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TITLE: **GA 22 Operational User Requirements Document**

DOCUMENT No: BAES-AS&FC-AP-GEN-REQ-03988

ADD. REF. No:

ISSUE: 1

DATE: 22nd October 2007

COPY No:

Prepared for and on behalf of BAE SYSTEMS — *Signatures on File Copy*

[redacted]

Approved for and on behalf of BAE SYSTEMS — *Signatures on File Copy*

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AMENDMENT HISTORY

ISSUE	REASON FOR CHANGE	DATE	AUTHOR
1	First issue	26/10/07	M Veevers / P Thomas

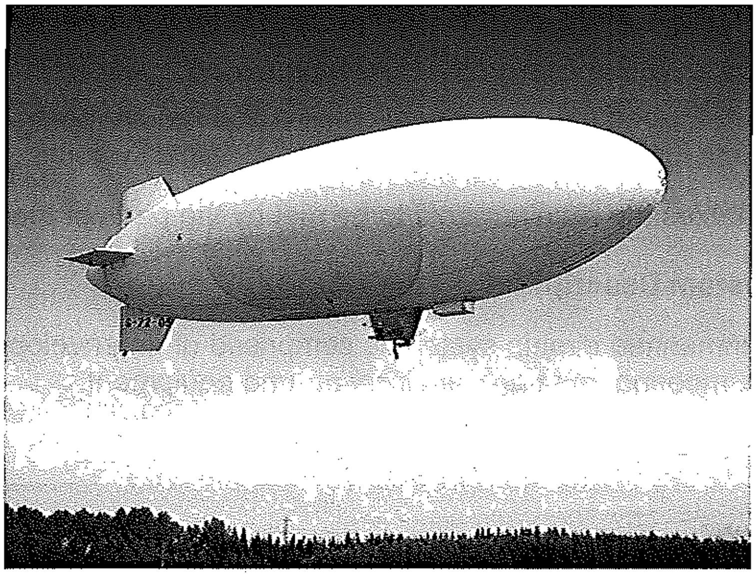
RELATED DOCUMENTS AND REFERENCES

1	[redacted]	[redacted]

ABBREVIATIONS

ATC	Air traffic Control
CONEMP	Concept of Employment
FD	Fire Detected
ft	Feet
GCS	Ground Control Station
HQ	Headquarters
IR	Infra Red
kg	kilogram
Km	Kilometre
Kts	Knots
LTA	Lighter Than Air
m	Metre
mm	millimetres
NIIRS	National Imagery Interpretability Rating Scale
Nm	Nautical Mile
TBD	To Be Determined
UAV	Unmanned Air Vehicle
UCAV	Unmanned Cobbat Air Vehicle

1 INTRODUCTION



The GA-22 Unmanned Airship was developed by Lindstrand Technologies for the Spanish Air Force. It is currently being operated in Northern Spain where its use is to monitor pollution levels in the region's rivers. In this operation the GA-22 is remote control, when within line of sight of the Ground Control Station; the airship then follows an automatic pattern of pre-designated way-points. [redacted]

It is perceived that there is a market for a similar product, with a significant level of autonomy, to perform persistent surveillance within Civil (and some Military) markets and therefore a potential BAE Systems opportunity.

A feasibility study has been performed which established that an autonomous version of the GA-22 could have some utility in a number of Civil (and some Military) applications including Communications Relay, Major Event Surveillance (pre-planned), Major Incident Surveillance (normally unplanned) [redacted] assuming that a suitable sensor payload is available. It concluded that for any particular application the most suitable vehicle configuration, payload and Concept of Employment (CONEMP) would need to be identified.

In order to develop GA-22 to meet the market opportunities, a set of requirements will need to be defined for each application where the GA-22 is to be used.

This document shall define these requirements for the selected application(s). The requirements definition process should start by describing the task to be performed from the users' perspective and then going on to derive the system requirements to meet this need from which the system design can be performed. In this instance the system design has already been constrained to using a GA-22 as the basis of the solution. Therefore the requirements will drive other parts of the solution such as the autonomous systems and the user payload.

The structure of the report is as follows:

- Section 1 provides the introduction to the report and a brief description of the current GA-22 system and the potential levels of autonomy to be applied.
- Section 2 gives an overview of the requirements and how they will be determined.
- Section 3 describes the operational context and requirements including a time line of events for the GA-22 system and the external systems.
- Section 4 tables the requirements to be met by the parts of the GA-22 system.

1.1 Current System Description

The Lindstrand unmanned airship system is comprised of an envelope, gondola, fins, electrical system, mooring mast and ancillary ground equipment.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

1.2 Autonomy

Various levels of autonomy are possible and the level suitable for each segment of a given operation will be dependant on technology, regulations and operational requirements.

The United States Office for Naval Research defines 6 levels of autonomy as follows:

1. Human Operated
2. Human Assisted
3. Human Delegated
4. Human Supervised
5. Mixed Initiative
6. Fully Autonomous

(These Autonomy Levels are further explained in Appendix A)

Ground handling on GA-22 is currently at [redacted] A move to [redacted] would be highly desirable to reduce operator workload e.g. by adding a truck mounted mooring mast that could allow ground handling to be performed by a single operator.

Take-off and Landing are potentially complicated procedures, especially when the weather conditions can be quite variable, and requires a skilled operator. Introducing [redacted] would be appropriate for these phases of the flight [redacted]

2 REQUIREMENTS OVERVIEW

Lighter than Air (LTA) vehicles are suitable for a wide variety of different applications.

A relatively small LTA vehicle, such as GA-22, will be suitable for a subset of these applications and each will produce its own set of requirements which in turn will drive a set of system requirements and necessary characteristics. Typical civil applications would include:

- Major Event Surveillance
- Major Incident Surveillance

[redacted]

Analysis and requirements definition for a single application will result in system requirements and subsequent vehicle specification optimised for that application whilst analysis of a number of applications will result in a broader set of requirements and may lead to a vehicle with broader utility. The consequence of this could be a more complex and potentially more expensive solution.

In order to find a possible compromise between vehicle utility and complexity, the requirements will initially focus on two key applications. Once the system requirements have been identified for these applications then other applications could be analysed and alternative system requirements identified. A judgement can then be made as to how different they are from the original system requirements and whether they can be sensibly satisfied by the same solution in which case they can be added to the original system requirements to form a multi-application system.

Given the nature of the interest in GA-22 from current potential customers, and the timescales for these customers, the initial operational requirements will be derived for Major Event Surveillance and Forest Fire Detection (as a type of Major Incident Surveillance).

