achieved within 45 minutes. Another factor is the glide rate for a GH with gear up and engine out and wind-milling, which is approximately 1:25 (or 1000 ft per 4.11 nm). Emergency fields are therefore planned within 125 nm of track to account for winds and 45 minutes of battery life.

6.4.2 Where practicable, using the departure and or arrival aerodrome as divert alternate or emergency alternate should be planned. The programmed descent route shall be within segregated airspace.

Guideline ATMGH40. The programmed divert-alternate and emergency-alternate airfields shall be the departure/arrival aerodrome where possible, and the programmed descent route shall, where, practicable, be within segregated airspace.

6.4.3 If the PIC gets warning of an impending malfunction, he may elect to perform a precautionary landing before failure actually takes place, in which case he will change the GH squawk to 7700 (ie 'Emergency') if so directed by ATC as well as inform ATC about the programmed intentions of GH. Otherwise, if the malfunction occurs without prior warning, GH will initiate an automatic turn towards its currently selected emergency-alternate airfield and will immediately squawk 7700.

Guideline ATMGH41. In the event of GH suffering a failure requiring an emergency landing, the UA shall be programmed to squawk 7700.

6.4.4 The challenge for ATC in these circumstances, in addition to providing assistance to the GH PIC, is to safeguard other airspace users as GH descends through their levels, especially given the absence of any onboard collision avoidance capability. It will therefore present as a major ATC emergency, albeit not uniquely so, since ICAO already prescribes action to be taken by ATC in the event that a manned aircraft makes an emergency descent through other traffic. This requires that 'all possible action shall be taken immediately to safeguard all aircraft concerned'[15].

6.4.5 The activation of temporary segregated airspace at minimal or no notice to accommodate the emergency landing of a GH is not regarded as practicable because of the difficulty of notifying other airspace users in sufficient time.

6.4.6 If the engine is out, or there is a major electrical failure, GH will revert to battery power. If the UA is following an emergency descent flight path under engine power, the engine will be shut off and the aircraft will revert to battery power at or before the mission-planned Initial Approach Fix (IAF).

6.4.7 If GH reverts to battery power, this provides power to flight-critical equipment during an emergency glide. However, flight-critical equipment does not include radio receive/transmit capability, so all communication between the GH PIC and ATC will be via telephone. Ideally GH shall be within glide distance of an emergency-alternate airfield at all times during its flight. These shall be considered for coordination with the States concerned before departure.

6.4.8 It should be possible for the PIC to be able to intervene in management of the descending GH at any time provided there is no failure of the control link. However, if GH is taken off its

[15] ICAO PANS-ATM (Doc 4444), para 15.1.4.

programmed C3 routing, the UA will not have enough energy to glide to the airfield. Such deviation should be avoided unless there is absolutely no other option, since it will almost certainly result in loss of the GH with consequent risk to people on the ground.

6.4.9 Forewarned is forearmed. It is essential that ANSPs are aware beforehand of what will happen and what is required of ATC in the event of GH needing to make an emergency landing.

<u>Guideline ATMGH42</u>. GH operators shall ensure that procedures to be followed in the event of GH needing to make an emergency landing are coordinated beforehand with relevant ANSPs. Where practicable, GH shall be within glide distance of an emergency-alternate airfield at all times during its flight. This shall be considered when coordinating with the States concerned before departure. Furthermore, while GH's divert-alternate or emergency-alternate airfield is still the departure aerodrome segregated airspace shall remain activated.

6.4.10 In the event of a GH malfunction that requires an emergency landing, the emergency should be declared by the PIC on the ATC radio frequency in use at the time if the radio is still available. If the radio is not available, the PIC should immediately telephone the duty supervisor of the relevant air traffic control unit with details of the emergency. Thereafter, the PIC and the duty supervisor should agree on how to best maintain communications until the emergency is resolved.

6.4.11 There is no standard emergency message[16]. However, the initial call (radio and telephone) by the GH PIC to ATC should include all the essential details required by ATC to safeguard other airspace users and to support the safe recovery of the UA, eg divert/emergency airfield, expected track, distance to touchdown, estimated landing time, etc.

<u>Guideline ATMGH43</u>. In the event of a GH malfunction that requires an emergency landing, the emergency shall be declared by the PIC on the ATC radio frequency in use at the time if the radio is still available. If the radio is not available, the PIC shall immediately telephone the duty supervisor of the relevant air traffic control unit with details of the emergency, and, as soon as practicable, the PIC shall inform ATC what GH is going (programmed) to do.

6.5 Flight Termination

6.5.1 GH has a flight-termination capability which, if activated by the PIC, will shut down the engine and set the controls to spin to impact. This requires a functioning control link, which means that if the control link is lost, the flight cannot be terminated. However, the likelihood of the PIC needing to initiate such flight termination is extremely remote.

6.5.2 Different and separate from the flight termination capability, a GH mission plan can include *termination points*. These are designated ground impact points for use when it is determined the UA is uncontrollable for landing or a landing at a suitable airfield cannot be made safely without undue risk to persons or property on the ground.

<u>Guideline ATMGH44</u>. GH shall be within glide distance of a termination point at all times during its flight. These shall be coordinated with the States concerned beforehand.

6.5.3 Where practicable, such termination points shall be near to the departure / arrival aerodrome and the programmed descent route shall be inside segregated airspace. Such termination points are the subject of coordination with host nation authorities. Likewise to emergency landing, it is essential that especially ANSPs are aware beforehand of what will happen and what is required of ATC in the event of GH needing to make use of the *termination point* procedure.

[16] ICAO PANS-ATM (Doc 4444), para 11.4.1.1.

<u>Guideline ATMGH45</u>. Where practicable, a termination point shall be near to the departure/arrival aerodrome, and the programmed descent route shall, where practicable, be inside segregated airspace.

6.5.4 If GH is not able to reach a designated termination point, the PIC will direct the UA to an unpopulated area and initiate flight termination or allow it to crash on course. In case the 3D route for a divert / emergency alternate aerodrome or a *termination point* is outside activated segregated airspace, the route shall avoid congested airspace where practicable.

<u>Guideline ATMGH46.</u> If the 3D route for a divert-alternate or emergency-alternate airfield or a termination point is outside activated segregated airspace, the route shall avoid congested airspace, where practicable.

7 SAFETY MANAGEMENT

7.1 Safe Operation

7.1.1 The unit cost and expected lifetime of each GH is comparable to that of similar manned reconnaissance aircraft. It can therefore in no way be regarded as a disposable asset, notwithstanding the absence of an onboard pilot. Instead, its design, manufacture and operation are all intended to ensure that missions are completed safely and successfully, and without risk to other airspace users or people on the ground.

7.2 National Responsibility

7.2.1 Notwithstanding the safety assurance process conducted by EUROCONTROL and described below, it remains the responsibility of each Member State - by application of its own Safety Management System (SMS) - to assure the safety of other airspace users and members of the general public with regard to the operation of GH in its national airspace.

7.3 Safety Assurance Process

7.3.1 Scope

From the point of view of the formal safety assessment, loss of GH is not a safety issue itself because it is an unmanned aircraft. Safety issues arise from the risk to humans on the ground or in other aircraft.

The safety assessment focused on the climb, high level cruise and descent phases only, and excluded aerodrome operations:

- **Climb:** from 35 feet above the aerodrome to the arrival at the initial assigned cruise altitude;
- **High altitude cruise:** any level flight segment after arrival at initial cruise altitude until the start of the descent to the destination aerodrome.
- **Descent:** the descent from the high altitude cruise to the initial approach fix (IAF).

These definitions come from standard ICAO definitions[17]. Aerodrome operations were excluded from this study.

7.3.2 Method

This safety assessment was carried out using the method described in Safety Assessment Made Easier (SAM*E*) parts one and two. SAM*E* Part 1 explains the need for a broader approach for safety assessments and therefore why SAM*E* was created, whereas SAM*E* Part 2 describes the theory and practice[18]

7.3.3 Process

The safety argument was the starting point for the process of deriving the safety performance objectives for GH. This process comprised the following steps, in the order shown:

(1) develop the safety argument; then

(2) identify the pre-existing hazards/risks – that is, those inherent in aviation in the absence of ATM and which would affect GH;

(3) identify the ATM services to address the pre-existing hazards; then

[17] CAST/ICAO, Taxonomy Team, Phase of Flight Definitions and Usage Notes, version 1.0.2, June 2010 (see www.intlaviationstandards.org).
[18] Eurocontrol, *Safety Assessment Made Easier*, Part 2, version 0.5a

(4) identify the safety performance objectives for the success case – these specify what has to be achieved by the ATM services to mitigate the pre-existing hazards and therefore to minimise the risks arising from them;

(5) identify the system-generated hazards at the service level – that is, what can go wrong with the ATM services, however caused, and assess the severity of each, taking account of any mitigations that might be available;

(6) identify safety performance objectives for the failure case – these specify how to mitigate the consequences of system-generated failures at the service level (which are captured in step (5) above), given that these failures have occurred; and

(7) compare and contrast the safety performance objectives with the management guidelines.

The focus was on setting the safety performance objectives to ensure the safe operation of GH in the first place and to reduce, as far as practicable, the safety consequences of system-generated hazards should they occur.

7.3.4 Safety Performance Objectives

Safety performance objectives describe what needs to be achieved in order that the ATM services sufficiently mitigate risk to GH. They do not state by whom or by what means this is accomplished, which is a system design issue. Safety performance objectives are described at the service level.

There are two types of safety performance objectives. One for maximising the success of the ATM services to mitigate pre-existing hazards, the other for minimising the effects of a system-generated failure at the service level. These are sometimes referred to as success and failure safety performance objectives, respectively.

These safety performance objectives of the safety assessment report were compared with the draft Management Guidelines (v0.6a).

7.3.5 Safety Performance Objectives

Two workshops were held during the early part of the project, with experts from the ATC and UAS communities.

The first workshop was particularly useful in understanding the GH concept and the operational environment. It was used to confirm the safety argument and the pre-existing hazards, and to help identify the ATM services. This was assisted by walking through a prepared scenario with the group.

In the second workshop a GH pilot was present. This workshop focussed on learning more about the GH concept, and identifying some of the hazards and mitigations.

7.3.6 Safety Performance Objectives

A report was written that documented the safety assessment work. The report details the safety method, assumptions, results and conclusions. Having carried out a comparison of the safety performance objectives and the Management Guidelines, the report made three kinds of recommendations:

- accept the management guideline without change,
- modify the description of the management guideline, and
- adopt a safety performance objective as a new management guideline

The report recommends that:

(1) the 22 new issues arising from the safety assessment are *added* to the Management Guidelines;

(2) the descriptions of 12 of the draft Management Guidelines (in version 0.6a) are *modified*, in accordance with the comments for each;

(3) the other 17 current Management Guidelines are *retained* unmodified;

(4) each GH operating authority carries out a specific safety assessment to show that the residual risk of an accident, associated with GH operations in European airspace, is acceptable compared with equivalent military, manned-aircraft operations.

7.3.7 Summary of the Safety Assessment

This qualitative safety assessment assessed the Global Hawk (GH) concept in a European operational environment.

Due to the following two aspects of the design of GH operations:

(1) the use of segregated airspace for the climb and descent phases of GH operations; and

(2) the fact that the cruise phase takes place at an altitude at which no GAT will be present and only a very limited amount of OAT traffic will be present,

the risk from GH operations *should be extremely low under normal working conditions*.

Furthermore, a set of performance safety objectives were identified that are designed to ensure that, under normal working conditions (i.e. in the absence of failure), the risk of an accident due to GH operations is reduced as far as reasonably practicable.

The assessment also identified a further set of safety performance objectives to reduce the risk of an accident in the event of a system-generated failure by mitigating the consequences of such failures as far as reasonably practicable.

It was not practicable to achieve, in what was a high-level, generic safety assessment, the specification of quantitative safety integrity requirements for the frequency of occurrence of the causes of system-generated failure. Thus, it was not possible to demonstrate generically that GH operations are at least as safe as those for manned OAT operations in non-segregated airspace. This is necessarily left to the operating authorities for GH to demonstrate for their specific GH operations.

However, the main objective of the study was to check that the draft Management Guidelines for GH (version 0.6a) were complete and correct. This objective has been achieved, by following a formal, rigorous safety approach, with the assistance of other safety experts where required, and by drawing upon the expertise of ATC and GH experts during two workshops.

A detailed comparison between the draft Management Guidelines and the safety study's safety performance objectives has lead to recommendations. The recommendations in the report have been accepted, and thus between the two pieces of work a full and comprehensive set of guidelines has been produced. Consequently the numbering used in the safety assessment report (Annex K, Appendix F) does not correspond to the final numbering of the guidelines document, as they were the outcome of this comparison.

Annex A – Operation of Global Hawk in the National Airspace System

1. Background

1.1 The operation of GH in the NAS in the USA is governed by a Certificate of Waiver or Authorization (COA) issued to the Department of the Air Force by the Federal Aviation Administration (FAA)[19]. This annex identifies the main ATM aspects of the arrangement.

1.2 In the USA, airspace is categorized as follows:

- Class A. Generally airspace from18,000ft MSL up to and including FL600.
- Class B. Generally airspace from the surface to 10,000ft MSL surrounding busy airports.
- Class C. Generally airspace from the surface to 4,000ft above airport elevation surrounding airports that have an operational control tower and are serviced by radar approach control.
- Class D. Generally airspace from the surface to 2,500ft above airport elevation surrounding airports that have an operational control tower.
- Class E. Generally, if airspace is not Class A, Class B, Class C, or Class D, and it is controlled airspace, it is Class E airspace. Class E airspace extends upward from either the surface or a designated altitude to the overlying or adjacent controlled airspace. Unless designated at a lower altitude, Class E airspace begins at 14,500ft MSL.
- Class G. Airspace not designated as Class A, B, C, D, or E.

1.3 In the USA, Special Use Airspace is airspace of defined dimensions wherein activities must be confined because of their nature, or wherein limitations may be imposed upon aircraft that are not a part of those activities. There are five types: Prohibited Area, Restricted Area, Warning Area, Military Operations Area, and Alert Area.

2. Relevant Airspace

2.1 The COA addresses the operation by GH in the NAS, outside of restricted and warning areas, including oceanic controlled airspace under the jurisdiction of the FAA.

2.2 Normal GH operations will be in special use airspace, Class A airspace or Class E airspace above FL600.

3. De-confliction from Other Traffic

3.1 ATC will provide separation between GH and other IFR traffic in Class A airspace and Class E airspace (above FL600) on the basis of a filed IFR flight plan and related ATC clearances and instructions. The Department of Defense (DoD) responsible for GH operations is responsible for deconflicting GH from possible military traffic operating VFR in Class E airspace above FL600 through prior coordination.

4. Coordination Procedures

4.1 All routine flights into the NAS must be coordinated at least 3 working days in advance with the local FAA En-route Centre. The GH Mission Commander (MC) is responsible for coordination with all affected ATC facilities to develop and/or ensure compliance with standard operating procedures. The MC is likewise responsible for coordinating with the relevant authority for the use of any special use airspace.

4.2 All routes will be coordinated with each affected ATC facility in advance. All flights will entail an IFR flight plan using standard navigational aids and five-letter identifiers and/or fix/radial/distances to identify the route of flight.

[19] DOT FAA Certificate of Waiver or Authorization issued to the Department of the Air Force, dated 13 Aug 03, signed by the Programme Director Air Traffic Plans and Procedures.

4.3 A list of telephone numbers for each ATC supervisory position responsible for airspace the GH is programmed to operate in will be prepared as part of the advance coordination action.

4.4 Contingency plans will be coordinated with ATC. Items should include possible landing sites en-route, phone numbers of GH pilot and ATC facilities, primary and backup frequencies to be used, and any other information deemed appropriate by the operator or ATC.

5 Contingencies

5.1 General. The GH flight management system is programmed, for each route segment, to autonomously perform a specific contingency mission profile in the event of specified anomalies or system/subsystem failures. In such an event, the affected ATC facility/facilities will be immediately notified of the contingency course of action that the GH will perform when a contingency route is executed.

5.2 Lost-Link Procedures. In the event of loss of the command and control data link between GH and the LRE/MCE, the GH will execute a preplanned lost-link contingency mission plan and the GH transponder will automatically change to code 7600. Because ATC voice relay is precluded whenever data links are lost, the affected ATC facility/facilities will be apprised immediately via telephone of the contingency course of action the GH will execute when a lost link occurs.

