Communications System Concept of Operations (ConOp) for Supporting Second Shift (SS) Operations

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1 Introduction

1.1 Overview

Wildland fires take place most often in remote areas without access to communications infrastructure. Communication during wildfire operations is crucial for safe and effective command and control of air assets, ground-based firefighters, and fire management. Without connectivity, Incident Command (IC) cannot exchange information, receive alerts or work with all parties involved in the wildfire suppression operation. Current policy directs IC to use voice radio communications, which require no prior infrastructure, to provide information needed for the command, control and safety of personnel and resources. Cellular communications are used only for logistical purposes unless no other method is available. To address some of the shortcomings of the current state of communications, the Advanced Capabilities for Emergency Response Operations (ACERO) Second Shift (SS) technical team is developing characteristics of an air-to-ground Mesh Radio System (MRS) and preparing for a future demonstration. The MRS will allow air and ground assets to automatically join a radio network without relying on existing infrastructure and exchange information critical to maintaining situation awareness and air traffic management by the onsite IC. The MRS will also give users more options for communications in addition to voice communications.

A wireless mesh network is an ad-hoc system wherein nodes are automatically organized into a self-healing and dynamically routed network. Assets equipped with the proper mesh radio and credentials can automatically join the network as they enter the area of operations. Once a user becomes a node of the network, they can wirelessly exchange and receive data on the network with other nodes. When the node exits the area of operations the mesh network performs self-healing, if necessary, as the node stops exchanging data and leaves the network.

Deployment of the MRS will consist of a simple pre-operational check list to ensure all management, radio and personal devices are ready for use in the operation. The types of data that are exchanged will depend on the devices and applications connected to the MRS as well as the operational needs of the mission. The MRS will act simply as a conduit. Users joining the MRS during an operation should be able to simply power on their approved device and connect to the network using the default configuration.

1.2 Operational Example

Figure 1 depicts an example of the standard operation of the MRS in an incident airspace. Using mesh radios each air asset and ground support station can join the mesh network and be connected to all nodes in the mesh. Nodes will connect other information systems to the mesh radios to transmit outside data to all nodes within the mesh. For example, air assets will connect the MRS to an Automatic Dependent Surveillance–Broadcast (ADS-B) system, which will allow ground stations and connected ground units without ADS-B access to aircraft positions and headings. This would also be used by the Air Tactical Group Supervisor (ATGS) or ground support station to send updated maps and wind charts to aircraft and ground units using real-time data. Operational Data will be distributed around the MRS and made available to users in a Common Operational Picture (COP) application or another app on the connected device. To ensure network stability the mesh can reroute connections when a node leaves the range of the network. The MRS will improve 24/7 suppression operational goals envisioned by SS with increased situational awareness and connectivity even during nighttime operations.

Figure 1 – Concept of Mesh system in use

2 Problem Statement

2.1 Problem Statement

The wildland aerial firefighting environment is a complex space that is very dynamic. Not only are aircraft entering and exiting the airspace, but ground crews are also moving within the fire zone. All assets in a fire fighting area are managed by ground and air supervisors. The aerial supervisor is responsible for facilitating safe, effective, and efficient air operations in support of incident objectives.

The ATGS coordinates incident airspace and manages incident air traffic. The ATGS is an airborne firefighter who coordinates, assigns, and evaluates the use of aerial resources in support of incident objectives. Currently the ATGS and other incident commanders use voice communications over radios and manually entered data to maintain situation awareness of airborne assets and coordinate the utilization of assets. There is a desire for enhanced situational awareness along with the ability to pass additional information at a very low or no operating cost to the owners of the system. The desired MRS uses mesh-network technology to establish a topology of peer nodes in the incident space that communicate with each other and share information in support of the management of aircraft or other assets.

2.2 System Goal

This concept proposes adding an additional tool, the MRS, to augment the ability of the IC to oversee wildfire operational assets. To be an effective tool the MRS must be built to support common communication protocols and radio standards to ensure interoperability with hardware carried by prospective users. The MRS must also be flexible to suit the needs and capacities of the operation and IC. The MRS will both be able to distribute information about each connected node and allow communication between specific nodes. Establishing a connection with any node in the system will give an operator access to distributed data and identifying information from each of the connected vehicles and ground-based operators. Real-time air vehicle flight dynamics generated from on-board systems like ADS-B can be connected to the MRS, allowing the dissemination of position, altitude, velocity, and other available flight information to connected nodes. This system will also allow all operators to send and receive data, mission directives, fire status, and emergency messages throughout the MRS. At least two nodes will be connected to an internet backhaul to allow for uploading of mission data and downloading of outside information to update weather, map and wind aloft charts. This system will give the ATGS more information and allow them to distribute information, orders and fire conditions. A primary configuration of the system will incorporate SideLink enabled devices utilized by ground units to connect into the main mesh network while still allowing for off mesh network local device to device communication. The goal of this technology is to offer wildfire operational command and support a tool that can increase the speed, efficiency and accuracy of information within the communications system, reducing risk to the operation.