3 OPERATIONAL REQUIREMENTS

3.1 Major Event Surveillance

3.1.1 Overview

The police will perform continuous surveillance across the area of responsibility (in and around the event venue) using personnel, vehicles and remote sensors. This would be achieved by foot patrols, vehicle patrols, airborne patrols and a range of fixed and mobile high resolution cameras/audio devices. [redacted] Overt continuous airborne surveillance will be conducted by GA-22. The combination and integration of these various systems will provide a detailed situational awareness picture of the major event.

The event will be pre-planned and will not require any high speed transit. GA-22 will need to perform surveillance over a pre-defined area for the duration of the event. [redacted]

Information from personnel, vehicles and sensors shall be linked directly to the C2 network so that rapid decisions can be made by the command authority who can then notify the relevant patrols of the nature of the potential problem in their area of responsibility. [redacted]

A number of more specific instances can be defined that will each require a different level of capability. Three levels of capability could be as follows:

- Minimum Capability e.g. Surveillance at a Football Match
  - Cover an area of interest around a football stadium [redacted]
  - Continuous coverage with a resolution of [redacted]
  - Continuous surveillance for the period of peak demand [redacted]
  - In daylight or under flood lights
- Medium Capability e.g. Surveillance at a Grand Prix
  - Cover an area of interest around a Grand Prix [redacted]
  - Spot Coverage with a higher resolution on a particular area when necessary.
  - [redacted]Continuous surveillance for the period of peak demand [redacted]
  - In Daylight (Dawn to Dusk)
- Maximum Capability e.g. Surveillance at a cycle road race
  - [redacted]. Crowds and traffic disruption could be within 1km either side of the route. [redacted]
  - Broadcast quality imagery of a particular area of the race or any particular trouble spot.
  - For the duration of the road closures [redacted]
  - In Daylight (Dawn to Dusk)

For the purpose of this requirements definition the focus will initially be on the medium capability.

3.1.2 Operational Architecture

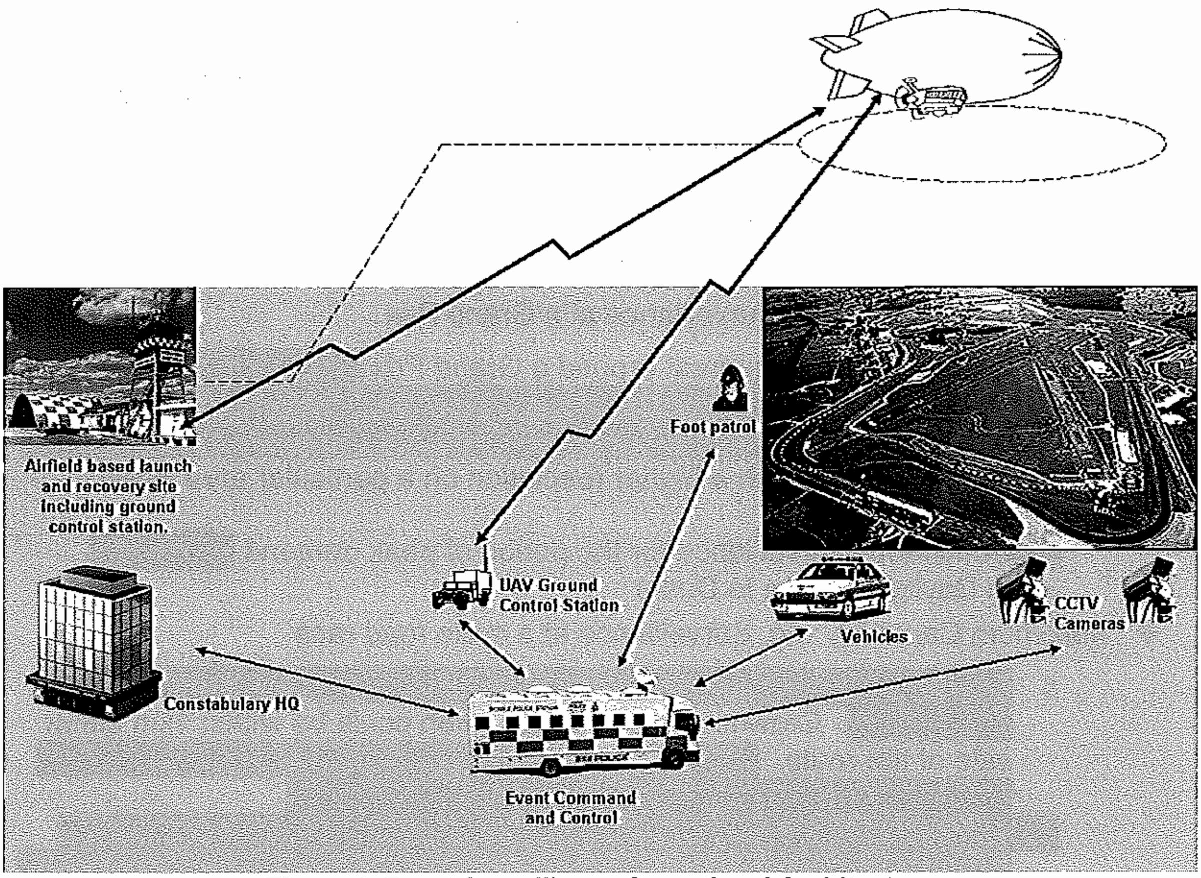


Figure 1. Event Surveillance Operational Architecture

The architecture in which the GA-22 system will operate should be flexible to suit the requirements of multiple customers though subsequent customer specific options should be possible. Figure 1 above illustrates a generic operational concept architecture.

The operational concept is based on conducting autonomous pre-planned missions, operating from a single launch and recovery site, at a local airfield, which includes a ground control station. Once launched, air vehicles can continue to be monitored and controlled from the ground control station at the launch and recovery site or can be handed over to a ground control station located near to the event (as depicted by Figure 1.). This ground control station could be co-located within the event command and control or could be separate and linked by a communications network. Both ground control stations should have the ability to perform three primary roles – UAV mission commander, image exploitation and air vehicle manager.

Either ground control station should have the ability, at any time, to modify or change the mission being conducted by the air vehicle, thus enabling reaction to events. The ground control station should be able to request down load of surveillance data from the air vehicle for exploitation and/or onward transmission.

3.1.3 Operational Data

Terrain and Culture

The take-off and landing site will be a prepared runway at an airfield a short distance away from the event location. The land in the area of interest is varied but low lying.

Operating Altitude

To provide a good combination of communications range, area of observation and image quality the GA-22 would benefit from the ability to fly at altitudes [redacted].

Flight path

The flight path should be pre-planned with a facility for operator intervention during operation. The following is an example of a typical flight path that would be suitable for this application.