5.3 Lost Voice Communication Procedures. If direct voice radio communications between the GH pilot and ATC are lost, the GH pilot will command GH's transponder to squawk code 7600. GH will then continue to operate along its programmed route. The GH pilot will also notify ATC by telephone that the GH has lost ATC voice capability.

5.4 Mission Abort Procedures. In the event of a malfunction that jeopardizes the operational capability of a GH, the GH is programmed to autonomously return to the departure airport or a pre-selected alternate landing site. The GH pilot will ensure that appropriate ATC facilities are apprised of the emergency and return-to-base routing. If the emergency is flight critical and requires immediate recovery, the GH transponder will automatically change to code 7700.

6. Additional Special Provisions

6.1 The GH pilot will maintain 2-way radio communication with ATC in domestic airspace. In oceanic controlled airspace, the GH pilot will forward position reports to ATC via direct landline/telephone.

6.2 GH will operate external navigation and strobe anti-collision lights at all times. GH will operate with an operational transponder with Mode C altitude encoding set at the code assigned by ATC.

6.3 The Department of the Air Force, and/or its representatives, is responsible at all times for collision avoidance with non-participating aircraft and the safety of persons or property on the surface during all phases of GH's flight.

6.4 The Department of the Air Force will enter into a Letter of Agreement (LOA) with all affected ATC facilities for operations into and out of specific airports outside of restricted areas. The LOA will address operational and ATC requirements unique and specific to each location and/or airport.

Annex B – Exemplar News Item on Global Hawk

Issue 2010/04 UVS NEWS FLASH **February 19, 2010**

GLOBAL HAWK CONTINUES ROUND-THE-CLOCK RECONNAISSANCE IN HAITI
Space Daily, USA
www.spacedaily.com
February 15, 2009

The RQ-4 Global Hawk, Northrop Grumman premier unmanned reconnaissance aircraft system, continues its persistent watch over Haiti. To date, the Global Hawk has flown six missions, approximately 130 hours, and provided more than 3,600 images of Port-au-Prince and areas damaged by the massive earthquake and ensuing aftershocks that rocked the Caribbean nation earlier this year.

«Thanks to Global Hawk's highly advanced sensors, which are capable of taking hundreds of images in a single mission, we've provided disaster assessments for various agencies to make real-time decisions,» said Gen. Bob Otto, commander of the 9th Reconnaissance Wing, Beale Air Force Base, Calif.

«The ability to fly 24-hour duration sorties meant the Global Hawk could support hundreds of ad-hoc requests while staying well clear of the relief workers and neighboring airports. Truly, Global Hawk's capabilities have proven invaluable to the worldwide humanitarian efforts in Haiti.»

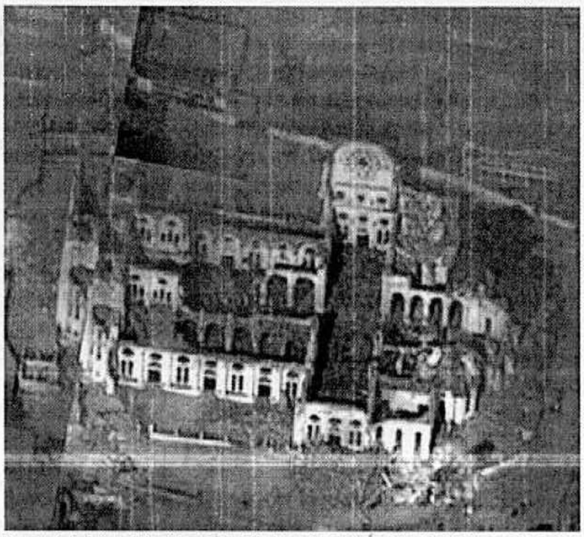
On Jan. 13, a U.S. Air Force Block 10 Global Hawk was diverted by the 12th Reconnaissance Squadron at Beale Air Force Base from its trip en-route to support usual wartime operations in Afghanistan to assist in relief efforts after Haiti's 7.0 magnitude earthquake on Jan. 12.

A Global Hawk took off from its main operating base at Beale Air Force Base, flew to Haiti, and provided 12 hours of coverage over the disaster area before landing at Patuxent River Naval Air Station, Md.

Subsequent missions were launched from Maryland to provide 14 to 16 hours of persistent watch over Haiti before landing back at Patuxent River.

«Not only has Global Hawk helped determine the extent of damages and usability of Haiti's infrastructure, it has also helped to find and recommend roadways and airfields accessible for delivering emergency supplies and rescuing injured and trapped people,» said George Guerra, Northrop Grumman vice president of high-altitude, long-endurance systems.

«We are committed to supporting the ongoing relief efforts in Haiti for as long as necessary to help rebuild the lives of those affected.»



An aerial view of the damaged National Cathedral in Haiti from a U.S. Air Force Global Hawk unmanned aircraft Jan. 14. Aerial images are providing U.S. military planners valuable situational awareness as they coordinate U.S. military support to the Haiti relief effort. Courtesy of U.S. Southern Command and Air Force.

The Global Hawk team collaborated with other agencies to assist in all aspects of recovery and relief. Officials and analysts from U.S. Southern Command in Miami, the 548th Intelligence, Surveillance and Reconnaissance (ISR) Group from Beale Air Force Base, the 480th ISR Wing from Langley Air Force Base, and the Naval Air Systems Command Broad Area Maritime Surveillance Demonstration program from Patuxent River helped provide critically needed imagery and information.

Capable of flying at altitudes up to 60,000 feet for more than 32 hours at a time at speeds approaching 340 knots, Global Hawk is equipped with an integrated sensor suite, which includes synthetic aperture radar, electro-optical and infrared sensors. Global Hawk has supported previous humanitarian relief efforts, including the southern and northern California wildfires in 2007 and 2008, respectively, as well as Hurricane Ike in 2008.

Annex C - Abbreviations

ACAS	Airborne Collision Avoidance System
ADR	Air Defence Radar
AGS	Alliance Ground Surveillance
AIP	Aeronautical Information Publication
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATM	Air Traffic Management
BAMS	Broad Area Maritime Surveillance
CAS	Controlled Airspace
CFMU	Central Flow Management Unit
CNS	Communications, Navigation & Surveillance
COA	Certificate of Waiver or Authorisation
DGPS	Differential Global Positioning System
EADS	European Aeronautics Defence and Space Company
ECAC	European Civil Aviation Conference
EH	Euro Hawk
ERAF	EUROCONTROL Regulatory and Advisory Framework
FAA	Federal Aviation Administration
FL	Flight Level
FMS	Flight Management System
GAF	German Air Force
GAT	General Air Traffic
GH	Global Hawk
GHOC	Global Hawk Operations Centre
GPS	Global Positioning System
HALE	High-Altitude Long-Endurance
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
LOS	Line-of-sight
LRE	Launch and Recovery Element
MCE	Mission Control Element
NAS	National Airspace System
NATO	North Atlantic Treaty Organization
NOTAM	Notice to Airmen
OAT	Operational Air Traffic

PIC	Pilot-in-Command
RCF	Radio Communications Failure
RLOS	Radio Line-of-Sight
RTB	Return to Base
RTF	Radio Telephony
RVSM	Reduced Vertical Separation Minima
S&A	Sense and Avoid
SATCOM	Satellite Communication
SHAPE	Supreme Headquarters Allied Powers Europe
SMS	Safety Management System
SSR	Secondary Surveillance Radar
TAGS	Tactical Auxiliary Ground Station
TCAS	Traffic Collision Avoidance System
TCDL	Tactical Common Data Link
TRA	Temporary Reserved Area
TSA	Temporary Segregated Area
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
USAF	United States Air Force
USN	United States Navy
VFR	Visual Flight Rules

Annex D - Glossary of Terms

All terms are defined within the context of Air Traffic Management.

Air Traffic Control Unit	A generic term meaning variously, area control centre, approach control unit or aerodrome control tower. (3)
Air Traffic Control Service	A service provided for the purpose of preventing collisions between aircraft/ /and expediting and maintaining an orderly flow of air traffic. (3)
Air Traffic Management	The dynamic, integrated management of air traffic and airspace including air traffic services, airspace management and air traffic flow management - safely, economically and efficiently - through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions. (3)
Autonomous Flight	UAS flight that is conducted independent of a pilot-in-command in the sense that the latter has no capability of influencing the flight path of the UAV.
Autonomy	The ability to execute processes or missions using integral decision capabilities. (2)
Collision avoidance	Averting physical contact between an aircraft and any other airborne object. (1)
Controlled airspace	A volume of air of defined dimensions within which air traffic control service is provided in accordance with the airspace classification. (3)
Control link	The combination of the command link (uplink) and the status link (downlink). (1)
Control station	One or more facilities or devices from which a UA is controlled. (2)
Divert-Alternate Airfield	An airfield that is not for routine operation but which is available if a GH cannot land at its normal operating base due to weather or temporary airfield closure.
Emergency-Alternate Airfield	An airfield which will only be used in emergency conditions.
Flight plan	Specified information provided to air traffic services units, relative to an intended flight or portion of a flight of an aircraft. (3)
Instrument flight rules	A set of procedures prescribed by the appropriate controlling authority for conducting flight operations under conditions not meeting the requirements for visual flight or in certain types of airspace.
Latency	The time incurred (or delay) between the time of an event and the time it is detected at a remote location (the latter minus the former). (4)
Operator	A person, organisation or enterprise engaged in or offering to engage in an aircraft operation. (3)
Pilot-in-command	The pilot designated by the operator/as being in command and charged with the safe conduct of a flight. (3)

Restricted Area	An airspace of defined dimensions, above the land areas or territorial waters of a State, within which the flight of aircraft is restricted in accordance with specific conditions. (5)
Sense and avoid	The principle of the capability of a UA or UAS to sense traffic which may be in conflict, evaluate flight paths, determine traffic right-of-way, and manoeuvre to avoid the traffic.
Separation provision	The maintenance of prescribed separation minima from other traffic.
Temporary Reserved Area	A defined volume of airspace normally under the jurisdiction of one aviation authority and temporarily reserved, by common agreement, for the specific use by another aviation authority and through which other traffic may be allowed to transit, under ATC clearance. (5)
Temporary Segregated Area	A defined volume of airspace normally under the jurisdiction of one aviation authority and temporarily segregated, by common agreement, for the exclusive use by another aviation authority and through which other traffic will not be allowed to transit. (5)
Unmanned aircraft	An aircraft which is designed to operate with no human pilot onboard. (2)
Unmanned aircraft system	The totality of unmanned aircraft system elements necessary to enable the servicing, maintenance, security, taxiing, take-off/launch, flight and recovery/landing of UA, and the elements required to accomplish its mission objectives. (2)

Sources:

(1) RTCA SC203.
(2) EASA.
(3) ICAO.
(4) DO-289
(5) EUROCONTROL.

Annex E – Global Hawk Block 20 - Physical Attributes and Performance Data

Dimensions

Wingspan………………………………………..	130.9 ft (39.9 m)
Length…………………………….…………..	47.6 ft (14.5 m)
Height………………………………………….	15.4 ft (4.6 m)
Gross Take-off Weight………………………….	32,500 lbs (14,628 kg)
Payload………………………………………...	3,000 lbs (1,360 kg)

Performance

Ferry Range…………………………………….	12,300 nm (22,780 km)
Maximum Altitude……………………………..	+60,000 ft
Loiter Velocity…………………………………..	310 kts True Air Speed
On-Station Endurance at 1,200 nm…………..	24 hours
Maximum Endurance…………………………..	36 hours

Communications

Ku SATCOM Datalink (Over-the-horizon)……	Command and Control/ATC Voice
Common Datalink (Line-of-sight)……………..	Command and Control/ATC Voice
UHF SATCOM (Over-the-horizon)…………..	Command and Control
IMMARSAT (Over-the-horizon).……………..	Command and Control
UHF (Line-of-sight)…………………………….	Command and Control

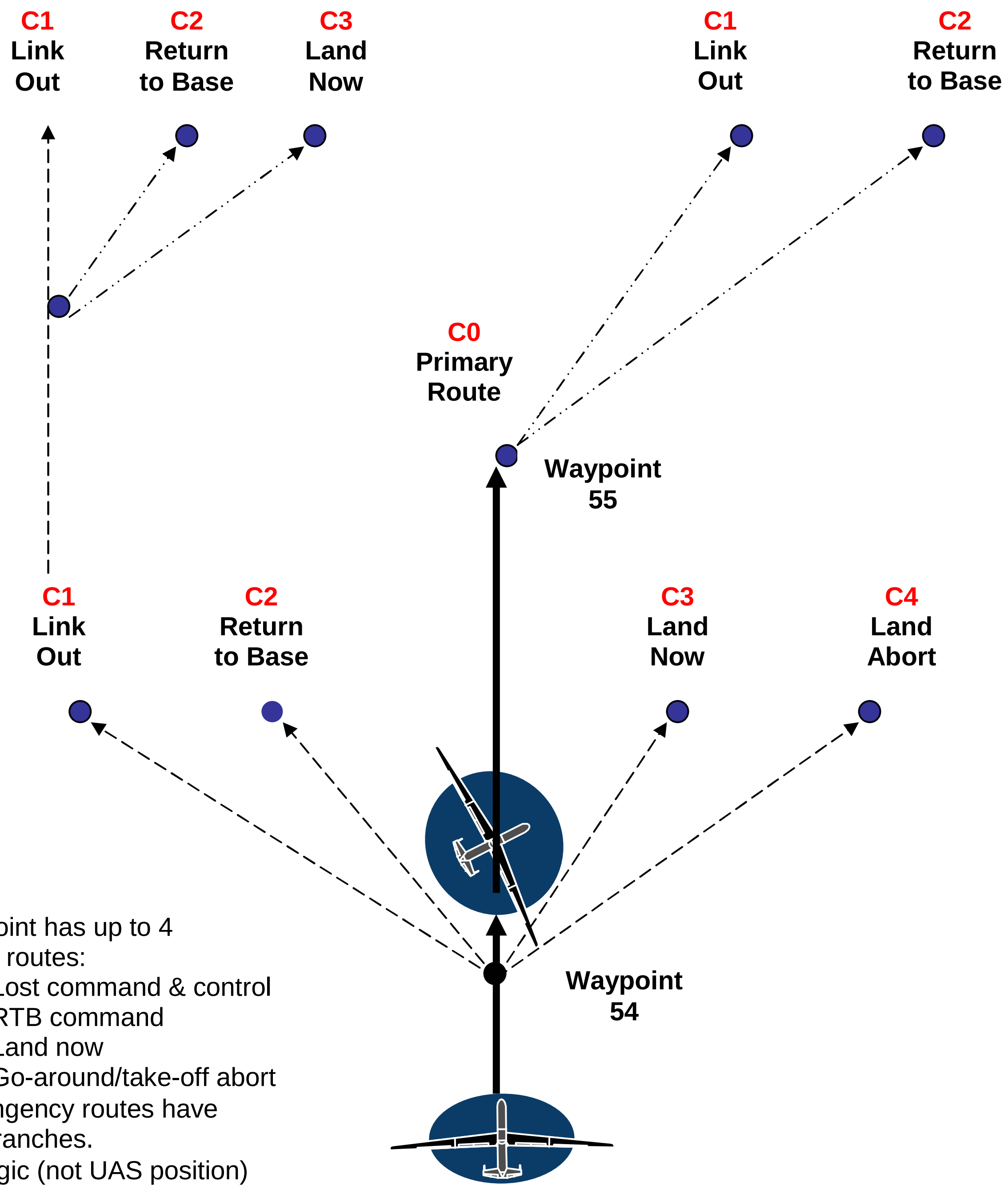
Propulsion

Rolls-Royce AE3007H turbofan, producing approximately 8000 lbs of thrust.