3 Concept of Operations

3.1 Concept Overview

The MRS concept starts with installing multi-mode radios capable of transmitting and receiving to air assets and ground units that have sufficient power to support the radios. These radios will be configured before wildfire operations to operate in a mesh routing mode, which will allow for the creation of a mesh network once operations begin. At the minimum level of utilization, the MRS will give ground and air units another method of communication as well as access to the internet. Nodes will not require direct line-of-sight to share information with another node as nodes blocked by obstructions or transmission distance can exchange information through the rebroadcasting of nearby nodes. The self-healing properties of the mesh network allow for nodes to enter and exit the network without disputing the transfer of data. To increase utilization of the network each node can also connect other information systems to the mesh network radio to broadcast that system's data throughout the network. With a proper two-way connection between the mesh radio and another system, the mesh network could enhance a locally sourced data system with regional information from other nodes or the internet. SideLink enabled devices could also be configured for the network to allow on-foot ground units more portable access to the mesh network. The mesh network will allow for passive data ingestion from operators while giving command units the ability to send out updates to maps and mission objectives.

3.2 System Description

3.2.1 Features

a) System will be interoperable across multiple vendors without a secondary radio / hardwired interface.
b) The System will support at least 30 nodes (i.e., members of the mesh network), including an estimated 14 air assets entering and exiting the traffic restricted area along with ground command posts and other systems.
c) The System will transmit and receive 2.5 Kilobytes/second or greater to each member of the mesh network. This is based on estimates of the necessary information rate for transmission of state information and retransmission of received state information from other nodes along with addressed messages as a secondary payload.
d) The System will operate at no additional costs to owner other than initial procurement and normal maintenance.
e) The System should have a radio line of sight range of 30 nautical miles or greater.
f) The System will interoperate with 4 or more other vendor waveforms and IP based systems.
g) System will be capable of authenticating state information data.
h) System will connect automatically to the internet for upload and download of information when available.
i) System will reach back to defined servers automatically when internet is available.
j) The system will operate in a GPS/GNSS denied environment, no-external timing synchronization. (Heavy smoke, foliage, ash and intense heat etc. impacts GPS/GNSS reception.)
k) System communications between mesh nodes will be capable of operating without internet access.

3.2.2 Operational Logistics

a) The System will be operable in a crewed aircraft with little to no added workload to the crew.
b) System will be maintainable with line replaceable units.
c) System will be available 99.9% per sortie.
d) Operator training necessary for system use will be minimal.

e) System operational life should be 30 years, compatibility with new systems for a lifetime of 30 or more years.
f) System usability will be automatic: all system configurations will be done prior to mission start.
g) System will utilize a developed profile for operations, Convergence and Network layer profile or an agreed to operation profile for interoperability.
h) The system will pass data to separate processors/display systems via standard connection protocols, such as Avionics data-bus, Wi-Fi and/or Bluetooth and Ethernet.

3.2.3 Data Communications

a) System will have an external Cell Phone / 3GPP transceiver, with capabilities up to release 19 and backward compatibility.
b) System Cell Phone transceiver system will include all standardized SideLink modes.
c) System will have an external 2.4 GHz ISM/Wi-Fi transceiver.
d) System will have an external ADS-B receiver 978 MHz.
e) System will have an external ADS-B receiver 1090 MHz.
f) System will have an external Remote ID receiver as defined by the FAA (TBD).
g) System will have two additional Software Defined Radio channels/frequency's (TBD)
h) System will have an APCO P25 transceiver 700/800 MHz.
i) System will utilize the developed profile for operations, Convergence and Network layer profile or an agreed to operation profile for interoperability.