- Take-off from a small airfield
- Climb to [redacted]
- Transit to area of interest [redacted]
- Perform surveillance over area of interest for the duration of the event
- Return to base
- Descend and attach to mooring

Airspace

The airspace in which the GA-22 would have to operate would be predominantly class G airspace. Although the airspace could be expected to be reasonably quiet at GA-22 operating altitudes, airspace above the GA-22 would be quite busy due to major airport(s) in the vicinity. The GA-22 will of course be operating over a populated area. Any local air traffic due to travel into the event e.g. helicopters should also be considered.

Environment

In general many weather conditions are possible including heavy rain. Operation in the evening is likely although the event will be lit.

Support Assets

As described by the operational architecture, the GA-22 vehicle will be embedded into a wider system of systems. Ideally there would be a hangar at the launch and recovery airfield where the GA-22 can be serviced, inspected, refuelled and data uploaded to and downloaded from its onboard mission computer. In the hangar would be a data storage system and a ground control station. For launches the use of a mooring truck instead of a fixed mooring would allow ground manoeuvre of the GA-22 to be simplified and could reduce the ground crew required

It is likely that the platform will be operated on the county level, as is generally the case with police surveillance systems. Therefore, the platform is likely to be based locally and operated from a prepared airstrip.

Collaborating Assets

As described in the operational architecture the GA-22 system will comprise of an air vehicle and one or more ground control stations, located at the launch and recovery site and local to the event. The GA-22 system will need to collaborate with a number of different assets.

Surveillance data may be required at police headquarters or a regional command centre and this will come from a local command and control centre located at the event. Other assets at the event, such as police officers on foot or in vehicles, will be controlled by the event command and control centre. Therefore the event command will require a direct link to the GA-22 system and in particular the ground control station. The local ground control station could be embedded into the event command and control centre or could be separate. Either way the ground control station will perform the surveillance data exploitation for use by the external assets.

Any of the external assets may make requests for additional information (e.g. "please look over there") and these will be relayed via the event command and control centre to the ground control station which will then command the air vehicle to move and gather the requested information.

Communications

Internal to the GA-22 system will be commands from ground station to air vehicle and surveillance data from the air vehicle to the ground station.

The GA-22 system will need to communicate directly with the following external systems:

- The data storage system in the hangar
- The event command and control
- Air Traffic Control

Mission Objectives

The objective for this mission will be to [redacted] The user of the GA-22 system should be able to observe any detected incidents [redacted]

In general, all information must be available in real or near real time, in a format that can be immediately reviewed or disseminated, so that the appropriate response to the situation developing on the ground can be made quickly. [redacted]

[redacted] This activity could be performed autonomously within the GA-22 system or could be performed externally to the Ga-22 system with the required images being provided by GA-22.

High definition digital still photographs and continuous real time streaming video will be required in many instances.

3.1.4 Timeline of events

A typical timeline of events for the GA-22 to perform this type of operation would be as follows:

04:00	Crew arrive at main operating base (small airstrip)
04:05	Start Pre-flight (visual) Inspection
04:15	Leave Hangar, towed by mooring truck
04:20	Take off from centre of airfield (into wind) and climb to operating altitude.
04:30	Fly towards event area at between [redacted] (above ground level).
04:30 to 06:30	Transit at [redacted]
06:30	Arrive at event area
06:30 to 07:00	Perform initial surveillance of event perimeter
07:00 to 08:00	Perform surveillance of area where event will take place
08:00 to 08:30	Perform Surveillance of area just outside Event Perimeter
08:30 to 09:00	Perform Surveillance extending beyond the event perimeter while continuously monitoring the area around the main Gate.
09:00	**Event Opens to Public**
09:00 to 12:30	Fly round event area taking video and High quality still images Relaying all video & selected Stills to a display on the ground. Stills can be selected by clicking on a map of the area (or an image overlaid on that map)
12:30 to 17:30	Fly to one side of the event and observe events using a telephoto lens
17:30 to 19:00	Fly round event area taking video and High quality still images Relaying all video & selected Stills to a display on the ground.
19:00	**Event activities Cease**
19:00 to 20:00	Perform Surveillance of event perimeter while continuously monitoring the area around the main Gate.
20:00	**Gates Close to Public**
20:00 to 22:00	Transit [redacted]
22:10	Attach to mooring truck on airfield
22:15	Enter Hangar, towed by mooring truck
22:15 to 22:25	Download all data stored during day
22:30	All Systems Shut down

For an event lasting several days alternative basing may be desirable.

It is assumed that on this mission the GA-22 will fly from its operating base so there will not be a deployment phase as such. [redacted] If GA-22 spent its time performing missions from a main operating base, issues such as minimising helium loss would be more important than speed of inflation or size of packed vehicle.

3.1.5 Operational Requirements

Given the general description of the application and the operational context described above the following sections define the operational requirements.

3.1.5.1 *Environment*

The area of operation will be level ground with some gentle undulation possible. The area will be densely populated as it is a major public event.

The operation will be predominantly in class G airspace although the event is likely to be in the vicinity of operational airports. The platforms will therefore have to satisfy the requirements of CAA.

The event may occur in all weather conditions including heavy rain.

The event will occur during daytime and/or evening and the area will be lit when required.

3.1.5.2 *Vehicle Performance*

Geographical Reach & Coverage

The event will cover an area of interest of [redacted]

The operating base will be a distance of [redacted]

Persistence

Surveillance will be required for the duration of event [redacted] and any surveillance before and after the event [redacted] In addition transit to and from the operating base will be required [redacted] This results in a total mission duration of [redacted]

Vehicle Performance

The system should be capable of transit and operation in crosswind and headwind (Details to be defined in a system specification).

The optimum operating altitude for the surveillance will be approximately [redacted] above ground level [redacted]

3.1.5.3 *Autonomy*

The operation should be as autonomous as possible, especially during the transit and surveillance, without compromising safety in the area of operation. The route for the air vehicle to fly through a predefined search area to enable efficient search by the onboard sensor suite shall be calculated and updated autonomously as required. The system should automate key detection functions, reducing operator workload and minimising the data transmitted to the ground station.

The ground handling should be at least Autonomy Level [redacted] (This could be achieved by using a mooring truck rather than requiring human operators to man handle it.)

Take-off and Landing should be at least [redacted] fully autonomous take-off and landing would be an aspirational requirement.

3.1.5.4 *Mission Performance*

During the surveillance activity the operational need is [redacted]

To satisfy the operational need the following will be required:

- Rapidly produce a still image, or series of still images, covering the event area at moderate resolution to give a Context Map for orientation.
- Produce high resolution still images of any part of the event area so that a user can effectively zoom in on any area of interest. Ideally displaying them within [redacted]
- Produce Video images (visible band) of any part of the event area with an appropriate resolution and field of view (user specified). Ideally displaying them within [redacted]
- Produce Video images (IR band) of any part of the event area with an appropriate resolution and field of view (user specified). Ideally displaying them within [redacted]

NOTE:

The surveillance needs can be further defined in terms of resolution requirements at the target. When these are combined with the likely range at which the platform must operate, they will produce requirements for the angular resolution of the sensor.