Sensors

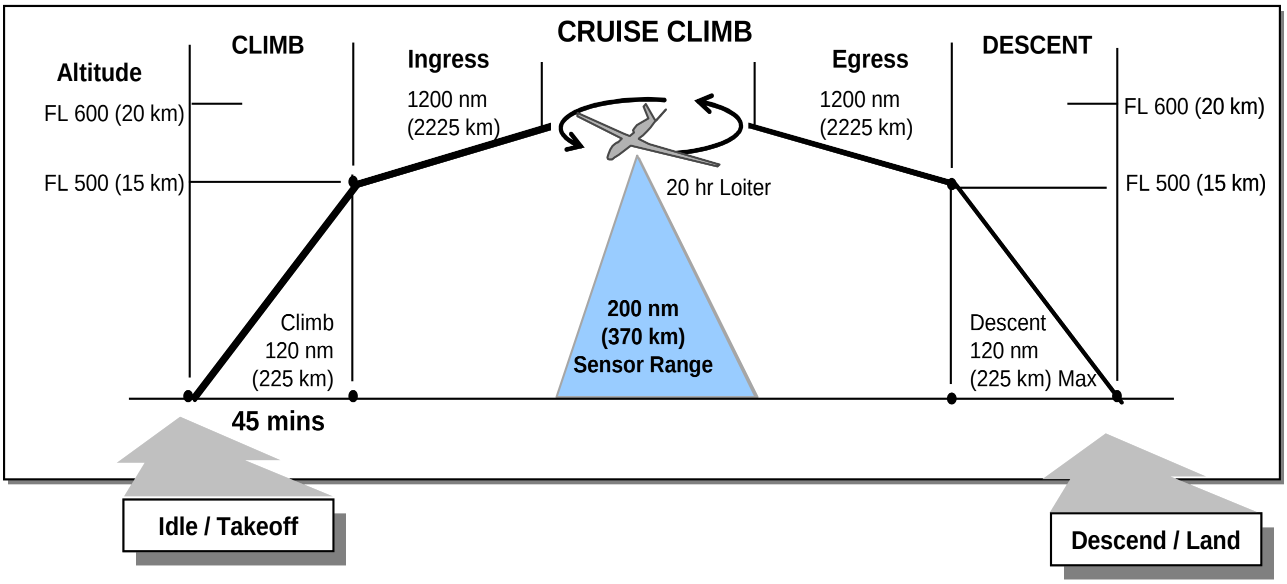
Synthetic Aperture Radar
Electro-Optical
Infrared

Annex F – GH Mission Plan and Logic



- Each way point has up to 4 contingency routes:
  - o C1 = Lost command & control
  - o C2 = RTB command
  - o C3 = Land now
  - o C4 = Go-around/take-off abort
- Some contingency routes have additional branches.
- Waypoint logic (not UAS position) determines route

Annex G – Typical GH Mission Profile



Annex H – Radio Communications Between ATC and LRE/MCE

1. The RQ4 system provides several layers of redundancy for command and control (C2) of the aircraft and communication with ATC from the ground control stations.

2. The primary means of C2 is a UHF LOS Data Link. This link is reliable out to a distance of approximately 150 nm and is required to be available when launching from the LRE. Health and status of the aircraft can also be monitored with this link.

3. The secondary method of LOS C2 is via Tactical Common Data Link (TCDL), which is a point-to-point high reliability X-band radio frequency link between the LRE and the aircraft. This link is used for transmitting and receiving the C2 data including aircraft system health and status info. It also links nose camera video back to the pilot for visual situational awareness during taxi, takeoff, and landing.

4. The primary means of communications inside the LRE is via wall mounted UHF/VHF radios. These radios are independent of the aircraft and aircraft systems. They are tuned to ATC frequencies and switched to the pilot’s headset. However, radio range using this method is somewhat limited. Therefore, an AM relay bridge can be used. AM relay uses an LRE wall radio to transmit audio to the aircraft via radio frequency where an aircraft radio receives it. A second aircraft radio is configured to bridge-relay the audio to the ATC over normal ATC frequency. This process produces acceptable audio quality, but not optimal. In the unlikely event that all aircraft communication systems fail, the LRE wall radio can be used to talk directly to local ATC within range. If that cannot be achieved, the telephone can be used as a secondary method during communications outage.

5. Other available LRE links are INMARSAT and UHF MILSATCOM. These links are only capable of C2 at this point. In the FY13-14 timeframe, wideband INMARSAT will be implemented and will support ATC voice communications.

6. In the MCE, in addition to UHF LOS and INMARSAT links for C2, the CDL and the Ku-band SATCOM have full duplex digital voice links for voice communication relay through the aircraft radio. A processor decodes the command link digital voice data to analog voice data for transmission on the UHF/VHF voice radio. The processor encodes received UHF/VHF analog voice data to digital voice data as required for downlink on the appropriate data return link. The KU-band SATCOM link is the primary method used for voice communication with ATC for GH beyond radio LOS operations from the MCE. The AN/ARC-210 UHF/VHF voice radio transmits and receives on UHF frequencies 225.000 through 399.985 and VHF frequencies 118.000 thru 136.975 MHz. Channel spacing is selectable at 8.33 Kilohertz (kHz) or 25 kHz.

Annex I - Exemplar GH Flight Plan

PRIORITY
<≡FF →

ADDRESSEE(S)
KZNYZQZX KZWYZOZX KNHKYXYX OTBHYXYX LPPOZOZX LPPOZQZX LPPCZQZX
LPAMYWYD LPPTYWYA LPAMYWYA LECMZQZX LECBZQZX LEACZQTE LFRRZQZX
LFMMZQZX LFPJZXVB
LFPJYWZQ LIRRZQZX LMMMZQZX LGGGYXYK LGGGZQZX LCCCZQZX LLBGZYZY LLTAZDZX
LLBGYDYX OJACZQZX ORBBZQZX EBBDZMFP LFPYZMFP KBABYXYX

<≡

FILING TIME

ORIGINATOR

SPECIFIC IDENTIFICATION OF ADDRESSEE(S) AND/OR ORIGINATOR______

3. MESSAGE TYPE: <≡(FPL
7. AIRCRAFT IDENTIFICATION: — HAWK10
8. FLIGHT RULES: — I
TYPE OF FLIGHT: M <≡
9. NUMBER: —
TYPE OF AIRCRAFT: RQ4A
WAKE TURBULENCE CAT.: / M
10. EQUIPMENT: — GINUV / C <≡
13. DEPARTURE AERODROME: KNHK
TIME: 1745
15. CRUISING SPEED: — N0330
LEVEL: F570
ROUTE: → DCT PXT090020 PXT178033 PXT179079 PXT161087
SWL140077 SWL118119 DCT 3750N07100W 3803N07000W 3837N06700W 3900N06419W 40N060W
4030N05500W 4056N05000W 4110N04500W 4111N04000W 41N035W 4032N03000W 3952N02500W
DCT KOMUT SONAP OSLAD ORTOP UT100 ETOIL TABOT DCT 3830N00923E DCT MEGAN UM732 UPLIT
UN46 EVIRA UN4 ARLOS DCT SALUN METRU GUDIS KAVOS DCT 3250N03143E 3219N03403E
3150N03530E 3120N03544E 3133N03631E 3218N03916E DCT

16. DESTINATION AERODROME: — ZZZZ
TOTAL EET HR/MIN: 1722
ALTN AERODROME: → XXXX
2ND ALTN AERODROME: <≡

18. OTHER INFORMATION
— EET/KZNY0128 LPPO0538 LPPC0902 LECM1008 LECB1058 LFMM1159 LIRR1230
LMMM1324 LGGG1447 LCCC1552 LLLL1630 OJAC1650 ORBB1722
RMK/MDCN LL US040654 OJ US 09-0613-HAWK10
RMK/REMOTELY PILOTED AIRCRAFT GLOBAL HAWK
RMK/PILOT TELEPHONE NUMBER x xxx xxx-xxxx
RMK/REQUEST BLOCK ALTITUDE FL510B600
RMK/FLIGHT PLAN CONTINUES AFTER ORBB FIR TO DEST/OMAM
REG/022013 OPR/USAF DOF/090618 STS/NONRVSM

NOT FOR TRANSMISSION

19. SUPPLEMENTARY INFORMATION
ENDURANCE — FUEL / 30+00
PERSONS ON BOARD → POB / 0
EMERGENCY AND SURVIVAL EQUIPMENT → RDO / 121.5 → 243 → ~~500~~ → ~~8364~~ <≡
TYPE OF EQUIPMENT | LIFE JACKETS | RADIO FREQUENCY
~~POLAR~~ → ~~DESERT~~ → ~~MARITIME~~ → ~~JUNGLE~~ → ~~GLOBAL~~ → ~~JACKETS~~ → ~~LIGHT~~ → ~~FLUORESCENT~~ → <≡
DINGHIES | COLOR | NUMBER | TOTAL CAPACITY | OTHER EQUIPMENT
~~DINGHIES~~ → ~~COVER~~ → RMK /)

REMARKS WX Briefed by ____ @ ____
NOTAMS CHECKED ______

AIRCRAFT SERIAL NUMBERS AND TYPE OF AIRCRAFT IN FLIGHT

CREW LIST ATTACHED LOCATED AT: 12RS/GHOC
PASSENGER MANIFEST ATTACHED LOCATED AT: 12RS/GHOC

NAME OF PILOT IN COMMAND	SIGNATURE OF APPROVING AUTHORITY	AIRCRAFT HOME STATION OR ORGANIZATION
ON FILE KBAB x xxx-xxx-xxxx		9WG BEALE AFB

Note: Some details such as destination aerodrome and pilot telephone number have been omitted.

Annex J - EUROCONTROL ATM Guidelines for GH in European Airspace

GUIDELINES - ATM

ATM MODE OF OPERATION

ATMGH1. For ATM purposes, the primary mode of operation of GH shall be automatic and shall entail oversight by the PIC, who shall at all times be able to intervene in the management of the flight. A back-up mode of operation shall enable the GH to revert to autonomous flight in the event of loss of the control link between the PIC and the UA.

ATMGH2. All GH sorties flown in accord with these ATM guidelines shall be classified as IFR/OAT. Separation minima shall be at least the same as for manned aircraft. Coordination and transfer (COTR) of GH flights shall be carried out in accordance with normal coordination and transfer procedures. Vectoring GH shall be considered if there is no better alternative (e.g. for resolving a conflict with another airspace user).

ATMGH3. ATC shall monitor GH's conformance to its clearance, irrespective of whether it is following its pre-defined 3D route or is being vectored by ATC, and issue corrective instructions as necessary.

DEPARTURE AND ARRIVAL

ATMGH4. Where required for departure and arrival, segregated airspace for GH shall be established in accordance with the Flexible Use of Airspace Concept, and should extend to an altitude above the maximum normally used by conventional manned aircraft. Segregated airspace for the climb and descent phases of flight shall be pre-defined for each airfield such that it begins from the boundary of aerodrome operations to not less than FL510. Airspace users shall be notified sufficiently in advance of a forthcoming activation of segregated airspace. The climb and descent phases shall be managed using programmed 3D routes within segregated airspace.

ATMGH5. Arrangements for the establishment of segregated airspace for GH should include consideration of an early return to base.

ATMGH6. The 3D geometry of segregated airspace shall be designed to maintain separation between GH and other airspace users. The design shall take into account the manner in which GH climbs and descends, its mission requirements, its navigation performance, the class of airspace through which it passes, and the minimum separation of the airspace.

ATMGH7. An air traffic service utilising surveillance radar and communications between controller and PIC shall be employed to support GH during departure and arrival in segregated airspace.

ATMGH8. While GH is within segregated airspace, the planned 3D route (in the Mission Plan) shall take account of local arrangements for the provision of a buffer in order that at least the minimum separation is maintained with other aircraft outside segregated airspace.

ATMGH9. During the climb or descent phase, and subject to traffic, if ATC requires GH to manoeuvre for separation, this should be effected wherever possible by instructing the UA to level off until clear of the confliction.

ATMGH10. The geometry of the 3D route (in the Mission Plan) shall be designed to maintain adequate separation between GH and terrain and obstacles taking account of the height and track keeping performance of the aircraft.

ATMGH11. Segregated airspace shall be designed to allow two GHs to pass each other while maintaining at least the minimum separation from each other and other airspace users in the airspace being transited.

ATMGH12. More than one GH may use the segregated airspace at the same time, in which case the mission profiles shall be planned and coordinated such that their 4D trajectories are mutually deconflicted prior to departure in accordance with relevant separation minima for the airspace concerned.

ATMGH13. During the initial climb and while a risk from wake vortices persists, GH shall be separated according to the appropriate wake vortex separation minima.

CRUISE

ATMGH14. If there is a requirement for GH to vary its level once at operating altitude, clearance for this shall be obtained by the PIC from ATC. Where convenient, ATC should issue a clearance for a GH to operate within an altitude block agreed beforehand with the PIC.

ATMGH15. Separation from other airspace users shall be achieved by compliance with ATC instructions. GH shall be separated from other airspace users in accordance with the minimum separations that apply for that airspace.

ATMGH16. At high altitude, and subject to traffic, if ATC requires GH to manoeuvre for separation, this should be effected by instructing the UA to descend, if safe to do so. However, where separation is only possible in the horizontal plane, ATC should take into account the slow rate of turn of GH.

ATMGH17. When GH is outside segregated airspace (e.g. above FL510) ATC shall plan to keep other aircraft away from GH in order to avoid having to vector GH.

COLLISION AVOIDANCE

ATMGH18. Collision avoidance for GH shall normally be addressed by operating it either within segregated airspace at or below FL 510 or in airspace where it is isolated from other aircraft by virtue of its extreme altitude.

STRATEGIC DECONFLICTION

ATMGH19. GH operators should liaise with nations being over-flown and with other HALE operators for the purpose of avoiding potentially conflicting tracks at high altitude.

ATMGH20. The geometry of the 3D route (in the Mission Plan) shall be designed to stop GH from infringing prohibited airspace at any point during its flight.

ATMGH21. GH shall plan to avoid predicted adverse weather.

FLIGHT PLANNING

ATMGH22. In the absence of local segregated airspace, diversion airfields shall be selected so, where practicable, that the programmed 3D route (in the Mission Plan) will avoid uncontrolled airspace while at or below FL510 for normal and abnormal situations.

ATMGH23. All flights by GH in European airspace shall be notified to ATC by submission of a flight plan. This shall contain relevant supplementary information, including a telephone number to enable ATC to contact the GH PIC if required during the mission.

COMMUNICATIONS, NAVIGATION AND SURVEILLANCE FUNCTIONALITY

ATMGH24. GH shall be fitted with an operable transponder that will allow its PIC to respond to ATC requests to alter code settings and squawk identification. In the event of transponder failure, the PIC shall inform ATC of GH’s intentions and shall provide position and altitude / FL information if required. The mission may be recalled on the basis of agreement between GH operator and ATC through (re-)activated segregated airspace.

ATMGH25. The GH UAS shall be equipped with radios to enable the PIC to communicate with ATC on published ATC frequencies.

RADIO COMMUNICATIONS BETWEEN PILOT-IN-COMMAND AND ATC

ATMGH26. Neither the command and control link between the pilot-in-command, nor the voice communications link between the pilot-in-command and ATC shall suffer from significant delay under normal conditions that could affect the safety of GH.

ATMGH27. While in receipt of an air traffic service, a GH pilot-in command shall maintain 2-way communications with ATC, using standard phraseology when communicating via RTF. The word 'unmanned' shall be included on first contact with an ATC unit.

PILOT-IN-COMMAND

ATMGH28. GH pilots-in-command shall conduct position reporting to ATC in terms that are readily understandable to controllers and that accord with procedures and phraseology contained in ICAO PANS-ATM (Doc 4444).

ATMGH29. GH pilots-in-command shall have a full understanding of both the airspace that GH will fly in at high altitude, the corresponding buffers (if existing) and the airspace which lies beneath.

ATMGH30. The pilot-in-command shall monitor GH's conformance to its clearance, irrespective of whether it is following its pre-defined 3D route or is being vectored by ATC, and apply corrections to the flight trajectory as necessary..

ATMGH31. Information on the ATC situation shall be included in any formal handover of control between pilots-in-command.

ATMGH32. The pilot-in-command shall check regularly that GH's programmed 3D route will not pass through segregated airspace that has been published and activated for other flights after the time that GH's Mission Plan was uploaded.

ATMGH33. While receiving a separation service, deviations from the primary route (such as an early return to the departure/arrival aerodrome) shall require permission from ATC, where practicable

.***GUIDELINES - EMERGENCIES***

LOSS OF RADIO COMMUNICATIONS WITH ATC

ATMGH34. In the event of loss of voice communication between the pilot-in-command and ATC, standard radio communications failure procedures shall be followed (described in ICAO's PANS ATM doc 4444) for a flight in instrument meteorological conditions.