4 System Operation Description

4.1 Network Connections

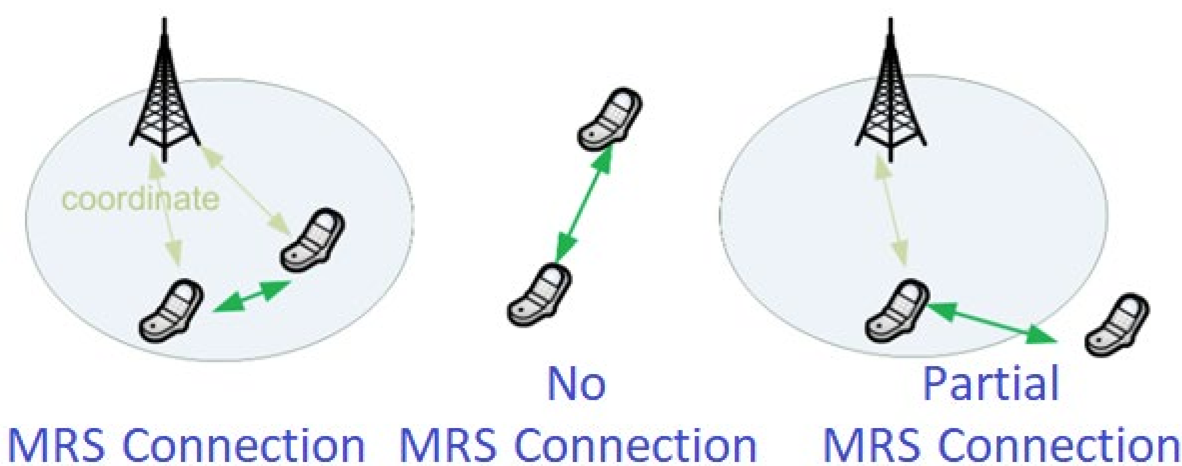

Figure 2 – Sidelink UE Network Scenarios

The MRS will aggregate disparate frequencies and networks into a single network giving network users access to more information without requiring an increase in use of individual radio hardware. This will be achieved by using a network management system where multiple wireless signals can be received and transmitted via one local device that can then give connectivity to multiple local devices by placing them on the MRS using a single connection. The system will have hardware that can receive ADS-B and Remote ID, interface with Sidelink devices, act as an APCO P25 transceiver intermediary and connect to local UE (User Equipment). ADS-B and Remote ID are information that will be circulated throughout the mesh network and made available to UE through COP apps or uploaded as part of the archived mission. This data could be used to update maps on a COP app with real-time aerial traffic without the need for each network user to have an ADS-B receiver. Sidelink devices give a network more resilience and versatility as shown in Figure 2. While connected to the MRS Sidelink devices may be programmed to use the Sidelink connection as a backup link or use the link for specific network traffic. During times when two or more UEs are disconnected from the MRS Sidelink enabled devices will be able to form a local network. If one of the Sidelink UEs is connected to the MRS it will act as a relay to other Sidelink devices that are outside of the MRS.

An APCO-25 radio is an interoperable two-way radio used in the public safety sector for reliable voice communications. Prime vendors of these radios are L3Harris and Motorola. The addition of this radio to the system will allow ill-equipped UEs access to some aspects of the two-way radio communication, depending on how COP apps are configured and UEs demand for services. The radios will also act as relays for local APCO-25 users to extend the range and versatility of the voice communications network.

4.2 Operational Environment

Incident airspace in wildfire operations is often located in remote locations without existing communications infrastructure. During active daytime wildfire operations firefighters must contend with poor visibility due to smoke, tree cover and changing elevation, elevating risk. These extreme conditions are combined with aircraft entering and leaving the airspace as well as the low altitude maneuvers performed during fire suppressant drops. Line of sight to aircraft may be disrupted when aircraft are flying at low altitude, behind terrain, or into valleys. Nighttime operations offer even more risk as visibility is reduced and ground crews are unable to participate in helping direct aircraft. Flying conditions may also rapidly change due to heat from the fire, rapid elevation changes and the proximity to the ground and treetops, making navigating the incident airspace more difficult for pilots.

Figure 2 – Operational Environment Example

5 Summary of Impacts

5.1 Benefits to Current Operations

The expected benefits are providing redundant and more sophisticated communication options to wildfire operations. The system could also expand the usefulness of ADS-B systems and connected visual mapping systems through integration into the mesh network providing access to more regional and targeted data. Additionally, the system will have the capability to pass internet style traffic to members of the mesh and connections to the internet.

The extension to and from the internet is so that information may be passed to mesh assets for enhanced situational awareness and that mesh assets can pass information to internet addresses when available for enhanced sensor information to increase situational awareness.