Two methods are commonly used to determine resolution requirements at the target. Both methods are based upon experiments with experienced image interpreters. The first is the NIIRS scale which describes resolution requirements on a rating scale and is useful for discussion purposes. The second is the Johnson criteria, which looks at the probabilities of achieving detection, recognition and identification, and is most suited to resolution calculations.

[redacted]

[redacted]

[redacted]

3.1.5.5 *Data Handling Requirements*

The ability to record all information gathered would be required.

See communication and interoperability for data transmission.

It should be possible to download all data stored during the mission to a computer in the hangar within a reasonable time period from when the system is tethered [redacted] This will also facilitate a rapid turn around.

3.1.5.6 *Displays and Controls*

The UAV operator/mission commander will be located at a ground station and will require a suitable workstation so that real-time re-tasking and monitoring can be conducted.

Ground Station Display Requirements

Vehicle speed, altitude, position, attitude and other flight data should be available to view throughout the operation.

General Requirements

- A display of the view from a forward looking flight camera with flight data superimposed on it.
- A suitably scaled map display to plot the position of the vehicle and the ability to re-direct the vehicle as necessary.
- A Status display to give the value of various vehicle & system parameters e.g. fuel state, battery condition, alternator output.
- A screen that can display an image of the event area (if necessary a composite image) with boxes superimposed showing the location and scale of images from other sensors displayed on other screens.
- A screen to display High Resolution Still images of a selected area.
- A Screen to display Video images of a selected area at a given resolution. This screen should have the ability to display Visual Images, IR Images or Visual Images with IR superimposed on them.

3.1.5.7 *Communications & Interoperability*

Internally to the Ga-22 system a two way command and control link between the UAV operator/mission commander, based at the ground control station, and the air vehicle will be required. In addition real time surveillance data will need to be transmitted from the air vehicle to the ground control station. Both these will require line of sight communications links.

Air vehicle navigation data should be transmitted at all times so that the position of any areas of interest, detected by low-resolution situational awareness sensors, can be recorded to allow further investigation. If high resolution data is recorded for analysis later, it should be time and position stamped to enable a rapid response of ground elements to a potential problem that is found in the imagery.

The air vehicle could also include a transponder and altitude encoder to enable supervision by Air Traffic Control for cases when it must fly into terminal control areas.

The GA-22 system will operate as part of a complete surveillance system including ground based sensors. Therefore a local area command and control network will be required to link all surveillance assets, including the GA-22 system, to the event command centre. Real time surveillance data will need to be transmitted from the GA-22 system to the event command and control centre and potentially on to the wider area command and control (e.g. police HQ). This will require suitable line of sight communication with a range of up to TBD km.

3.1.5.8 *ILS & Service Life*

The support solution should be self-contained and require minimum technical support.

Processing of surveillance data (including high-resolution imagery) may be required post flight for audit or intelligence purposes.

The system should be operated from a hangar at a local airfield and should require minimum ground handling for launch and landing. This may include the use of a mooring truck rather than a static mooring post.

The system should be ready to leave hangar within [redacted]

The system and launching platform must be reliable in order to operate for extended periods and to keep maintenance overheads to a minimum.

The role of the system will not change during its lifetime but there may be some growth in requirement to accommodate new sensors.

3.1.5.9 *Constraints (e.g. Legal, Affordability)*

The system must be able to receive a Certificate of Airworthiness from the regulating authority.

3.2 Major Incident Surveillance - Forest Fire Detection

3.2.1 Overview

The GA-22 operates for the regional government of a European Country and performs surveillance of forests within their area of responsibility. The GA-22 would need to detect forest fires before they become firmly established so that fire fighting teams can respond rapidly and put them out. The GA-22 would therefore need to supply information to Fire-fighting units on the ground as and when they required it, via a portable ground station. It would also need to supply information to fire fighting aircraft, to enable them to plan and execute their water delivery.

3.2.2 Operational Architecture

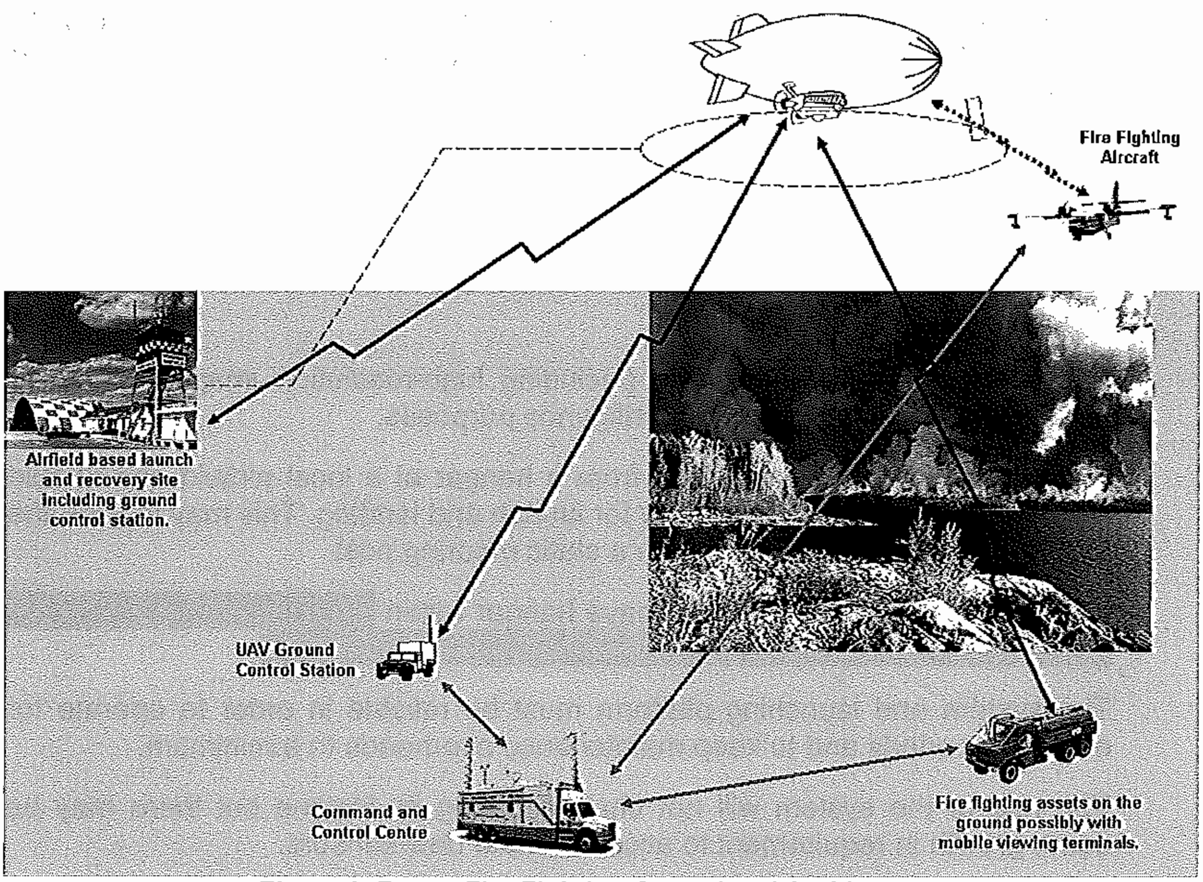


Figure 2. Forest Fire Fighting Operational Architecture

The architecture in which the GA-22 system will operate should be flexible to suit the requirements of multiple customers though subsequent customer specific options should be possible. Figure 1 above illustrates a generic operational concept architecture.