ATMGH35. GH pilots-in-command shall hold the telephone numbers of duty supervisors at the air traffic control units that are expected to provide an air traffic service to their UA, and these numbers shall be tested within 7 days prior to flight.

LOSS OF CONTROL LINK

ATMGH36. The UAS shall provide up to date health information, which shall include up-to-date health information on the aircraft's systems, including the transponder and on the main functions that allow GH to complete its mission including, as a minimum, propulsion, flight control and navigation.

ATMGH37. Normal operating procedure for GH in the event of loss of control link shall be for the UA to continue flying its current routing until the communications timer expires. As soon as possible, the PIC shall alert ATC to the situation and to the expected actions of the GH at the expiration of the communications timer. At that time, GH will autonomously squawk 7600 and proceed along its programmed lost-link routings.

ATMGH38. The profile to be followed in the event of loss of control link shall be coordinated beforehand by GH operators with the relevant ANSPs.

ATMGH39. In the event that a GH known to be suffering loss of control link is seen by ATC to change its squawk to 7700, ATC shall notify the PIC as soon as possible.

EMERGENCY LANDING

ATMGH40. The programmed divert-alternate and emergency-alternate airfields shall be the departure/arrival aerodrome where possible, and the programmed descent route shall, where, practicable, be within segregated airspace.

ATMGH41. In the event of GH suffering a failure requiring an emergency landing, the UA shall be programmed to squawk 7700.

ATMGH42. GH operators shall ensure that procedures to be followed in the event of GH needing to make an emergency landing are coordinated beforehand with relevant ANSPs. Where practicable, GH shall be within glide distance of an emergency-alternate airfield at all times during its flight. These shall be considered when coordinating with the States concerned before departure. Furthermore, while GH's divert-alternate or emergency-alternate airfield is still the departure aerodrome segregated airspace shall remain activated.

ATMGH43. In the event of a GH malfunction that requires an emergency landing, the emergency shall be declared by the PIC on the ATC radio frequency in use at the time if the radio is still available. If the radio is not available, the PIC shall immediately telephone the duty supervisor of the relevant air traffic control unit with details of the emergency, and, as soon as practicable, the PIC shall inform ATC what GH is going (programmed) to do.

ATMGH44. GH shall be within glide distance of a termination point at all times during its flights. These shall be coordinated with the States concerned beforehand.

ATMGH45. Where practicable, a termination point shall be near to the departure/arrival aerodrome, and the programmed descent route shall, where practicable, be inside segregated airspace.

ATMGH46. If the 3D route for a divert-alternate or emergency-alternate airfield or a termination point is outside activated segregated airspace, the route shall avoid congested airspace, where practicable.

Annex K - EUROCONTROL ATM Guidelines for GH in European Airspace

Global Hawk / Euro Hawk Safety Assessment Report

SAFETY ASSESSMENT FOR GLOBAL HAWK / EURO HAWK IN EUROPEAN AIRSPACE

Edition Number	**:**	**v1.00**
Edition Date	**:**	**5/11/2010**
Status	**:**	**final release**
Intended for	**:**	**DCMAC**

DOCUMENT CHARACTERISTICS

SAFETY ASSESSMENT FOR GLOBAL HAWK / EURO HAWK IN EUROPEAN AIRSPACE

Safety Assessment

Document Identifier	Edition Number:	v1.00
	Edition Date:	5/11/2010

Abstract

This qualitative safety assessment has assessed the Global Hawk / Euro Hawk concept (hereafter referred to as just GH) in a generic European operational environment.

Due to the following two aspects of the design of GH operations:

(3) the use of segregated airspace for the climb and descent phases of GH operations; and

(4) the fact that the cruise phase takes place at an altitude at which no GAT will be present and only a very limited amount of OAT traffic will be present,

the risk from GH operations *should be extremely low under normal working conditions*.

Furthermore, the safety assessment identified safety performance objectives that are designed to ensure that, *under normal working conditions* (i.e. in the absence of failure), the risk of an accident due to GH operations *is reduced as far as reasonably practicable*.

The assessment also identified a further set of safety performance objectives to reduce the risk of an accident *in the event of a system-generated failure* by mitigating the consequences of such failures *as far as reasonably practicable*. However, the generic nature of this assessment has meant that it was not practicable to quantify the absolute, residual level of risk because this would be dependent on many factors specific to particular GH operations.

The safety performance objectives have been compared and contrasted to DCMAC's draft Management Guidelines. The safety assessment recommends that the set of draft Management Guidelines are updated in accordance with the recommendations made in this report.

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DOCUMENT CHANGE RECORD

The following table records the complete history of the successive editions of the present document.

EDITION NUMBER	EDITION DATE	REASON FOR CHANGE	PAGES AFFECTED	WRITTEN BY	CHECKED BY	APPROVED BY
1.00d	7/10/2010	Draft		Steve Kirby		
1.00	27/10/2010	Final Release (draft)	Most pages	Steve Kirby	Derek Fowler Ron Pierce	Eric Perrin
1.00	5/11/2010	Final Release	A few pages: those affected by a change to SO53, a new safety performance objective: SO55, and two new assumptions.	Steve Kirby	Derek Fowler Ron Pierce	Eric Perrin

1 Introduction

1.1 Background

Global Hawk, and the European equivalent, European Hawk, are a specific type of military unmanned aerial system (UAS). Its introduction into European airspace is planned for 2010. Throughout this report the term ‘GH’ is the generic term which refers to the original Global Hawk and also the very similar European Hawk. Reference [1] gives a technical précis of the aircraft, and an image is provided in Appendix A.

A draft set of Management Guidelines [1] has been produced by Eurocontrol’s Directorate of Civil-Military ATM Coordination and Single European Sky Implementation (DCMAC) to ensure the safe operation of GH in European airspace. DCMAC has asked for a formal safety assessment to be carried out to check that the Management Guidelines are complete and correct. This report summarises this safety assessment.

1.2 Scope

From the point of view of the assessment, loss of GH is not a safety issue itself because it is an unmanned aircraft. Safety issues arise from the risk to humans on the ground or in other aircraft.

The safety assessment focuses on the climb, high level cruise and descent phases only, and excluded aerodrome operations – this is in line with the scope of the Management Guidelines [1]. Definitions for these phases are given in section 4.2.

1.3 Structure of the Report

Section two presents an overview of the concept. **Section three** introduces the method that was used to carry out the safety assessment. **Section four** focuses on the analysis and results. **Section five** compares the performance safety objectives from this study with the Management Guidelines developed by DCMAC. The conclusions are presented in **section six**, which is followed by the study’s recommendations in **section seven**.

2 GH Concept

The following bullets summarise the pertinent parts of the GH aircraft's concept of operations [1].

- Unmanned, IFR operational air traffic (OAT);
- Operated by a pilot-in-command on the ground;
- Modes of operation:
  - Automatic, with intervention by pilot-in-command if needed – this is the primary mode of operation;
  - Flown manually by the Pilot-in-command;
  - Autonomous (in the event of a control-link failure);
- No see-and-avoid capability;
- Separation:
  - The standard minimum separations apply for the given airspace;
  - Achieved by isolation from other airspace users, specifically:
    - Climb and descent in segregated airspace (which is fixed for all the GH missions, and is designed to provide standard, routine passage to/from the high level cruise);
    - High altitude cruise in non-segregated airspace;
- Subject to ATC instructions in controlled airspace;
- No automatic collision avoidance system;
- Has a working transponder;
- Pilot-in-command has voice communications with ATC;
- Autonomous action at pre-determined waypoints can occur as a result of a certain type of event and GH's logic; at each waypoint up to four contingency routes can be implemented:
  - Lost command and control;
  - Return to base;
  - Emergency landing;
  - Go around / takeoff abort[20];
- The uploaded mission plan cannot be modified after takeoff.

3 Method

This safety assessment was carried out using the method described in Safety Assessment Made Easier (SAM*E*) parts one and two. SAM*E* Part 1 explains the need for a broader approach for safety assessments and therefore why SAM*E* was created, whereas SAM*E* Part 2 describes the theory and practice [2].

3.1 ATM Safety Barrier Model

[20] Out of scope of the safety assessment – see section 1.2 above.

ATM Services exist to mitigate *pre-existing* hazards to airspace users. An ATM safety barrier model (Figure 1) is a helpful way of presenting how these services are delivered.

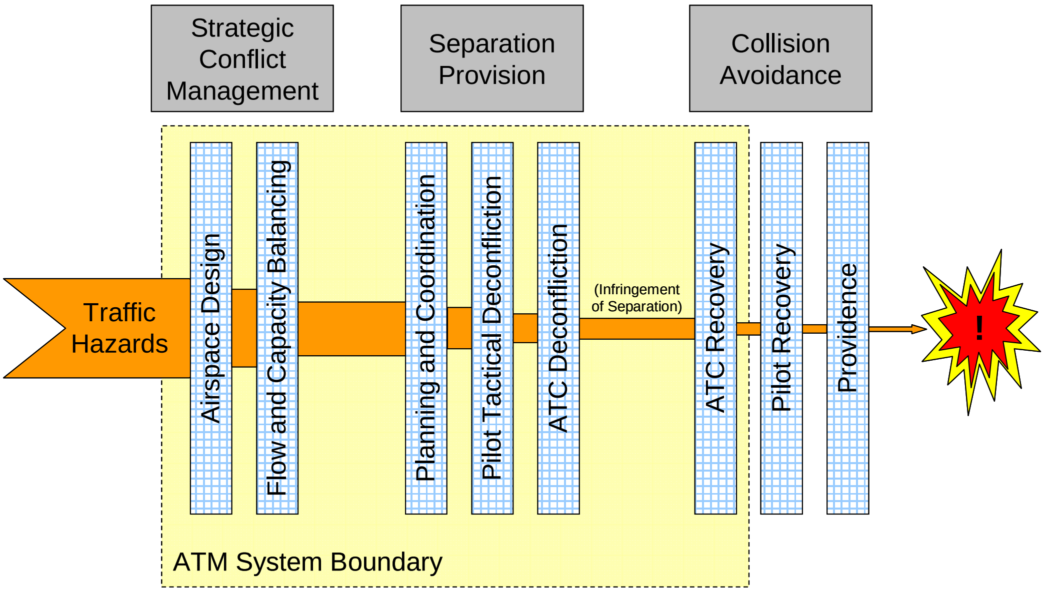

***Figure 1** – A safety barrier model for ATM.*

The inputs to the model are the pre-existing hazards that are present in aviation in the absence of ATM. In the model, the eight vertical blue-coloured bars represent the barriers (definitions for which are given in [2] and repeated verbatim below). The barriers are grouped into three different categories – Strategic Conflict Management, Separation Provision and Collision Avoidance, in line with the ICAO global ATM concept [3].

Within the *Strategic Conflict Management* layer:

- Airspace Design provides structuring of the airspace so as to keep aircraft apart spatially, in the lateral and/or vertical dimensions.
- Flow and Capacity Management mainly prevents overload of the barriers in Separation Provision although, by simply smoothing out the flow of traffic, it does in effect reduce the peak number of potential conflicts in the areas affected.

Within the *Separation Provision* layer:

- Sector Planning and Coordination involves planning the routing and timing of individual flights so that the aircraft, if they followed their planned trajectories, would not pass each other within the prescribed minimum separation. It includes the whole of the proactive role of ATC in avoiding conflicts c.f. ATC Tactical Deconfliction including coordination with adjacent sectors.
- ATC Tactical Deconfliction reflects the more reactive ATC role in monitoring the execution of the plan (see Sector Planning and Coordination) by detecting conflicts if and when they do occur and resolving the situation by changing the heading, altitude or speed of the aircraft.
- Pilot Tactical Deconfliction involves the Flight Crew detecting conflicts when they do occur and resolving the situation by changing the heading, altitude or speed of the aircraft appropriately – pre-SESAR, this barrier applies only to VFR aircraft in managed airspace and to all traffic in unmanaged airspace.

The *Collision Avoidance* layer is intended to recover the situation only for those potential accidents that Strategic Conflict Management and Separation Provision have failed to remove from the system. In general, these may be considered as:

- ATC Recovery, which represents late intervention by ATC, triggered, for example, by STCA and/or MSAW.
- Pilot Recovery, which is intervention by the Flight Crew triggered, for example, by an ACAS RA and/or GPWS.
- Providence, which is the chance that aircraft involved in a given encounter, albeit in close proximity, would not actually collide.

In Figure 1 the horizontal orange-coloured arrow represents the magnitude of the pre-existing hazards. The arrow goes deliberately from left to right, encountering barriers as it does so. As the figure shows, each barrier reduces the magnitude of these hazards. If all the barriers are breached (are ineffective) a hazard is realised, resulting in, for example, a mid-air collision. The goal is, of course, to ensure that the barriers are sufficiently numerous and/or strong that the risk becomes acceptably small.

Depending on the operation, not all barriers may be effective. Furthermore, some barriers may be more effective (*thicker*) than others. Usually, a barrier on the right hand side will only come into play if a barrier on the left hand side is breached. For example, in controlled airspace the pilot recovery barrier (pilot makes a collision avoidance manoeuvre following a TCAS resolution advisory) would follow only if the ATC Tactical Deconfliction barrier had failed.

Neither Pilot Tactical Deconfliction nor Pilot Recovery apply to GH because the UAS has no see-and-avoid capability.

3.2 The Safety Argument

3.2.1 Overview

The safety assessment process is argument-driven, and the key to the process is the safety argument. In this study the safety argument was adapted from the generic safety argument that is described in [2].

The safety argument begins with a top level *claim* that GH operations will be *acceptably safe*. This claim is decomposed into a set of arguments at the next level down, which, if all shown to be true, the top-level claim will also be true. This process of decomposition of the argument continues downwards until, at the lowest level, safety assurance objectives are identified. Each assurance objective has at least one associated safety activity. Each safety activity describes how its associated objective is to be achieved. When executed, the safety activity produces evidence to support the safety argument. Thus, if all the safety activities are completed satisfactorily, and hence all the assurance objectives are shown to have been achieved, the argument structure is such that the claim necessarily is true.

Other features at the top-level of the safety argument are the *justification for the change*, a description of the *operational environment* in which GH will find itself, the *safety targets* that the change should reach, and the high-level *assumptions* that underpin the safety assessment. These are described below.

3.2.2 The Claim

The safety argument for this study began with the top-level claim, that GH OAT operations will be acceptably safe (in accordance with the safety criteria) for the specified operational environment, given the stated assumptions.

3.2.3 Justification for Change

The justification for the introduction of GH OAT into European airspace is to meet a compelling military operational need.

3.2.4 The Operational Environment

The operational environment in which GH will operate is summarised in Table 1.

Ref.	Category	Property
P1	Airspace	GH is expected to pass through aerodrome, TMA and en-route European airspace, up to FL650.
P2	Airspace	Controlled airspace in Europe ceases at either FL460 or FL660 (with one exception, where no upper limit is specified).
P3	Airspace	Between FL195 and the upper limits given immediately above the class of airspace is Class C. There are two States that provide an exception to this rule (one has class A, the other has no classification).
P4	Airspace	GH will fly though different airspace classes, different sectors and the airspace of different European States. The rules may not necessarily be the same in each State.
P5	Separations	In airspace where there are *likely* to be other airspace users, GH will operate in *segregated* airspace.
P6	Separations	In airspace where there are *not likely* to be other airspace users, GH will operate in *non-segregated* airspace.
P7	CNS	The pilot-in-command of GH will communicate with ATC using UHF/VHF radios within line of sight of the departure/arrival aerodrome, and will have other means of communication available in case the primary means fails such as the telephone. When the pilot-in-command doesn't have line of sight to GH the primary means of communication will be via a Ku-band Satcom link.
P8	CNS	The pilot-in-command of GH commands and controls the GH aircraft using a line of sight UHF data link. This link is reliable out to a distance of about 150 NM. As a back-up, line of sight command and control is available via Tactical Common Data Link (an X band radio frequency link). Other links available are INMARSAT and UHF MILSATCOM.
P9	CNS	GH flies a pre-defined mission profile, the relevant details of which are also contained in a flight plan that is submitted in the standard ICAO format. GH may also be subject to radar vectoring by ATC from time to time.
P10	Airspace Users	GH will fly in busy European airspace and will therefore require separation from general air traffic (GAT), manned OAT and unmanned OAT.