5.2 Integration Plan

The integration plan is TBS. There are two competing concepts:

- A consortium of venders to supply the system.
- An interoperability specification for purchase.

5.3 Workforce Training Requirements

The system should require little to no training for flight crews, however procedures need to be developed to maintain the network.

It is the intent to minimize flight crew training to powering on the radio system. System activation should also be a checklist item, such as the pre-taxi checklist. External display and sensor functions are outside the scope of this document.

Installation, maintenance, and repair technicians will require training for the systems to be installed on aircraft, ground vehicles, command and control locations.

The COML will require training in addition to the requirements of PMS 308 to perform their functions and responsibilities related to the mesh system operations.

5.4 Task Loading

The COML will be responsible for managing data distribution and system performance.

Ground maintenance is to be restricted to software loads, installation of certificate databases, Line Replicable Unit (LRU) swapping, connecting any external monitors and or sensors to the radio system. Standard Operating Procedures (SOP) will be developed.

Sensor and display systems will be specific to the flight system and is outside the scope of this document. However Standard Operating Procedures will be developed, for each unique installation to assist the maintenance and the operations of those systems.

5.5 Future Work

Build, test and validate operational systems to provide validated information for the development of an interface standard or as reference information for the consortium of developers.

Radio management and radio message management operations will be specified.

In conjunction with the radio build, networking interface standards will be specified.

6 References

Reference Manual #18: Wildland Fire Management - Fire (U.S. National Park Service) (nps.gov)

Device to Device Communication in LTE Whitepaper (Rohde-Schwarz)

7 Appendices

7.1 Assumptions

a) All Police, Fire, EMS and nontraditional public safety agencies VHF/UHF portable and mobile radios may be programmed with the common interoperability channels.

b) Federal, State and local non-traditional public safety agencies will be provided with the channel/frequency assignments.
c) Incident Commanders will familiarize themselves with the communication/operation plans and ensure that proper use of the channels is accomplished to ensure that interoperability exists. They will be utilized for on-scene interoperable communications at the direction of the Incident Commander and the Communication Unit Leader (COML) when authorized.
d) The Incident Commander or designated representative through the Communications Unit Leader (COML) will assign channels as needed, based upon the nature of the event or incident.
e) Interoperability with agencies operating on frequencies outside the common VHF High Band spectrum will be resolved using available technologies. Non-traditional public safety agencies will have communications capabilities with first responders through the Incident Commander.
f) The selection and use of channels will be determined by the Incident Commander, or, on a developing incident, the COML.
g) Confidentiality integrity and nonrepudiation of the payload information will be the transmitting and receiving applications responsibility.
h) Public safety officials (Law Enforcement, Fire & EMS) will have the ability to communicate with each other and agree upon channel/frequency assignments.

7.2 Abbreviations

3GPP	3rd Generation Partnership Project
ACERO	Advanced Capabilities for Emergency Response Operations
ADS-B	Automatic Dependent Surveillance–Broadcast
ATGS	Air Tactical Group Supervisor
CA	Certificate Authority
COML	Communication Unit Leader
COP	Common Operating Picture
EMS	Emergency Medical Service
GPS/GNSS	Global Positioning System / Global Navigation Satellite System
ISM	Industrial, Scientific, Medical
LRU	Line Replicable Unit

HALE	High Altitude Long Endurance UAS
MRS	Mesh Radio System
PKI	Public Key Infrastructure
RF	Radio Frequency
TBS	To Be Specified
UE	User Equipment
UHF	Ultra High Frequency
VHF	Very High Frequency

7.3 Definitions

Authentication- RFC 9374 or similar mechanism

Automatic Dependent Surveillance Broadcast – A technology that allows an aircraft to broadcast information about itself, such as position, velocity, heading and identification gathered from onboard sensors or systems like GPS.

Latency- The time it takes between the generation, transmission, and ingest of the information to the time the information is processed and acted upon.

Mesh Network- A local area network topology in which the infrastructure nodes connect directly, dynamically and non-hierarchically to as many other nodes as possible and cooperate with one another to efficiently route data to and from clients.

Node- A connection point within the network where data can be input or extracted.

State High latency- Greater than 3 seconds for state information (Stale) for safety applications.

State Low latency- Under 1 second for state information (actionable) for safety applications.

State Medium latency- Between 1 second and 3 seconds for state information (advisory) for safety applications.