The operational concept is based on conducting autonomous pre-planned missions, operating from a single launch and recovery site, at a local airfield, which includes a ground control station. Once launched, air vehicles can continue to be monitored and controlled from the ground control station at the launch and recovery site but more likely will be handed over to a ground control station located near to the forest fire (as depicted by Figure 1.). This ground control station could be co-located within the command and control centre or could be separate and linked by a communications network. Both ground control stations should have the ability to perform three primary roles – UAV mission commander, image exploitation and air vehicle manager.

Either ground control station should have the ability, at any time, to modify or change the mission being conducted by the air vehicle, thus enabling reaction to events. The ground control station should be able to request down load of surveillance data from the air vehicle for exploitation and/or onward transmission.

3.2.3 Operational Data

Terrain and Culture

The land in the area of interest varies from [redacted] and is predominantly forest. Although the area of interest has a low population, there will be few places where the GA-22 could make a safe emergency landing. [redacted]

Operating Altitude

The GA-22 would need the ability to fly at least [redacted]. It is not certain what affect a forest fire might have on air temperature and air currents, but it is not expected to be benign. [redacted]

Flight path

The flight path should be pre-planned with a facility for operator intervention during operation. The following is an example of a typical flight path that would be suitable for this application.

- Take-off from a small airfield [redacted]
- Transit to area of interest [redacted]
- Perform surveillance over area of interest
  Coordinating with other assets as necessary
- Return to base
- Descend and attach to mooring truck

Airspace

The airspace the GA-22 would have to operate in would be predominantly class G airspace. [redacted]

The GA-22 will predominantly be operating over a sparsely populated area. [redacted]

Environment

In general many weather conditions are possible in this part of Europe, but operations for the prevention of forest fires are unlikely to be necessary in snow or heavy rain. Fire risk is likely to be relatively low during the early morning, when mist is likely to occur, but could still be fairly high on overcast days. The GA-22 would therefore need to be able to operate below the clouds. If a cloud inversion occurred, the most dangerous place for fires would be above the clouds. GA-22 may therefore need the ability to move from above to below the clouds in order to determine fire risk in all parts of the forest. Flight at night could be necessary, but forest fires do not usually start accidentally when the sun is down. Perhaps the most demanding weather conditions would be the GA-22 was operating in and around the smoke produced by a forest fire.

Support Assets

The GA-22 will operate from a hangar at the launch and recovery airfield where it can be serviced, inspected, refuelled and data uploaded to and downloaded from its onboard mission computer. In the hangar will be a data storage system connected to a ground control station. For launches the use of a mooring truck instead of a fixed mooring would allow ground manoeuvre of the GA-22 to be simplified and could reduce the ground crew required

Collaborating Assets

As described in the operational architecture the GA-22 system will comprise of an air vehicle and a number of ground control stations. In addition to the ground control station near the airfield, there will be one or more mobile ground control stations located with fire-fighting units on the ground. In addition to the ground control stations the GA-22 system could include portable viewing terminals capable of viewing real time imagery from the air vehicle. These portable viewing terminals would be carried by the fire fighting crew on the ground.

Surveillance data will be required at the command and control centre located near the forest fire and this will be provided from the local ground control station. The local ground control station could be embedded into the event command and control centre or could be separate. Either way the ground control station will perform the surveillance data exploitation.

Other assets in the area, such as fire fighters on foot or in vehicles, will be controlled by the command and control centre and may receive information from there. They may also require direct access to real time surveillance data and this could be provided directly from the air vehicle to mobile viewing terminals which they have with them.

Any of the assets outside the GA-22 system may make requests for additional information (e.g. “please look over there”) and these will be relayed via the event command and control centre to the ground control station which will then command the air vehicle to move and gather the requested information.

The command and control centre will need to collaborate with fire-fighting aircraft; giving it sufficient information to decide where to drop its load of water or foam. The GA-22 system could include a direct link to the fire-fighting aircraft which would have a portable viewing terminal for real time surveillance information.

Communications

Internal to the GA-22 system will be commands from the ground control station to the air vehicle and surveillance data from the air vehicle to the ground control station.

The GA-22 system will need to communicate directly with the following external systems:

- The data storage system in the hangar
- The local Command and Control Centre
- Fire-fighting Assets
- Air Traffic Control

It is possible that there could be poor line of sight communication in the area of the forest fire due to terrain and culture. In this case the Ga-22 air vehicle could act as a communications relay for communication in and out of the area e.g. ATC communications.

Mission Objectives

The objective for this mission will be to monitor the forest in the area of interest, looking for areas which are generally high risk, finding and reporting any hot spots, informing emergency services of any fires detected and assisting them in extinguishing those fires. These objectives are detailed below:

Long Term Data Gathering

The GA-22 system will need to survey a large area of forest, revisiting it at regular intervals throughout the day. Data should be recorded for future use, enabling a pattern of daily temperature variations to be built up for every location within the forest for the part of the year when fire risk is the greatest. This long term information can be downloaded via the ground control station in the hangar at the end of each mission. [redacted]

Short Term Data Gathering

In addition to the systematic gathering of long term "Risk" data, the GA-22 system should rapidly (& automatically) detect areas where a fire was just about to start or had just started. If a long term risk map of the forest had already been calculated (from previous missions) establishing which areas of the forest required the most frequent surveillance will be possible. These will typically be areas of natural high risk plus areas of significant human contact.

Ideally all areas of the forest should be surveyed when the risk is relatively low (e.g. just after dawn) and the onboard risk map updated to match the conditions of the day. The GA-22 air vehicle will autonomously plan its route aiming to revisit the highest risk areas most frequently. The GA-22 ground control station will be informed of the vehicle's proposed flight path, and this can be passed to ATC.