P11	Airspace Users	According to the Central Flow Management Unit (CFMU) FL470 is the highest recorded level filed and flown by contemporary general air traffic. However, the Cessna Citation X business jet has a service ceiling of FL510.

***Table 1** – The operational environment in which GH will operate.*

3.2.5 Safety Targets

The proposed **safety targets** (Cr001) are:

The risk of an accident from GH OAT operations will be acceptably safe if the risk:

(1) is no greater than that for manned OAT operations in non-segregated airspace[21]; and

(2) will be reduced as far as reasonably practicable (AFARP), as required by ESARR 3.

Thus, this study makes a *comparative* assessment of safety rather than an *absolute* assessment (an absolute assessment being a quantitative assessment with absolute numbers).

3.2.6 Assumptions

The following high-level assumptions have been made during the course of this safety assessment:

(A1) The analysis and subsequent guidelines in this report apply equally to Global Hawk and European Hawk. The differences are the sensor package and the engine, with Euro Hawk having a slightly lower cruise altitude. The derived safety performance objectives should be robust to differences in engine performance.

(A2) Manned OAT operations in non-segregated airspace are acceptably safe, which should be a reasonable assumption given that these operations occur daily in Europe and are allowed to continue;

(A3) he controllers that provide an air traffic service to manned OAT will be those that provide a service to GH;

(A4) The maximum service ceiling of GAT in European airspace is FL510– see P11 in Table 1;

(A5) If a control link failure occurs while GH is at or above FL450, GH is 'hard-wired' to climb autonomously up to FL600, after which it is able to follow a pre-programmed route for a control link failure;

(A6) GH can be programmed to land autonomously.

3.3 Process

The safety argument was the starting point for the process of deriving the safety performance objectives for GH. This process comprised the following steps, in the order shown:

(8) develop the safety argument;

(9) identify the pre-existing hazards/risks – that is, those hazards/risks that are inherent in aviation in the absence of ATM, and which would affect GH;

[21] OAT typically climbs or descends in *non-segregated airspace* rather than segregated airspace. (Note that GH flying inside segregated airspace as an integral part of its concept of operation.)

(10) identify the ATM services to address the pre-existing hazards;

(11) identify the safety performance objectives for the success case – these specify what has to be achieved by the ATM services to mitigate the pre-existing hazards and therefore to minimise the risks arising from them;

(12) identify the system-generated hazards at the service level – that is, what can go wrong with the provision of ATM services related to GH, however caused, and assess the severity of each, taking account of any mitigations that might be available;

(13) identify safety performance objectives for the failure case – these specify how to mitigate the consequences of system-generated failures at the service level (which are captured in step (5) above), given that these failures have occurred; and

(14) compare and contrast the safety performance objectives with DCMAC's Management Guidelines.

It is not feasible in a generic safety assessment such as this to derive safety objectives and then safety integrity requirements to limit the frequency with which the system-generated hazards can be allowed to occur. Rather, the focus necessarily is on setting the safety performance objectives to ensure the safe operation of GH in the first place and to reduce, as far as practicable, the safety consequences of system-generated hazards should they occur.

The tasks of deriving safety objectives and safety integrity requirements, and thus estimating the residual risk from specific GH operations in European airspace, are necessarily left to those directly responsible for the safety of those operations.

3.4 Workshops

Two workshops were held during the early part of the project, with participants who are experts from the ATC and UAS communities.

The first workshop was particularly useful in understanding the GH concept and the operational environment. It was used to confirm the safety argument and the pre-existing hazards, and to help identify the ATM services. This was assisted by walking through a prepared scenario with the group.

In the second workshop a GH pilot was present. This workshop focussed on learning more about the GH concept, and identifying some of the system-generated hazards and mitigations.

4 Analysis

4.1 Pre-Existing Hazards

A hazard presents a risk to the safety of *persons*. Pre-existing hazards are risks that are inherent to flying, and are not associated with air traffic management (ATM). Rather, the role of ATM is to remove or limit the effect of (mitigate) the pre-existing hazards while providing an efficient, expeditious service to airspace users.

The pre-existing hazards are not necessarily universal, and those that apply to GH in this safety assessment are as follows:

- hazards that could lead to a mid-air collision;
- hazards that could lead to controlled flight into terrain (CFIT) (and therefore cause harm to persons on the ground);
- wake vortex encounters (sufficiently severe enough to cause loss of control of GH and hit another aircraft or persons on the ground);
- airspace infringements (into military danger areas, where there is a risk of GH being shot down and therefore cause harm to persons on the ground);
- encounters with adverse weather (sufficiently severe enough to cause loss of control and hit another aircraft or persons on the ground).

ATM itself can increase the risk of an accident, albeit slightly, through failure within the ATM system. These are known as *system-generated hazards/risks*. Although these are usually small compared with the much larger benefit brought about by ATM to mitigate the pre-existing hazards/risks, they usually constitute a very significant part of the overall, residual risk of an accident.

4.2 Phases of Flight

This safety assessment considered the following phases of flight with respect to GH:

- **Climb:** from 35 feet above the aerodrome to the arrival at the initial assigned cruise altitude;
- **High altitude cruise:** any level flight segment after arrival at initial cruise altitude until the start of the descent to the destination aerodrome;
- **Descent:** the descent from the high altitude cruise to the initial approach fix (IAF).

These definitions come from standard ICAO definitions [4]]. Aerodrome operations were excluded from this study to be consistent with the scope of the Eurocontrol Air Traffic Management Guidelines for Global Hawk in European Airspace [1]).

4.3 ATM Services

The primary objective of ATM services is to mitigate the pre-existing hazards. Table 2 presents the ATM services that are associated directly with GH operations, taking account of the assumptions (section 3.2.5) and the operational environment (section 3.2.3) in which GH will operate. The term *separate* is used in the table in the normal English sense, although in some cases that includes the specific ATC meaning of applying prescribed separation minima. Table 2 also provides forwards traceability from the ATM services to the safety performance objectives of Table 3 below.

ATM Service Reference	ATM Service Provided	Pre-Existing Hazards that Are Mitigated	Related Safety Performance Objectives (see Table 3)
1	Separate GH from[22] GAT operating under IFR during GH's climb/descent phases.	Mid-air collision-type	SOs: 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 16, 17, 19, 23, 24, 24a, 25
		Wake vortex encounters	SO13
2	Separate GH from GAT operating under VFR during GH's climb/descent phases.	Mid-air collision-type	SOs: 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 16, 17, 19, 23, 24, 24a, 25
		Wake vortex encounters	SO13
3	Separate GH from other OAT operating under IFR during GH's climb/descent phases.	Mid-air collision-type	SOs: 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 16, 17, 19, 23, 24, 24a, 25
		Wake vortex encounters	SO13
4	Separate GH from other OAT operating under VFR during GH's climb/descent phases.	Mid-air collision-type	SOs: 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 16, 17, 19, 23, 24, 24a, 25
		Wake vortex encounters	SO13
5	Separate GHs from each other (which are all IFR) during GH's climb/descent phases.	Mid-air collision-type	SOs: 1, 4, 6, 7, 8, 11, 12, 16, 17, 19, 20, 21, 23, 24, 24a, 25
		Wake vortex encounters	SO13
6	Separate GH from terrain and obstacles during GH's climb/descent phases.	Controlled flight into terrain-type	SOs: 6, 10, 11, 12, 14, 16, 17, 23, 24, 24a
7	Separate GH from adverse weather.	Encounter with bad weather	SOs: 6, 11, 12, 16, 17, 23, 24, 24a
8	Separate GH from OAT operating under IFR in GH's high level cruise phase.	Mid-air collision-type	SOs: 1, 4, 6, 7, 11, 12, 16, 17, 19, 22, 23, 24, 24a, 25
9	Separate GH from OAT operating under VFR in GH's high level cruise phase.	Mid-air collision-type	SOs: 1, 6, 7, 11, 12, 16, 17, 19, 22, 23, 24, 24a, 25
10	Separate GHs from each other during GH's high level cruise phase.	Mid-air collision-type	SOs: 1, 6, 7, 11, 12, 16, 17, 19, 22, 23, 24, 24a
11	Separate GH from prohibited areas.	Infringing prohibited airspace (and getting shot down)	SOs: 6, 11, 12, 15, 17, 23, 24, 24a

[22] No order of precedence or priority is implied in the use of "Separate GH from…" in this table. "GH" always appears first irrespective of *who* has to avoid *whom/what* and irrespective of how this might be accomplished.

Table 2 *– The ATM services provided to GH.*

4.4 Introduction to Safety Performance Objectives

Safety performance objectives describe *what* needs to be achieved in order that the ATM services sufficiently mitigate risk to GH. They do not state by *whom* or by *what means* this is accomplished, which is a system design issue. Safety performance objectives are described at the *service level*.

There are two types of safety performance objectives. One for maximising the success of the ATM services to mitigate pre-existing hazards, the other for minimising the effects of a system-generated failure at the service level. These are sometimes referred to as *success* and *failure* safety performance objectives, respectively.

4.5 Safety Performance Objectives to Mitigate Pre-Existing Hazards

Beginning from the broad concept for GH (Section 2), and using information about the operational environment in which GH will operate, a scenario was created to describe a GH flight under *normal* conditions. In the normal scenario there are no problems or failures, and the ATM service works as intended. The safety performance objectives ensure that what was intended will be sufficient for a safe operation in the absence of failure.

In the scenario that is presented below, safety performance objectives are identified as **[SOx]**. A list of all them appears after the scenario. The safety barrier model was used in developing the scenario and proved very helpful to clarify how the ATM service was provided in each case (e.g. through airspace design, or sector planning and coordination, or ATC recovery).

4.5.1 Normal Scenario

Figure 2 presents some of the important features of the scenario and so may help the scenario to be followed. For this example, GH returns to the same departure aerodrome using the same 3D route. For simplification, segregated airspace is shown as a vertical cylinder.

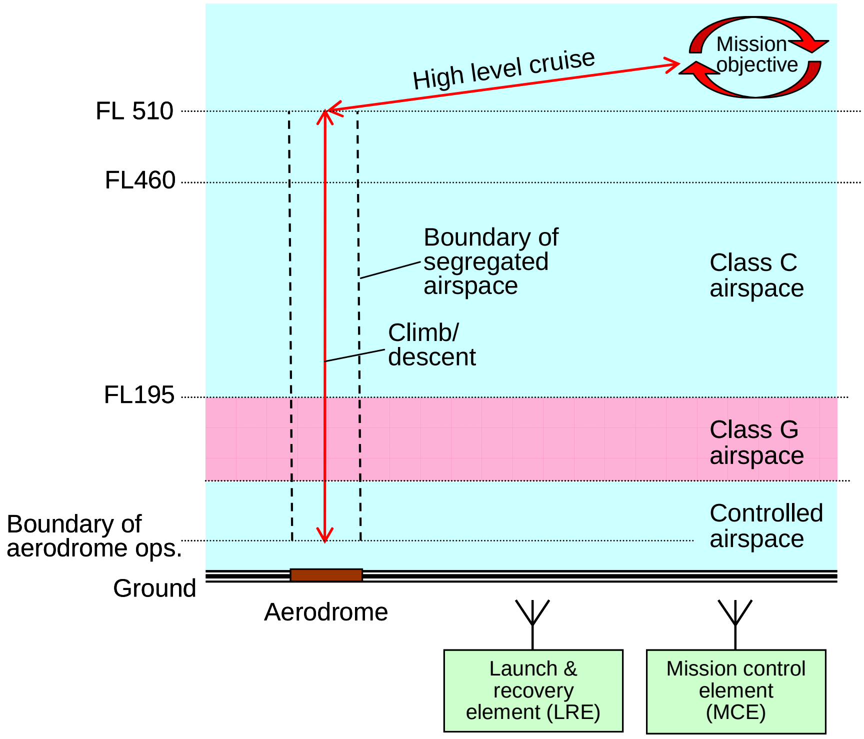

Figure 2 – *Normal Scenario.*

The scenario is described in the remainder of this section.

Pre-Conditions

GH operates under IFR as OAT **[SO1]**. Segregated airspace is designed and implemented to take GH all the way from the start of the initial climb (i.e. just after take-off) up to an altitude where there is unlikely to be any GAT **[SO2]**. Thus, by confining GH to segregated airspace, except above FL 510 **[SO4]**, safety is provided by the airspace design barrier in the ATM Safety Barrier Model in Figure 1. The airspace is activated when needed in accordance with the normal flexible use of airspace (FUA) practices.

The segregated airspace may be likened to a tunnel through which GH flies. The tunnel might be a vertical column or an inclined cylinder, for example. The design of segregated airspace takes account of the manner in which GH gains altitude, its overall navigation performance, the class of airspace that it passes through, and the minimum separation **[SO3]**, **[SO4]** to be achieved.

In order to ensure that the required separation minima are respected throughout the flight in segregated airspace, it is essential that the GH Mission Plan design is entirely consistent with the way that the segregated airspace is designed and the way that controllers in the surrounding (non-segregated) airspace apply separation **[SO5]**. The problem for the GH Mission Planner is that the design of segregated airspace and the application of separation can vary from State to State. The following practical cases illustration the problem:

- Case #1: ATC applies a buffer *outside* the boundary of segregated airspace to ensure minimum separation between GH and other aircraft. This means that GH can operate safely anywhere within the boundaries of the segregated airspace, though the Mission Plan would still need to include its own, additional buffer to take account of the variability in GH's height and track-keeping performance so that GH would never intrude into the separation-buffer area.

- Case #2: the segregated airspace designer applies a separation buffer in the *inside* edge of segregated airspace. This would mean that flights in non-segregated airspace could be allowed to touch the edges if the segregated airspace and therefore GH mission planning would need to take this into account by implementing a much more constrained flight profile, closer to the longitudinal axis of segregated airspace.

- Case #3: there is no separation buffer applied to segregated airspace. This means that the GH Mission Plan must take account of both the separation minima for the (non-segregated airspace) and the variability in GH's height and track-keeping performance so that GH would never come with the minimum separation distance of the boundary.

It also means that the GH pilot-in-command must know to what extent he/she has freedom to manoeuvre within the segregated airspace, according to which of the above cases apply during each stage of the flight through the various European States **[SO5a]**. Additionally, other pilots need to know the rules that apply and abide by them.

In all three cases above, segregated airspace will have been designed to take account of GH's mission requirements and navigational performance such that GH can remain within segregated airspace and any associated buffer **[SO3]**, **[SO4]** and **[SO5]**.

It can take nine hours or more to prepare a Mission Plan for GH. During this process a flight plan is submitted, addressed to all the agencies which need to know about the flight in accordance with requirements stated in national AIPs. The flight plan will include the: departure airfield, divert/emergency divert alternate airfield, destination airfield (if landing away), cruise TAS and route / levels (all from the Mission Plan), plus ANSPs providing an air traffic service en route, national air defence agencies, etc. The submission of the flight plan will be no later than 60 minutes before GH's departure. The flight plan will, among other things, notify ANSPs of GH's intent to enter their airspace. The flight plan will be the standard ICAO one **[SO6]**, which will make clear that GH is unmanned **[SO7]**.

Airspace users are given sufficient advance information of a forthcoming activation of segregated airspace in order to avoid it (for example, via the Airspace Use Plan (AUP) or a NOTAM). This notification will be done in accordance with normal FUA procedures **[SO8]**.

Segregated airspace is activated, at the appropriate time, in accordance with normal FUA procedures **[SO9]**.

GH is loaded with its Mission Plan prior to start up.

<u>Climb</u>

Starting at about 35ft above the airfield (see section 4.2) GH begins its long climb inside segregated airspace following its Mission Plan **[SO4]**, **[SO10],**. ATC and the pilot-in-command both monitor GH's conformance to its clearance **[SO6]**, **[SO11]**, **[SO12]**.

During the initial part of the climb GH will be separated from other aircraft longitudinally by at least the minimum horizontal separation that applies for the wake vortex categories of GH and the other aircraft **[SO13]**.