The daily risk map will be continually updated by the GA-22 system and regularly transmitted to the external operators on the ground.

Emergency Response

Once a fire, or an area in imminent danger of catching fire, is detected the GA-22 system needs to inform its human operators immediately. These operators should be in regular contact with the fire fighting authority. The Fire fighting authority will, based on information from the GA-22 operators, form a plan of how best to deal with the emergency.

The GA-22 system now needs to perform an additional task. In addition to the long term (low priority) and short term data gathering (medium priority) tasks, it needs to provide the fire fighters with regular updates on the progress of the fire or area of extreme fire risk. To do this it will need to fly around the area of fire or extreme fire risk, gathering information, which it can send to the Ground Control Station and also directly to Mobile Ground Stations in vehicles and Portable Ground Stations carried by fire fighting units.

When the fire fighters are in a vehicle they might be able to carry moderately bulky display equipment, use heavy duty batteries, and make use of vehicle mounted radio antennae. [redacted]

When fire fighters are on foot they will need lightweight, low bulk equipment, with far less power and a far smaller antenna. Communicating with these ground stations will be more difficult.

In addition to sending information to these small ground stations the GA-22 will need to relay information from them to the Ground Control Station. The ground stations may not themselves be able to establish communications directly with the ground control station so this could be their primary means of communicating. If the fire fighters with the mobile and portable ground stations require more information from the GA-22 system they well use the GA-22 platform to relay their requests to the GCS, which may command (or request) that the GA-22 either redirects its camera or moves to where it can get a better view to gather such information.

Real Time Response Coordination

If the fire fighting authority decides it is appropriate, they may call in an aircraft to drop water onto a fire. The primary benefit of a fire fighting aircraft, compared to ground units, is its speed of response, but this comes at the expense of endurance and payload. The best way to make use of a fire-fighting aircraft is therefore to have very accurate and timely information so that the aircraft can be called in precisely when and where it is required. A single accurate water strike on a recently established fire might be sufficient to completely extinguish it.

When an aircraft was called in, the GA-22 system will need to gather information about the fire from various different angles and send this to the fire-fighting aircraft. For direct communication with the fire fighting aircraft, suitable equipment would need to be provided on board the aircraft. The GA-22 air vehicle will need to move to an area out of the proposed flight path but from where it could still observe and relay information about the fire (ideally in real time).

[redacted]

3.2.4 Timeline of events

A typical timeline of events for the GA-22 to perform this type of operation would be as follows:

06:00	Crew arrive at main operating base (small airstrip)
06:05	Start Pre-flight (visual) Inspection
06:15	Leave Hangar, towed by mooring truck
06:20	Take off from centre of airfield (into wind) and climb to operating altitude.
06:30	Fly towards area of interest at between [redacted]
06:30 to 07:00	Transit [redacted]
07:00	Arrive at area of interest
07:00 to FD	Perform surveillance of forest area looking for Hot Spots (large or small) IR photographs of suspicious areas relayed to base with coordinates Close up images of Hot Spots taken and relayed to base
FD	**Fire Detected**
FD to FD +:10	Move closer to Suspected Fire and gather information about its extent and seriousness to relay back to base for planning purposes.
FD+:10 to +:30	Perform Surveillance of areas near Fire while monitoring progress of Fire.
FD+:30	**Fire Fighting Aircraft takes off**
FD+:30 to +:50	Perform Surveillance of areas near Fire while monitoring progress of Fire.
FD+:50 to +:60	Assist Fire Fighting Aircraft by providing regular updates of progress of Fire directly to the aircraft.
FD+:60	**Fire Fighting Aircraft drops water on Fire**
FD+:60 to +:75	Perform Surveillance of areas near Fire while monitoring progress of Fire.
FD+:75 (=FE)	**Fire Confirmed Extinguished**
FE to 23:00	Perform surveillance of forest area looking for Hot Spots (large or small)
23:00 to 23:30	Transit at [redacted]
23:40	Attach to mooring truck on airfield
23:45	Enter Hangar, towed by mooring truck
23:45 to 23:55	Download all data stored during day
24:00	All Systems Shut down

Note that if a fire was not detected promptly it could burn for 2 or 3 days so the GA-22 would be required to operate for considerably longer. In this situation a rapid turn around capability would be highly desirable.

It is assumed that on this mission the GA-22 will fly from its main operating base so there will not be a deployment phase as such. [redacted] If GA-22 spent its time performing missions, like the above, from a main operating base, issues such as minimising helium loss would be more important than speed of inflation or size of packed vehicle.

3.2.5 Operational Requirements

Given the general description of the application and the operational context described above the following section define the operational requirements.

3.2.5.1 *Environment*

The area of operation will be hills and small mountains, covered with forests. The terrain varies from [redacted] The area will be sparsely populated.

The operation will be predominantly in class G airspace although some forest areas may be in the vicinity of operational airports. The platforms will therefore have to satisfy the requirements of the appropriate national or international civil aviation authority.

The mission may occur in many weather conditions, but snow and heavy rain will generally be associated with low fire risk so, although the platform needs to be able to survive these phenomena, the system does not need to gather data in these conditions.

The time of highest fire risk is likely to occur during daylight hours, but the vehicle itself may be required to operate at any time of the day or night. Surveillance will be required at night if a fire has started.

The vehicle will need the ability to operate near the smoke and the air currents produced by a forest fire.

3.2.5.2 *Vehicle Performance*

Geographical Reach & Coverage

The forest to be surveyed will cover a large area; [redacted]

The operating base will be relatively close to the edge of the surveillance area; [redacted]

Persistence

Surveillance will be required for the duration of high fire risk [redacted] In addition transit to and from the operating base will be required [redacted]

If a fire breaks out the vehicle would benefit from the ability to extend its persistence to [redacted], with rapid turn around to allow very high availability during a 2 or 3 day period.

Vehicle Performance

The system should be capable of transit and operation in crosswind and headwind (Details to be defined in a system specification).

[redacted]

3.2.5.3 *Autonomy*

The operation should be as autonomous as possible, especially during the transit and surveillance, without compromising safety in the area of operation. The route for the air vehicle to fly through a predefined search area to enable efficient search by the onboard sensor suite shall be calculated and updated autonomously as required. The system should automate key detection functions, reducing operator workload and minimising the data transmitted to the ground station.

[redacted]

[redacted]

[redacted]

3.2.5.4 *Mission Performance*

The objective for this mission will be to monitor the forest in the area of interest, looking for areas which are generally high risk, finding and reporting any hot spots, informing emergency services of any fires detected and assisting them in extinguishing those fires.

To satisfy the operational need the following will be required:

- Rapidly produce a still image, or series of still images, covering the entire forest at moderate resolution to give an IR Risk Map of the forest at various times of day on various days of the year.
- Produce IR imagery to update the IR Risk Map, automatically identifying areas with extreme fire risk.
- Produce (High Resolution) Still images (IR band) of any part of the forest with an appropriate resolution and field of view (user specified). [redacted]. This data should be provided for fire fighting teams.
- Produce Video images (IR band) of any part of the forest with an appropriate resolution and field of view (user specified). Ideally displaying images from a new viewpoint as soon as possible after the user request. This data should be provided for fire fighting teams including the fire fighting aircraft.

3.2.5.5 *Data Handling Requirements*

Sufficient onboard data storage should be available to record all information gathered.

See communication and interoperability for data transmission.

It should be possible to download all data stored during the mission to a computer in the hangar within a reasonable time period [redacted] This will also facilitate a rapid turn around.

The GA-22 Platform needs to hold an onboard copy of the long term risk map of the forest. It needs to be able to update this to form a current risk map. There will need to be some processing to allow autonomous route optimisation so that revisit rates can be tailored to the risk of individual areas.

3.2.5.6 *Displays and Controls*

The operator/mission commander will be located at a ground station and will require a suitable workstation so that real-time re-tasking and monitoring can be conducted.

Ground Station Display Requirements

Vehicle speed, altitude, position, attitude and other flight data should be available to view throughout the operation.

General Requirements

- A display of the view from a forward looking flight camera with flight data superimposed on it.
- A map display to plot the position of the vehicle and the ability to re-direct the vehicle as necessary.
- A Status display to give the value of various vehicle & system parameters e.g. fuel state, battery condition, alternator output.
- A screen that can display an image of the whole forest (if necessary a composite image) with boxes superimposed showing the location and scale of images from other sensors displayed on other screens.
- A screen to display High Resolution Still images of a selected area.
- A Screen to display Video images of a selected area at a given resolution. This screen should have the ability to display Visual Images, IR Images or Visual Images with IR superimposed on them.

The ground control stations at the launch and recovery site and local to the fire will both have the same capability and should have dedicated screens for:

- Flight Camera & Data
- Vehicle location Map
- System Status
- Forest Map (Risk Map)
- High Resolution Still Images
- Video Images

The mobile viewing terminals do not need all the data, and would be seriously constrained in mass, bulk and power if they had the same capability as the ground control stations. They should have a single screen which displays data (perhaps in a window type format) from the three most interesting data-streams:

- Forest Map
- High Resolution Stills
- Video Images

The fire-fighting aircraft is not required to directly control the GA-22 and will require the same capability to the mobile viewing terminals. In addition it would be useful for the fire-fighting aircraft to have additional capability to help plan flight path and collision avoidance with the Ga-22 air vehicle (especially in areas of smoke) and also to plan an accurate water drop on the most critical area of the fire or fire risk. The extra information required will be:

- Flight Camera & Data
- Vehicle location Map

3.2.5.7 *Communications & Interoperability*

Internally to the Ga-22 system a two way command and control link between the UAV operator/mission commander, based at the ground control station, and the air vehicle will be required. In addition real time surveillance data will need to be transmitted from the air vehicle to the ground control station and the mobile viewing terminals. Both these will require line of sight communications links.

Air vehicle navigation data should be transmitted at all times so that the position of any areas of interest, detected by low-resolution situational awareness sensors, can be recorded to allow further investigation. If high resolution data is recorded for analysis later, it should be time and position stamped to enable a rapid response of ground elements to a potential problem that is found in the imagery.

The air vehicle could also include a transponder and altitude encoder to enable supervision by Air Traffic Control for cases when it must fly into terminal control areas.

The GA-22 system will require two way communications with the event command centre. Real time surveillance data will need to be transmitted from the GA-22 system to the event command and control centre. This will require suitable line of sight communication with a range of up to TBD km.

3.2.5.8 *ILS & Service Life*

The support solution should be self-contained and require minimum technical support.

Processing of surveillance data (including high-resolution imagery) may be required post flight for audit or intelligence purposes.

The system should be operated from a hangar at a local airfield and should require minimum ground handling for launch and landing. This may include the use of a mooring truck rather than a static mooring post.

[redacted]

The system and launching platform must be reliable in order to operate for extended periods and to keep maintenance overheads to a minimum.

The role of the system will not change during its lifetime but there may be some growth in requirement to accommodate new sensors.

3.2.5.9 *Constraints (e.g. Legal, Affordability)*

The system must be able to receive a Certificate of Airworthiness from the regulating authority.

4 USER REQUIREMENTS

Based upon the operational requirements for the applications described in the previous section the following set of user requirement has been defined. The applicability to the applications is indicated by a 'x'.

User Requirement		Applicability	
		Event	Forest Fire
1. Airspace Integration			
1.1	The user shall be able to operate within class G airspace.	x	x
1.2	The user shall be able to operate within TBDkm of major airports.	x	x
2. Autonomy			
2.1	The user shall be able to perform the operation with maximum autonomy and be informed of 'incidents' when they occur.	x	x
2.2	The user shall be able to take 'remote' control of the air vehicle when required.	x	x
2.3	The user shall be able to perform ground handling with an autonomy level of at [redacted]	x	x
2.4	The user shall be able to intervene to command autonomous controlled and safe termination of the operation at any time.	x	x
2.5	In the event that intervention is not possible (e.g. Communication System failure) it shall be possible for the user to safely recover the System without damage.	x	x
3. Availability and Reliability			
3.1	TBD		
4. Commercial			
4.1	TBD		
5. Communications & Interoperability			
5.1	The user shall be able to provide operational instructions to the air vehicle and at any point within the operation.	x	x
5.2	The user shall be able to operate as part of a wider surveillance network including ground based surveillance.	x	x
5.3	The user shall be able to receive tasking instructions from a third party	x	x

User Requirement		Applicability	
		Event	Forest Fire
5.4	The user shall be able to communicate with the local command and control network controlling the operation including:		
5.4.1	Fire Service (Ground and Air Assets)	x	x
5.4.2	Police	x	x
5.4.3	Air Traffic Control	x	x
5.5	The user shall be able to transmit real time surveillance data to the other parties in the local area.	x	x
5.6	The user shall be able to protect any command and control data links from sabotage and interception at any point during the operation.	x	x
5.7	The user shall be able to protect any surveillance data links from interception at any point during the operation.	x	x
6. Environmental Conditions			
6.1	The user shall be able to operate over the following terrain:		
6.1.1	For event surveillance over level ground with some gentle undulation.	x	
6.1.2	For forest fires detection an area of hills and small mountains, covered with forests.		x
6.2	The user shall be able to operate over a densely populated area.	x	
6.3	The user shall be able to operate over sparsely populated terrain ranging from [redacted].		x
6.4	The user shall be able to operate in class G airspace in the vicinity of operational airports.	x	x
6.5	The user shall be able to operate in all weather conditions including heavy rain.	x	x
6.6	The user shall be able to operate in all light conditions.	x	x
6.7	The user shall be able to operate near the smoke and the air currents produced by a forest fire.		x
6.8	The user shall be able to operate the system in temperatures from TBD to TBD	x	x