The climb may take two to three hours to get above FL510. The geometry of the 3D route (in the Mission Plan) will protect GH from collisions with terrain and obstacles **[SO14]**. In addition, the geometry of the 3D route will protect GH from infringing prohibited airspace, for example, an active danger area **[SO15]**.

Segregated airspace and any associated buffer provide important protection from other airspace users in both controlled and uncontrolled airspace **[SO3]**, **[SO5]**. In either case GH will be receiving an *air traffic service* such that GH is separated from other airspace users by at least the minimum separation for the airspace being transited **[SO16]**. Transponding in Mode A and C will be an enabler for receiving an air traffic service and making GH “visible” to other, ACAS-equipped airspace users. **[SO17]**.

If ATC instructs GH to vector (for whatever reason), the pilot-in-command will have to take over and fly GH manually. The GH pilot-in-command will generally wish to rejoin the 3D route in the Mission Plan. Once the route is rejoined (not necessarily at the point where it was left) the pilot-in-command will revert GH back to automatic control **[SO10]**. Receiving a vector might take GH outside of segregated airspace, and therefore that protection conferred by it would be removed temporarily **[SO4]**.

Later on in the scenario an IFR GAT aircraft asks ATC for a direct routing to its destination, but this would mean passing through GH’s segregated airspace. In accordance with the principles of FUA the sector working this aircraft tries to accommodate this request. The sector planner coordinates with the controller who is working GH **[SO19]**, and shortly afterwards ATC expedites the IFR GAT aircraft through segregated airspace. Minimum separation for the airspace is maintained throughout, and both aircraft remain under control by ATC throughout.

Later, still in the climb, GH enters *uncontrolled* airspace, but still resides within segregated airspace **[SO4]** and any associated buffer, which should ensure minimum separation **[SO5]**. GH is responsible for staying within segregated airspace **[SO4]**, **[SO12]**. The ATC service provided to GH will depend on the national airspace being transited. In all cases ATC provides an air traffic service to GH that is sufficient to ensure at least minimum separation adequate separation from other airspace users **[SO16]**. In uncontrolled airspace, airspace users themselves will be responsible for not entering segregated airspace.

More than one GH may use the segregated airspace at the same time. For example, two GHs could be climbing, or two descending, or one climbing and one descending. These flights will be planned and coordinated by GH’s mission planners such that their planned 4D profiles are deconflicted prior to departure **[SO20]**, **[SO21]**.

GH passes FL195 and enters *controlled* airspace again. Separation is provided by ATC through its planning and coordination activities **[SO19]**.

At some point during the mission, the Launch and Recovery Element (LRE), which is located close to the aerodrome, will cease to provide GH’s pilot-in-command. The task will be handed over to the Mission Control Element (MCE), which may be located 1000s of miles from the departure aerodrome. This changeover will occur while the Launch and Recovery Element is within radio line of sight of GH, and the range is less than about 250 NM. ATC should not be aware of (distracted by) this handover.

<u>High Altitude Cruise</u>

There is no record of GAT flights in Europe above FL510, and so airspace here will be very thinly populated: only OAT is expected, that is, either manned OAT or other UASs. The *Providence* barrier (Figure 1) has therefore strengthened significantly and this allows the airspace segregation to be removed, if desired **[SO4]**. Nonetheless, there may be other airspace users above FL510 so these will be planned to be kept away from GH **[SO22]**.

During the high altitude cruise (and indeed the climb and descent phases) GH will transit several airspace sectors, and possibly State airspace boundaries. This will be managed in accordance with normal coordination and handover (COTR) procedures **[SO19]**.

In accordance with its Mission Plan, GH levels off at FL530 (remaining in controlled airspace), and is receiving an ATC service sufficient to ensure at least minimum separation from other airspace users **[SO16]**. Other OAT will most likely be under the control of ATC or air defence radar, and if not, the aircraft will be self-separating using its own onboard radar.

During this phase of the flight GH will gradually gain altitude (in accordance with its Mission Plan) to optimise its fuel burn. Each time the pilot-in-command wants to climb to a new flight level it makes the request to ATC **[SO23]**. When cleared **[SO24]** (GH has a slow climb rate at this altitude), GH climbs to that level.

The command and control link between the pilot-in-command and the aircraft does not suffer from significant delay that could otherwise affect the safety of the aircraft. The same applies to the communications between the pilot-in-command and ATC **[SO24a]**.

During the latter part of this flight phase, segregated airspace for the descent is activated in accordance with FUA standard practice **[SO9]**.

GH has been airborne for 32 hours. Before reaching its own segregated airspace for the descent, the pilot-in-command checks that GH's programmed 3D route will not pass through segregated airspace that has been published and activated for other flights during the time that GH's Mission Plan was uploaded **[SO25]**.

Descent

GH descends in activated, segregated airspace, which has been designed for the descent **[SO2]**, **[SO3]**.

There are no new safety objectives for this flight phase because the description given for the climb phase is very similar.

4.5.2 Summary of the Safety Performance Objectives

The safety performance objectives to mitigate pre-existing hazards are divided into three different categories. The first category, *pre-conditions*, describes those that have to be met before GH enters the airspace. The second category, *general conditions*, describes those that must be met continuously during the whole flight. The third category, *specific conditions*, refer to those that have to be met at specific moments during the flight.

Category	Reference	Safety Performance Objectives	Related ATM Services (see Table 2)
Pre-Conditions	SO2	Segregated airspace for the climb and descent phases of the GH flight shall be pre-defined for each airfield such that it begins from the	1, 2, 3, 4

		boundary of aerodrome operations to not less than FL510.	
	SO3	The 3D geometry of segregated airspace shall be designed to maintain separation between GH and other airspace users. The design shall take into account the manner in which GH climbs and descends, its mission requirements, its navigation performance, the class of airspace through which it passes, and the minimum separation of the airspace.	1, 2, 3, 4
	SO5	While GH is within segregated airspace, the planned 3D route (in the Mission Plan) shall take account of local arrangements for the provision of a buffer in order that at least the minimum separation is maintained with other aircraft outside segregated airspace.	1, 2, 3, 4
	SO6	A flight plan for every GH flight, accurately reflecting the 3D route (pre-defined in the Mission Plan), shall be submitted as an OAT flight plan in the standard ICAO format.	Enabler for all ATM services
	SO8	Airspace users shall be notified sufficiently in advance of a forthcoming activation of segregated airspace, in accordance with normal flexible use of airspace (FUA) procedures.	1, 2, 3, 4, 5
	SO14	The geometry of the 3D route (in the Mission Plan) shall be designed to maintain adequate separation between GH and terrain and obstacles taking account of the height and track keeping performance of the aircraft.	6
	SO15	The geometry of the 3D route (pre-defined in the Mission Plan) shall be designed to stop GH from infringing prohibited airspace at any point during its flight.	11
	SO21	Segregated airspace shall be designed to allow two GHs to pass each other while maintaining at least the minimum separation from each other and other airspace users in the airspace being transited.	5
General Conditions	SO1	GH shall operate under IFR as OAT. Separation minima shall be at least the same as for manned aircraft.	1, 2, 3, 4, 5, 8, 9, 10
	SO4	Whether it is following its predefined 3D route, or is being flown manually by the pilot-in-command, GH shall be operated entirely within segregated airspace except: • when flying above FL 510 (unless	1, 2, 3, 4, 5, 8, 9, 10

	segregated airspace is specifically provided for that part of the route); • when specifically instructed otherwise by ATC, for the purposes of maintaining separation from other traffic; • when there is any other overriding safety reason for leaving segregated airspace.	
SO7	All ATC centres that may encounter GH (in normal or abnormal situations) shall be made aware that the GH aircraft is an unmanned flight, and therefore is without a see and avoid capability.	Enabler for 5, 8, 9, 10
SO10	The normal mode of operation of GH for the climb and descent phases shall be shall be automatic, i.e. following its programmed 3D routes.	1, 2, 3, 4, 6
SO11	ATC shall monitor GH's conformance to its clearance, irrespective of whether it is following its pre-defined 3D route or is being vectored by ATC, and issue corrective instructions as necessary.	Enabler for all ATM services
SO12	The pilot-in-command shall monitor GH's conformance to its clearance, irrespective of whether it is following its pre-defined 3D route or is being vectored by ATC, and apply corrections to the flight trajectory as necessary.	Enabler for all ATM services
SO16	ATC shall provide an air traffic service to GH that is sufficient to ensure at least minimum separation from other airspace users.	Enabler for all ATM services except 11
SO17	GH shall be equipped with a working transponder, being at least mode A and mode C.	Enabler for all ATM services
SO19	Coordination and transfer (COTR) of GH flights shall be carried out in accordance with normal coordination and transfer procedures.	Enabler for all ATM services except 6, 7 and 11
SO20	More than one GH may use the segregated airspace at the same time, in which case the mission profiles shall be *planned* and *coordinated* such that their 4D trajectories are mutually deconflicted prior to departure in accordance with relevant separation minima for the airspace concerned.	5
SO23	Voice communications between GH and ATC shall be no different to that between ATC and other OAT. Standard phraseology shall be used.	Enabler for all ATM services

	SO24	ATC centres that may encounter GH (in normal or abnormal situations) shall have knowledge of the flight envelope limitations of GH.	Enabler for all ATM services
	SO24a	Neither the command and control link between the pilot-in-command, nor the voice communications link between the pilot-in-command and ATC shall suffer from significant delay under normal conditions that could affect the safety of GH[23].	Enabler for all ATM services
Specific Conditions	SO5a	The GH pilot-in-command shall know the freedom that exists to manoeuvre within segregated airspace, according to how the buffer is applied (if at all) during each stage of the flight through the various European States.	1, 2, 3, 4
	SO9	Segregated airspace shall be activated and closed in accordance with normal flexible use of airspace (FUA) procedures.	1, 2, 3, 4
	SO13	During the initial climb and while a risk from wake vortices persists, GH shall be separated according to the appropriate wake vortex separation minima.	1, 2, 3, 4,5
	SO22	When GH is outside segregated airspace (e.g. above FL510) ATC shall *plan* to keep other aircraft away from GH in order to avoid having to vector GH.	8, 9, 10
	SO25	The pilot-in-command shall check regularly that GH's programmed 3D route will not pass through segregated airspace that has been published and activated for other flights after the time that GH's Mission Plan was uploaded.	1, 2, 3, 4, 5, 8, 9

Table 3 – *Safety performance objectives to mitigate the pre-existing hazards.*

4.6 Identifying and Mitigating System-Generated Failures at the Service Level

4.6.1 Hazard Identification

Despite having specified safety performance objectives to ensure safe GH operations, problems or failures in GH's operational environment or that are internal to the GH system itself can occur, and these may cause the ATM Service to work in a way that it is not designed to do. At the service level, these

[23] During the second workshop the GH pilot said that, at worst, the latency for command and control instructions is about three seconds, and that there is no noticeable delay for voice communications between the pilot-in-command and ATC.

problems/failures are termed *system-generated hazards*[24]. These failures have been identified and are summarised in Table 4. Referring to Figure 2 may help the reader to see the relevance of these hazards.

[24] Strictly speaking, some of the hazards are defined below the service level – this is done deliberately where the available mitigations are dependent on the particular cause of the hazard.

Type of Failure	Hazard	Brief Description	Analysis Technique
Internal GH	H1	Propulsion[25] failure.	Event trees
	H2	Navigation failure (GH's position is *unknown* by GH itself, but the aircraft is *controllable*).	Event trees
	H3	Flight control failure (GH's position is *known* by GH, but the aircraft is *uncontrollable*).	Scenarios
	H4	Ground guidance failure (main cause is likely to be loss of command and control link between the pilot-in-command and GH, although other ground system failures could also cause this hazard).	Event trees
	H5	Transponder failure.	Event trees
Operational environment	H6	An intruder penetrates segregated airspace.	Scenarios
	H7	GH-ATC voice communications failure.	Scenarios
	H8	Adverse weather. (This is a pre-existing hazard, and could have been covered in the normal scenario. However, given that GH operations will be planned to avoid adverse weather it is acceptable to consider adverse weather in this section.)	Scenarios

Table 4 *– System-generated hazards for GH.*

Taking each system-generated hazard in turn, the hazard has been analysed using either a short descriptive scenario or scenarios, or by using an event tree, as shown in the last column of Table 4. The choice was made according to what best suited the particular hazard including the number of available mitigations. The analysis led to the identification of further safety performance objectives.

The scenarios and event trees and the safety performance objectives that were derived from them follow.

Hazard 1 – *propulsion failure*

See the event tree in Appendix B.

Hazard 2 – *navigation failure*

See the event tree in Appendix C.

Hazard 3 – *flight control failure*

H3	**Loss of flight control of GH** **Starting Conditions:** GH is in the high level cruise at FL560.

[25] This is a major function of GH necessary for it to complete its mission. This and others come from ARP 4754A.

	Subjacent airspace is busy controlled airspace (class C). Suddenly there is a loss of flight control (although the command-control link between the pilot-in-command and GH aircraft is still working.
Who	**Action**
GH pilot	Sees the loss of flight control **[SO54]** and immediately informs ATC **[SO44], [SO16]**.
GH pilot	Continues to try to regain flight control of the aircraft.
ATC	Predicts (estimates) the path that GH will follow, including where it will impact the ground.
ATC	Manoeuvres other aircraft away from the immediate vicinity of GH and its predicted path.
GH pilot	In consultation with ATC, agrees whether to allow GH to follow its predicted path to the ground, or, to terminate the flight by cutting its engine (if this would likely result in a better outcome).
GH pilot	(GH is over Denmark and heading north-west to the North Sea). Switches off the engine which means that GH falls into the sea. Here there is a remote chance of harming persons on the sea.

A loss of flight control can happen for a manned flight. Whether manned or unmanned, the outcome will be similar, so to are the possible mitigations given that such a failure has occurred. Thus, the procedure to follow should be similar to that for manned flight.

Given that GH suffers this failure while descending inside activated segregated airspace, there may be a slight safety benefit compared to a manned flight in terms of a reduced collision risk with other airspace users.

Hazard 4 – *ground guidance failure*

See the event tree in Appendix D.

Hazard 5 –*transponder failure*

See the event tree in Appendix E.

Hazard 6 – *an intruder penetrates segregated airspace*

H6a	**Intruder responds** **Starting Conditions:** GH is climbing inside segregated airspace below FL510 **[SO4]**. Airspace is controlled (class C). GAT (operating under IFR) is about to penetrate segregated airspace and is on a course that will mean a loss of separation with GH. The GAT aircraft has a mass of 8000kg and so is equipped with TCAS, which is working.
Who	**Action**
ATC	Sees the potential intruder about to breach segregated airspace, and so contacts him to give an instruction to avoid segregated airspace and GH, *as per current ATC operations*.
Intruder	Acknowledges, and correctly follows the ATC instruction.

H6b	**Intruder does not respond; controlled airspace** **Starting Conditions:** Same as for H6a
Who	**Action**
ATC	Sees the potential intruder about to breach segregated airspace, and so contacts him to give an instruction to avoid segregated airspace and GH, *as per current ATC operations*.
Intruder	No response.
ATC	Makes several attempts to contact the intruder in order vector the aircraft away from GH, but still no response.
ATC	Contacts GH and gives an instruction to level off to avoid the intruder **[SO16]**, **[SO30]**, **[SO24]**.
Intruder	Enters segregated airspace.
GH	Now under manual control, complies with the ATC instruction **[SO31]**.
Intruder	Exits segregated airspace.
ATC	Instructs GH to resume previous course.

H6c	**Intruder does not respond; uncontrolled airspace** **Starting Conditions:** Same as for H6a except that airspace is uncontrolled (class G) – GH is responsible for ensuring adequate separation from other airspace users, although ATC provides provide enough timely information for GH to do this. The GAT aircraft is not in receipt of any ATC service, however.
Who	**Action**
ATC	Sees a conflict between GH and another aircraft and gives an instruction to GH in order that it avoids the intruder **[SO16]**, **[SO7]**.
GH	Acknowledges instruction, but does not carry it out.
ATC	Attempts to contact the GAT aircraft that is in conflict with GH.
Intruder	No response **[SO32]** (not obliged to respond, or even be in receipt of an ATC service in this airspace).
Intruder	Enters segregated airspace.
Intruder	Receives a TCAS resolution advisory (RA) as a result of its conflict with GH **[SO17]**.
ATC	(Unaware of the TCAS RA).
Intruder	Follows the RA correctly, but is slow to respond.
GH	Now carries out the instruction while under manual control **[SO31]**.
Intruder	Exits segregated airspace.