User Requirement		Applicability	
		Event	Forest Fire
6.9	The user shall be able to operate in up to moderate turbulence (ICAO definition).	x	x
6.10	The user shall be able to operate without undue effects experienced from EMI, EMC, HIRF or lighting strike.	x	x
6.11	The user shall be able to operate from prepared runways.	x	x
6.12	The user shall be able to operate in tailwind, crosswind and headwind (TBD).	x	x
7. Logistics and Deployment			
7.1	The support solution should be self-contained and require minimum technical support.	x	x
7.2	The user shall be able to process surveillance data post flight for audit or intelligence purposes.	x	x
7.3	The user shall be able to store and/or transport the System in a suitable transport container.	x	x
7.4	The user shall be able to operate with a minimal equipment footprint.	x	x
7.5	The user shall be able to replenish, service, check all system components within TBD.	x	x
8. Operation Planning and Preparation			
8.1	The user shall be able to define a plan of the operation, prior to commencement of operation, that the system shall follow within required tolerances. The mission plan should define the following parameters, as a minimum; - Boundaries of acceptable operation - Routes - Tasks to be performed during the operation - Action/Routes associated with failure / reversionary procedure(s)	x	x
8.2	The user shall be able to amend the plan of the operation during its execution.	x	x
8.3	The user shall be able to divert the vehicle from its pre-planned course within TBD minute of receipt of air-traffic instruction.	x	x

User Requirement		Applicability	
		Event	Forest Fire
8.4	The user shall be able to start the operation within TBD of receiving a request, when operating from an established location.	x	x
8.5	The user shall be able to perform a pre-operation check of the system components including validation of operation to be performed.	x	x
9. Operation Execution			
9.1	The user shall, be able to observe people and their behaviour over an area of interest of up to [redacted]	x	
9.2	The user shall, be able to observe ground movements (people and vehicles) over an area of interest of up [redacted]		x
9.3	The user shall, be able to perform fire surveillance over an area of interest of up to [redacted]		x
9.4	The user shall be able to perform continuous surveillance for a period of up to [redacted]	x	
9.5	The user shall be able to perform continuous surveillance for a period of up to [redacted]		x
9.6	The user shall aspire to be able to perform continuous surveillance for a period of up to [redacted]		x
9.7	[redacted]	x	
9.8	[redacted]	x	

User Requirement		Applicability	
		Event	Forest Fire
9.9	[redacted]	x	
9.10	[redacted]	x	
9.11	The user shall be able to detect and monitor forest fires in weather conditions in which forest fires occur (not snow or heavy rain) and at any time of day or night.		x
9.12	The user shall be able to detect forest 'hot spots' in weather conditions in which forest fires occur (not snow or heavy rain) and at any time of day or night.		x
10.	**Operation Information Exploitation**		
10.1	The user shall be able to view surveillance data in real time during the operation.	x	x
10.2	The user shall be able to view surveillance data collected during the operation, non real time but during the operation.	x	x
10.3	The user shall be able to record all surveillance information gathered.	x	x
10.4	The user shall be able to retrieve all the surveillance information gathered after the operation is complete within a time period suitable for rapid turnaround.	x	x
10.5	Post operation, the user shall be able to review a time history of system status data, position and orientation, and alerts collected during the operation.	x	x
10.6	The user shall be able to monitor and update (real time) a long term forest fire risk map of the forest of interest.		x
11.	**Safety**		
11.1	In the event of any single equipment/component failure in the System it shall be possible for the user to safely recover the air vehicle without damage.	x	x
12.	**Regulatory**		
12.1	The user shall be able to operate in accordance with all relevant statutory and legislative requirements.	x	x
13.	**Supportability**		

User Requirement		Applicability	
		Event	Forest Fire
13.1	The user shall have a complete set of support documentation in English.	x	x
14.	**Training**		
14.1	[redacted]	x	x
14.2	The user shall be able to operate the System as a training device to maintain operator currency.	x	x
15.	**User Interface**		
15.1	The user shall be able to perform real-time re-tasking and monitoring of the operation.	x	x
15.2	The user shall be able to monitor vehicle speed, altitude, position, attitude and other key data throughout the operation.	x	x
15.3	The user shall be able to monitor the current operational status at all times.	x	x
15.4	The user shall be able to view surveillance data of the area of interest in real time.	x	x
15.5	The user shall be able to request surveillance data for any part of the area of interest in real time.	x	x
15.6	The user shall be able to request and view surveillance data from the operation at any time during the operation but not real time.	x	x
15.7	The user shall be able to compare new surveillance data with old surveillance data of the same area.	x	x
15.8	The user shall be able to view a real time fire risk map for any part of the area of interest in real time.		x
15.9	The user shall be able to request and view surveillance data from TBD locations.	x	x
16.	**Vehicle Performance**		
16.1	The user shall be able to operate the air vehicle at a speed selected for optimum endurance.	x	x

User Requirement		Applicability	
		Event	Forest Fire
16.2	The user shall be able to operate the air vehicle at a speed that minimises transit time from launch to forward deployed operations.	x	x

5 APPENDIX A – AUTONOMY LEVELS

Autonomy Hierarchy
(US Office for Naval Research – UCAV)

Level	Name	Description
1	Human operated	All activity within the system is the direct result of human-initiated control inputs. The system has no autonomous control of its environment, although it may have information-only responses to sensed data.
2	Human assisted	The system can perform activity in parallel with human input, acting to augment the ability of the human to perform the desired activity, but has no ability to act without accompanying human input. An example is automobile automatic transmission and anti-skid brakes.
3	Human delegated	The system can perform limited control activity on a delegated basis. This level encompasses automatic flight controls, engine controls, and other low-level automation that must be activated or deactivated by a human input and act in mutual exclusion with human operation.
4	Human supervised	The system can perform a wide variety of activities given top-level permissions or direction by a human. The system provides sufficient insight into its internal operations and behaviours that it can be understood by its human supervisor and appropriately redirected. The system does not have the capability to self-initiate behaviours that are not within the scope of its current directed tasks.
5	Mixed initiative	Both the human and the system can initiate behaviours based on sensed data. The system can coordinate its behaviour with the human's behaviours both explicitly and implicitly. The human can understand the behaviours of the system in the same way that he understands his own behaviours. A variety of means are provided to regulate the authority of the system with respect to human operators.
6	Fully autonomous	The system requires no human intervention to perform any of its designed activities across all planned ranges of environmental conditions.