Hazard 7 – *Communications failure between GH and ATC*

H7a	**Radio failure on GH during the descent** **Starting Conditions:** GH is descending, passing through FL380 in segregated airspace. Airspace is controlled (class C). GH's pilot-in-command realises that a radio failure has just occurred **[SO54]**.
Who	**Action**
GH	Squawks 7600 using its mode-A transponder in accordance with standard radio communications failure procedures (ICAO doc 4444, section 8.8) **[SO45]**. GH continues its descent to the aerodrome, remaining inside segregated airspace and following its cleared route. The pilot-in-command contacts ATC using UHF/VHF radio with direct line of sight between the Launch and Recovery Element (LRE) and local ATC **[SO46]**.

Hazard 8 – *adverse weather*[26]

H8a	**Adverse weather predicted for the programmed descent** **Starting Conditions:** GH is in the high level cruise. Airspace is controlled (class C).
Who	**Action**
GH	Monitors forecasts for adverse weather **[SO38]**. A forecast predicts a 33% chance of adverse weather during the descent back to the departure aerodrome, 24 hours from now.
GH	Reviews options and decides to continue with the mission, and continues to review the forecasts.
	<1 hour later>
GH	Learns from the latest forecast that the chance of adverse weather has increased to 66%.
GH	Reviews options and decides to instruct GH aircraft to return to the departure aerodrome (thus arriving before the predicted adverse weather arrives **[SO38]**).
GH	Asks ATC for clearance back to departure aerodrome **[SO40]**. Asks for segregated airspace to be reopened for the early return to the departure aerodrome **[SO8]**, **[SO10]**, **[SO9]**.
ATC	Clearance granted.
GH	Pilot-in-command instructs GH aircraft to return to the departure aerodrome when it reaches the next waypoint (the 3D route back to the departure aerodrome has already been programmed from this waypoint).
GH	Before entering reactivated segregated airspace, confirms with ATC that the airspace has

[26] GH is sensitive to icing, for example.

	indeed been reactivated.
ATC	Instructs GH to hold before descending through FL520.
GH	Stays in a holding pattern, waiting for segregated airspace to be reactivated.
ATC	Informs GH that segregated airspace is now activated.
GH	Descends to the aerodrome in segregated airspace.

4.6.2 Summary of the Safety Performance Objectives

Below are the safety performance objectives to mitigate the risk *given that* a system-generated hazard has occurred.

Reference	Safety Objectives	Hazards Affected (see Table 4)
SO30	Vectoring GH shall be considered if there is no better alternative.	H1, H2, H5, H6
SO31	The pilot-in-command shall be capable of taking manual control of GH at any time (except, of course, during a command-control link failure).	H1, H2, H5, H6
SO32	Where practicable, the programmed 3D route (in the Mission Plan) shall avoid *uncontrolled* airspace while at or below FL510 for *normal* and *abnormal* situations.	H1, H2, H5, H6
SO38	GH shall *plan* to avoid predicted adverse weather.	H8
SO40	While receiving a separation service, deviations from the primary route (such as an early return to the departure/arrival aerodrome) shall require permission from ATC, where practicable.	H5, H8
SO41	Where practicable, GH shall be within glide distance of an emergency-alternate airfield at all times during its flight. These shall be coordinated with the States concerned before departure.	H1, H4b
SO42	The programmed divert-alternate and emergency-alternate airfields shall be the departure/arrival aerodrome where possible, and the programmed descent route shall, where, practicable, be within segregated airspace.	H1, H2
SO43	Segregated airspace shall remain activated while GH's divert-alternate or emergency-alternate airfield is still the departure aerodrome.	H1, H2
SO44	In the event of an emergency GH shall immediately squawk 7700, and, as soon as practicable, the pilot-in-command shall inform ATC what GH is going (programmed) to do.	H1, H2, H3, H4
SO45	In the event of loss of voice communication between the pilot-in-command and ATC, standard radio communications failure procedures shall be followed (described in ICAO's PANS ATM	H7

	doc 4444) for a flight in instrument meteorological conditions.	
SO46	Sufficient contact information shall be available to ATC and the pilot-in-command to be able to communicate with each other during *all* phases of GH's flight given a failure of the primary means of voice communication.	H7
SO47	In the event of a transponder failure, with the agreement of ATC GH shall either continue with its cleared 3D route, or, return immediately to the departure/arrival aerodrome (via activated segregated airspace), providing position and altitude information when required by ATC.	H5
SO48	Following a command-control failure, if after a period of time the link has not been re-established, GH shall squawk 7600 (lost communications), and the pilot-in-command shall inform ATC what the aircraft is going (programmed) to do.	H4
SO49	GH shall be within glide distance of a termination point at all times during its flight. These shall be coordinated with the States concerned beforehand.	H1, H2
SO50	Where practicable, a *termination point* shall be near to the departure/arrival aerodrome, and the programmed descent route shall, where practicable, be inside segregated airspace.	H1, H2
SO51	If the 3D route for a divert-alternate or emergency-alternate airfield or a termination point is outside activated segregated airspace, the route shall avoid busy airspace, where practicable.	H1, H2
SO52	When ATC sees that a GH squawking 7600 (the code reserved for communications failures) changes to 7700 (the code reserved for emergencies), he/she shall inform GH's pilot-in-command immediately.	H4
SO53	Following a command-control failure, if after a period of time the link has not been re-established, GH shall be pre-programmed to land by following a route that will minimise the risk to other airspace users and persons on the ground.	H4
SO54	GH shall provide the pilot-in-command with up-to-date health information on the aircraft's systems, including the transponder and on the main functions that allow GH to complete its mission including, as a minimum, propulsion, flight control and navigation.	H1, H2, H3, H4, H5, H7
SO55	Segregated airspace shall be designed to accommodate the route and climb profile for autonomous modes of flight.	H4

Table 5 *– Safety performance objectives to mitigate risk given that the hazard has occurred.*

5 Comparison of the Safety Performance Objectives with DCMAC's Management Guidelines

The study has assessed the GH concept operating in the European environment, and has identified 46[27] safety performance objectives. The work by DCMAC [1] identified 29 Management Guidelines. Despite the difference in terminology, the result is the same, namely a set of recommendations that describe, at a high level, what has to be achieved to ensure the safe operation of GH in European airspace. Thus, they are directly comparable. Table 6 in Appendix F presents this comparison.

For each Management Guideline and safety performance objective Table 6 gives a recommendation. There are three types of recommendation: *accept* the Management Guidelines without change, *modify* the description of the Management Guideline, and *adopt* a safety performance objective as a new Management Guideline.

In summary, 22 *new* Management Guidelines are recommended. Furthermore, it is recommended to modify the descriptions of 12 current Management Guidelines (the reason for each is provided in Table 6, Appendix F). No change is recommended for 17 (out of the 29) current Management Guidelines.

[27] The safety performance objectives do not go from one to 46, as might be expected. This is because several rounds of reviewing and editing this document have seen new safety performance objectives appear, some disappear, and some merged. Rather than updating the numbering of the safety performance objectives each time, the numbering was left untouched.

6 Conclusions

This qualitative safety assessment has assessed the Global Hawk (GH) concept in a European operational environment.

Due to the following two aspects of the design of GH operations:

(1) the use of segregated airspace for the climb and descent phases of GH operations; and

(2) the fact that the cruise phase takes place at an altitude at which no GAT will be present and only a very limited amount of OAT traffic will be present,

the risk from GH operations *should be extremely low under normal working conditions*.

Furthermore, a set of performance safety objectives has been identified that are designed to ensure that, under normal working conditions (i.e. in the absence of failure), the risk of an accident due to GH operations is reduced as far as reasonably practicable.

The assessment has also identified a further set of safety performance objectives that reduce the risk of an accident in the event of a system-generated failure by mitigating the consequences of such failures as far as reasonably practicable.

What has not been practicable to achieve, in what is a high-level, generic safety assessment, is the specification of quantitative safety integrity requirements for the frequency of occurrence of the causes of system-generated failure. Thus, it has not been possible to demonstrate generically that GH operations are at least as safe as those for manned OAT operations in non-segregated airspace. This is necessarily left to the operating authorities for GH to demonstrate for their specific GH operations.

However, the main objective of the study was to check that DCMAC’s draft Management Guidelines for GH are complete and correct. This objective has been achieved, by following a formal, rigorous safety approach, with the assistance of other safety experts where required, and by drawing upon the expertise of ATC and GH experts during two workshops. A detailed comparison between the draft Management Guidelines and the study’s safety performance objectives has revealed some gaps in the current Guidelines, leading to the recommendations below.

7 Recommendations

It is recommended that:

(1) the 22 new issues arising from the safety assessment are *added* to the Management Guidelines;

(2) the descriptions of 12 of the current Management Guidelines are *modified*, as identified in the safety assessment;

(3) the other 17 current Management Guidelines are *retained* unmodified

(4) each GH operating authority carries out a specific safety assessment to show that the residual risk of an accident, associated with GH operations in European airspace, is acceptable compared with equivalent military, manned-aircraft operations.

References

[1] Eurocontrol, Eurocontrol Air Traffic Management Guidelines for Global Hawk in European Airspace, edition 0.6a, 2010, (draft).

[2] Eurocontrol, *Safety Assessment Made Easier*, Part 2, version 0.5a.

[3] ICAO, *Global Air Traffic Management Operational Concept*, Doc 9854, 1st edition, 2005.

[4] CAST/ICAO, Taxonomy Team, *Phase of Flight Definitions and Usage Notes*, version 1.0.2, June 2010 (see www.intlaviationstandards.org).

Appendix A Euro Hawk

Photo owned by TKN, and taken at the Internationale Luft- und Raumfahrtausstellung, 2006. Image copied from: http://en.wikipedia.org/wiki/Northrop_Grumman_RQ-4_Global_Hawk

(not part of this document)

Appendix B H1 – Propulsion Failure

See the spreadsheet:
Global Hawk Safety Assessment, Appendix B, Propulsion Failure v1.00.pdf.

Appendix C H2 – Navigation Failure

See the attached spreadsheet:
Global Hawk Safety Assessment, Appendix C, Navigation Failure v1.00.pdf.

Appendix D H4 – Ground Guidance Failure

See the attached spreadsheet:
Global Hawk Safety Assessment, Appendix D, Ground Guidance Failure v1.02.pdf.

Appendix E H5 – Transponder Failure

See the attached spreadsheet:
Global Hawk Safety Assessment, Appendix E, Transponder Failure v1.01.pdf

Appendix F Comparison of the Management Guidelines and the Safety Performance Objectives.

DCMAC's Management Guidelines	The Safety Assessment's Safety Performance Objectives	Comment (Comparison)
ATM MODE OF OPERATION		
ATMGH1. For ATM purposes, the primary mode of operation of GH shall entail oversight by the PIC, who shall at all times be able to intervene in the management of the flight. A back-up mode of operation shall enable the GH to revert to autonomous flight in the event of loss of the control link between the PIC and the UA.	**SO10**[28] The normal mode of operation of GH for the climb and descent phases shall be shall be automatic, i.e. following its programmed 3D routes. **SO31** The pilot-in-command shall be capable of taking manual control of GH at any time (except, of course, during a command-control link failure).	Good match between the two, although there is no explicit safety performance objective for GH to have an autonomous mode of flight (this is implied, however, in safety performance objectives **SO48** and **SO53**). **Recommendation: NO CHANGE** necessary to the Management Guideline.
ATMGH2. All GH sorties flown in accord with these ATM Guidelines shall be classified as IFR/OAT.	**SO1** GH shall operate under IFR as OAT. Separation minima shall be at least the same as for manned aircraft.	Good match between the two. **Recommendation: MODIFY** the Management Guideline to include minimum separation.
	SO19 Coordination and transfer (COTR) of GH flights shall be carried out in accordance with normal coordination and transfer procedures.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.

[28] Where a safety performance objective in this table is underlined, as this one is, it appears more than once in the table, meaning that the safety performance objective matches well to at least two different Management Guidelines.

	SO30 Vectoring GH shall be considered if there is no better alternative.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
DEPARTURE AND ARRIVAL		
ATMGH3. Where required for departure and arrival, segregated airspace for GH shall be established in accordance with the Flexible Use of Airspace Concept, and should extend to an altitude above the maximum normally used by conventional manned aircraft.	**SO10** The normal mode of operation of GH for the climb and descent phases shall be shall be automatic, i.e. following its programmed 3D routes. **SO2** Segregated airspace for the climb and descent phases of the GH flight shall be pre-defined for each airfield such that it begins from the boundary of aerodrome operations to not less than FL510. **SO8** Airspace users shall be notified sufficiently in advance of a forthcoming activation of segregated airspace, in accordance with normal flexible use of airspace (FUA) procedures. **SO9** Segregated airspace shall be activated and closed in accordance with normal flexible use of airspace (FUA) procedures.	The Management Guideline contains three pieces of information: the need for segregated airspace during the departure/arrival (i.e. climb/descent in the language of the safety assessment), the need to adopt FUA principles, and the upper limit of segregated airspace. All three are covered by the identified safety performance objectives. The safety performance objectives give important, information that the Management Guideline is missing, namely that segregated airspace goes starts from the boundary of aerodrome operations and goes up to at least FL510, and that the flight shall be managed using programmed 3D route (i.e. not flown manually by the pilot-in-command). **Recommendation: MODIFY** the Management Guideline to incorporate the missing information.

<u>ATMGH4</u>. Arrangements for the establishment of segregated airspace for GH should include consideration of an early return to base.	**<u>SO8</u>** Airspace users shall be notified sufficiently in advance of a forthcoming activation of segregated airspace, in accordance with normal flexible use of airspace (FUA) procedures. **<u>SO43</u>** Segregated airspace shall remain activated while GH's divert-alternate or emergency-alternate airfield is still the departure aerodrome. **<u>SO47</u>** In the event of a transponder failure, with the agreement of ATC GH shall either continue with its cleared 3D route, or, return immediately to the departure/arrival aerodrome (via activated segregated airspace), providing position and altitude information when required by ATC.	Safety performance objective **SO8** is similar to the Management Guideline in general terms, and **SO43** and **SO47** give specific instances when segregated airspace should be available for an early return to the departure aerodrome. **Recommendation: NO CHANGE** necessary to the Management Guideline.

<u>ATMGH5</u>. Segregated airspace for GH departure and arrival shall be of sufficient size to assure the safety of aircraft flying outside the segregated airspace.	**<u>SO3</u>** The 3D geometry of segregated airspace shall be designed to maintain separation between GH and other airspace users. The design shall take into account the manner in which GH climbs and descends, its mission requirements, its navigation performance, the class of airspace through which it passes, and the minimum separation of the airspace.	The Management Guideline contains only a subset of information in the safety performance objective. **Recommendation: MODIFY** the Management Guideline to incorporate all the information given in the safety performance objective.
<u>ATMGH6</u>. An air traffic service utilising surveillance radar and communications between controller and PIC shall be employed to support GH during departure and arrival in segregated airspace.	**<u>SO16</u>** ATC shall provide an air traffic service to GH that is sufficient to ensure at least minimum separation from other airspace users.	Good match between the two. **Recommendation: NO CHANGE** necessary to the Management Guideline.
	<u>SO5</u> While GH is within segregated airspace, the planned 3D route (in the Mission Plan) shall take account of local arrangements for the provision of a buffer in order that at least the minimum separation is maintained with other aircraft outside segregated airspace.	There is no equivalent Management Guideline. The buffer is an important consideration when navigating segregated airspace across States in which differing buffer arrangements might be applied. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.

ATMGH7. During the climb or descent phase, and subject to traffic, if ATC requires GH to manoeuvre for separation, this should be effected wherever possible by instructing the UA to level off until clear of the confliction.	**SO24** ATC centres that may encounter GH (in normal or abnormal situations) shall have knowledge of the flight envelope limitations of GH.	These are quite similar. The wider point is made by the safety performance objective, whereas the Management Guideline gives more specific advice. **Recommendation: NO CHANGE** necessary to the Management Guideline.
	SO14 The geometry of the 3D route (in the Mission Plan) shall be designed to maintain adequate separation between GH and terrain and obstacles taking account of the height and track keeping performance of the aircraft.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
	SO21 Segregated airspace shall be designed to allow two GHs to pass each other while maintaining at least the minimum separation from each other and other airspace users in the airspace being transited.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.

	SO20 More than one GH may use the segregated airspace at the same time, in which case the mission profiles shall be *planned* and *coordinated* such that their 4D trajectories are mutually deconflicted prior to departure in accordance with relevant separation minima for the airspace concerned.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
	SO13 During the initial climb and while a risk from wake vortices persists, GH shall be separated according to the appropriate wake vortex separation minima.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
CRUISE		
ATMGH8. If there is a requirement for GH to vary its level once at operating altitude, clearance for this shall be obtained by the PIC from ATC. Where convenient, ATC should issue a clearance for a GH to operate within an altitude block agreed beforehand with the PIC.		There is no *specific* equivalent safety performance objective. **Recommendation: NO CHANGE** necessary to the Management Guideline.

ATMGH9. In CAS, separation from other airspace users will be achieved by compliance with ATC instructions. Separation minima shall be at least the same as for manned aircraft.	**SO1** GH shall operate under IFR as OAT. Separation minima shall be at least the same as for manned aircraft. **SO11** ATC shall monitor GH's conformance to its clearance, irrespective of whether it is following its pre-defined 3D route or is being vectored by ATC, and issue corrective instructions as necessary. **SO12** The pilot-in-command shall monitor GH's conformance to its clearance, irrespective of whether it is following its pre-defined 3D route or is being vectored by ATC, and apply corrections to the flight trajectory as necessary. **SO16** ATC shall provide an air traffic service to GH that is sufficient to ensure at least minimum separation from other airspace users.	The Management Guideline does not say how GH shall be separated from other aircraft in *uncontrolled* airspace. SO16 describes the need for an ATC service that shall ensure GH is separated from other aircraft. **Recommendation: MODIFY** the Management Guideline.

<u>ATMGH10</u>. At high altitude, and subject to traffic, if ATC requires GH to manoeuvre for separation, this should be effected by instructing the UA to descend. However, where separation is only possible in the horizontal plane, ATC should take into account the slow rate of turn of GH.	**<u>SO24</u>** ATC centres that may encounter GH (in normal or abnormal situations) shall have knowledge of the flight envelope limitations of GH.	These are quite similar. The wider point is made by the safety performance objective, whereas the Management Guideline gives more specific advice. **Recommendation: MODIFY** the Management Gudeline by adding the words "if safe to do so" after the word "descend"..
	SO22 When GH is outside segregated airspace (e.g. above FL510) ATC shall *plan* to keep other aircraft away from GH in order to avoid having to vector GH.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
	SO40 While receiving a separation service, deviations from the primary route (such as an early return to the departure/arrival aerodrome) shall require permission from ATC, where practicable.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
COLLISION AVOIDANCE		

<u>ATMGH11</u>. Collision avoidance for GH shall normally be addressed by operating it either in segregated airspace or in airspace where it is isolated from other aircraft by virtue of its extreme altitude.	**<u>SO2</u>** Segregated airspace for the climb and descent phases of the GH flight shall be pre-defined for each airfield such that it begins from the boundary of aerodrome operations to not less than FL510. **<u>SO3</u>** The 3D geometry of segregated airspace shall be designed to maintain separation between GH and other airspace users. The design shall take into account the manner in which GH climbs and descends, its mission requirements, its navigation performance, the class of airspace through which it passes, and the minimum separation of the airspace. **SO4** Whether it is following its predefined 3D route, or is being flown manually by the pilot-in-command, GH shall be operated entirely within segregated airspace except: • when flying above FL 510 (unless segregated airspace is specifically provided for that part of the route); • when specifically instructed otherwise by ATC, for the purposes of maintaining separation from other traffic; • when there is any other overriding safety reason for leaving segregated airspace. **<u>SO5</u>** While GH is within segregated airspace, the planned 3D route (in the Mission Plan) shall take account of local arrangements for the provision of a buffer in order that at least the minimum separation is maintained with other aircraft outside segregated airspace. **<u>SO7</u>** All ATC centres that may encounter GH (in normal or abnormal situations) shall be made aware that the GH aircraft is an unmanned flight, and therefore is without a see and avoid capability. **<u>SO8</u>** Airspace users shall be notified sufficiently in advance of a forthcoming activation of segregated airspace, in accordance with normal flexible use of airspace (FUA) procedures.	Good match between the two. The safety performance objectives give more specific guidance. However, no change is necessary. **Recommendation: NO CHANGE** necessary to the Management Guideline.

STRATEGIC DECONFLICTION		
<u>**ATMGH12**</u>. GH operators should liaise with nations being over-flown and with other HALE operators for the purpose of avoiding potentially conflicting tracks at high altitude.		There is no *specific* equivalent safety performance objective. **Recommendation: NO CHANGE** necessary to the Management Guideline.
	SO38 GH shall *plan* to avoid predicted adverse weather.	There is no equivalent Management Guideline. Good planning in the context of European weather will reduce the chances of a return to base, going to a divert-alternate airfield, or having to go to an emergency-alternate airfield. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
	SO15 The geometry of the 3D route (pre-defined in the Mission Plan) shall be designed to stop GH from infringing prohibited airspace at any point during its flight.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
FLIGHT PLANNING		

<u>ATMGH13</u>. In the absence of local segregated airspace, diversion airfields should be selected so as to avoid any requirement for GH to fly through uncontrolled airspace.	**SO32** Where practicable, the programmed 3D route (in the Mission Plan) shall avoid *uncontrolled* airspace while at or below FL510 for *normal* and *abnormal* situations.	These are quite similar. The safety performance objective wants GH to avoid flying through any uncontrolled airspace for the whole of its flight. The Management Guideline just focuses on avoiding having to make a divert through uncontrolled, unsegregated airspace. The risk of uncontrolled airspace is that some airspace users may not be aware of the segregated airspace, or they may ignore the restriction anyway. Not all airspace users will be in contact with ATC, or even squawking (therefore definitely no TCAS available). GH has no see and avoid capability, so any collision avoidance will have to come from ATC. With a significant failure such as a loss of the command-control link, GH will not be able to avoid anything – other airspace users will have to avoid *it*. **Recommendation: MODIFY** the Management Guideline to incorporate all the information given in the safety performance objective.
<u>ATMGH14</u>. All flights by GH in European airspace shall be notified to ATC by submission of a flight plan. This shall contain relevant supplementary information, including a telephone number to enable ATC to contact the GH PIC if required during the mission.	**SO6** A flight plan for every GH flight, accurately reflecting the 3D route (pre-defined in the Mission Plan), shall be submitted as an OAT flight plan in the standard ICAO format.	Good match between the two. **Recommendation: NO CHANGE** necessary to the Management Guideline.
COMMUNICATIONS, NAVIGATION AND SURVEILLANCE FUNCTIONALITY		

<u>ATMGH15</u>. GH shall be fitted with an operable transponder that will allow its PIC to respond to ATC requests to alter code settings and squawk identification. In the event of transponder failure, the mission may be recalled on the basis of agreement between GH operator and ATC.	**SO17** GH shall be equipped with a working transponder, being at least mode A and mode C. **<u>SO47</u>** In the event of a transponder failure, with the agreement of ATC GH shall either continue with its cleared 3D route, or, return immediately to the departure/arrival aerodrome (via activated segregated airspace), providing position and altitude information when required by ATC.	Good match between the two, although the Management Guideline does not mention returning via segregated airspace, which is important. The guideline ATMGH13, however, is not specific enough to cover being recalled to the *departure aerodrome* inside segregated airspace). **Recommendation: MODIFY** the Management Guideline to stress that the route taken if GH is recalled shall be in (re)activated airspace.
<u>ATMGH16</u>. The GH UAS shall be equipped with radios to enable the PIC to communicate with ATC on published ATC frequencies.		There is no *specific* equivalent safety performance objective. **Recommendation: NO CHANGE** necessary to the Management Guideline.
	SO24a Neither the command and control link between the pilot-in-command, nor the voice communications link between the pilot-in-command and ATC shall suffer from significant delay under normal conditions that could affect the safety of GH.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
RADIO COMMUNICATIONS BETWEEN PILOT-IN-COMMAND AND ATC		

ATMGH17. While in receipt of an air traffic service, a GH pilot-in command shall maintain 2-way communications with ATC, using standard phraseology when communicating via RTF. The word 'unmanned' shall be included on first contact with an ATC unit.	**SO7** All ATC centres that may encounter GH (in normal or abnormal situations) shall be made aware that the GH aircraft is an unmanned flight, and therefore is without a see and avoid capability. **SO23** Voice communications between GH and ATC shall be no different to that between ATC and other OAT. Standard phraseology shall be used.	Good match between the two. **Recommendation: NO CHANGE** necessary to the Management Guideline.
PILOT-IN-COMMAND		
ATMGH18. GH pilots-in-command shall conduct position reporting to ATC in terms that are readily understandable to controllers and that accord with procedures and phraseology contained in ICAO PANS-ATM (Doc 4444).		There is no *specific* equivalent safety performance objective. **Recommendation: NO CHANGE** necessary to the Management Guideline.
ATMGH19. GH pilots-in-command shall have a full understanding of both the airspace that GH will fly in at high altitude and the airspace which lies beneath**.**		There is no *specific* equivalent safety performance objective. **Recommendation: NO CHANGE** necessary to the Management Guideline.
	SO5a The GH pilot-in-command shall know the freedom that exists to manoeuvre within segregated airspace, according to how the buffer is applied (if at all) during each stage of the flight through the various European States.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.

<u>ATMGH20</u>. A GH shall be monitored continuously by its PIC for adherence to the current approved flight plan.	**<u>SO12</u>** The pilot-in-command shall monitor GH's conformance to its clearance, irrespective of whether it is following its pre-defined 3D route or is being vectored by ATC, and apply corrections to the flight trajectory as necessary.	Good match between the two, although it is recommended to adopt the additional details in the safety performance objective. **Recommendation: MODIFY** the Management Guideline to include the more detailed description of the safety performance objective.
<u>ATMGH21</u>. Information on the ATC situation shall be included in any formal handover of control between pilots-in-command.		There is no *specific* equivalent safety performance objective. **Recommendation: NO CHANGE** necessary to the Management Guideline.
	<u>SO11</u> ATC shall monitor GH's conformance to its clearance, irrespective of whether it is following its pre-defined 3D route or is being vectored by ATC, and issue corrective instructions as necessary.	There is no equivalent Management Guideline. It's a basic one, but important. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
	SO25 The pilot-in-command shall check regularly that GH's programmed 3D route will not pass through segregated airspace that has been published and activated for other flights after the time that GH's Mission Plan was uploaded.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
<u>GUIDELINES - EMERGENCIES</u>		
LOSS OF RADIO COMMUNICATIONS WITH ATC		

	SO45 In the event of loss of voice communication between the pilot-in-command and ATC, standard radio communications failure procedures shall be followed (described in ICAO's PANS ATM doc 4444) for a flight in instrument meteorological conditions.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
ATMGH22. GH pilots-in-command shall hold the telephone numbers of duty supervisors at the air traffic control units that are expected to provide an air traffic service to their UA, and these numbers shall be tested within 7 days prior to flight.	**SO46** Sufficient contact information shall be available to ATC and the pilot-in-command to be able to communicate with each other during *all* phases of GH's flight given a failure of the primary means of voice communication.	Good match between the two. **Recommendation: NO CHANGE** necessary to the Management Guideline.
LOSS OF CONTROL LINK		
ATMGH23. The UAS shall provide a prompt and obvious indication to the PIC of any interruption in the flow of health information from the GH.	**SO54** GH shall provide the pilot-in-command with up-to-date health information on the aircraft's systems, including the transponder and on the main functions that allow GH to complete its mission including, as a minimum, propulsion, flight control and navigation.	These are similar. The safety performance objective gives some specific information on the functions that should be included in the 'health information', notably for the transponder and the main functions of the aircraft. **Recommendation: MODIFY** the management objective to include the transponder and main functions as necessary information concerning the health of the aircraft.

<u>ATMGH24</u>. Normal operating procedure for GH in the event of loss of control link shall be for the UA to continue flying its current routing until the communications timer expires. As soon as possible, the PIC shall alert ATC to the situation and to the expected actions of the GH at the expiration of the communications timer. At that time, GH will autonomously squawk 7600 and proceed along its programmed lost-link routings.	**SO48** Following a command-control failure, if after a period of time the link has not been re-established, GH shall squawk 7600 (lost communications), and the pilot-in-command shall inform ATC what the aircraft is going (programmed) to do.	Good match. **Recommendation: NO CHANGE** necessary to the Management Guideline.
<u>ATMGH25</u>. The profile to be followed in the event of loss of control link shall be coordinated beforehand by GH operators with the relevant ANSPs.	**SO53** Following a command-control failure, if after a period of time the link has not been re-established, GH shall be pre-programmed to land by following a route that will minimise the risk to other airspace users and persons on the ground.	The Management Guideline does not say how separation shall be assured from other airspace users. **Recommendation: MODIFY** the Management Guideline to include the more detailed and precise description of the safety performance objective.
	SO55 Segregated airspace shall be designed to accommodate the route and climb profile for autonomous mode of flight.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.

<u>ATMGH26</u>. In the event that a GH known to be suffering loss of control link is seen by ATC to change its squawk to 7700, ATC shall notify the PIC as soon as possible.	**SO52** When ATC sees that a GH squawking 7600 (the code reserved for communications failures) changes to 7700 (the code reserved for emergencies), he/she shall inform GH's pilot-in-command immediately.	Good match between the two. **Recommendation: NO CHANGE** necessary to the Management Guideline.
EMERGENCY LANDING		
<u>ATMGH27</u>. In the event of GH suffering a failure requiring an emergency landing, the UA shall be programmed to automatically squawk 7700.	**<u>SO44</u>** In the event of an emergency GH shall immediately squawk 7700, and, as soon as practicable, the pilot-in-command shall inform ATC what GH is going (programmed) to do.	Good match between the two. However, the pilot-in-command needs to inform ATC about what GH will do. **Recommendation: MODIFY** the Management Guideline.
<u>ATMGH28</u>. GH operators shall ensure that procedures to be followed in the event of GH needing to make an emergency landing are coordinated beforehand with relevant ANSPs.	**SO41** Where practicable, GH shall be within glide distance of an emergency-alternate airfield at all times during its flight. These shall be coordinated with the States concerned before departure.	The Management Guideline is at a more general level than the safety performance guideline, which is a specific, *important*, procedure given an emergency. **Recommendation: MODIFY** the Management Guideline to incorporate the specific text from the safety performance objective. (If this is unacceptable for whatever reason, the safety performance objective should be made a Management Guideline in its own right.)

<u>**ATMGH29**</u>. In the event of a GH malfunction that requires an emergency landing, the emergency shall be declared by the PIC on the ATC radio frequency in use at the time if the radio is still available. If the radio is not available, the PIC shall immediately telephone the duty supervisor of the relevant air traffic control unit with details of the emergency.	<u>**SO44**</u> In the event of an emergency GH shall immediately squawk 7700, and, as soon as practicable, the pilot-in-command shall inform ATC what GH is going (programmed) to do.	Good match between the two. **Recommendation: NO CHANGE** necessary to the Management Guideline.
	SO49 GH shall be within glide distance of a termination point at all times during its flight. These shall be coordinated with the States concerned beforehand.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
	SO50 Where practicable, a *termination point* shall be near to the departure/arrival aerodrome, and the programmed descent route shall, where practicable, be inside segregated airspace.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
	SO51 If the 3D route for a divert-alternate or emergency-alternate airfield or a termination point is outside activated segregated airspace, the route shall avoid busy airspace, where practicable.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.

	SO42 The programmed divert-alternate and emergency-alternate airfields shall be the departure/arrival aerodrome where possible, and the programmed descent route shall, where, practicable, be within segregated airspace.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.
	SO43 Segregated airspace shall remain activated while GH's divert-alternate or emergency-alternate airfield is still the departure aerodrome.	There is no equivalent Management Guideline. **Recommendation: ADOPT** this safety performance objective as a new Management Guideline.

Table 6 – *A comparison of the Management Guidelines from DCMAC and the safety performance objectives from this safety assessment.*